**ARCADA**

# A Comparative Analysis of 3D Printers and Printing Materials for Art Designers in China

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Abstract:

In China, the group composed of art designers is becoming one of the biggest communities using 3D printing technology for their work. By analysis of 3D printing related technology, performance and cost performance factors of commonly used 3D printers and printing materials, this thesis aims to provide them with some unique references and suggestions for their selecting and purchasing 3D printers and printing materials.

The research method used in this thesis includes the method of literature induction, the method of comparative analysis and the questionnaire method. In addition, the writer's experience and awareness obtained from the personal practical training are also fully demonstrated in the research of the thesis.

Based on the status analysis of 3D printing in China, the writer chooses the Chinese art designers as the object to assert the importance of 3D printing to their design work. The writer divides all art design fields into 14 different specialties according to the departments set in China's most authoritative universities and then analyzes the professional characteristics of each specialty's work to find out their unique requirements and key concerns for art designers from each specialty when selecting and using 3D printers and materials. Through the analysis of the advantages and disadvantages in performance such as printing accuracy, printing speed, printable materials and printing volume of the 3D printers as well as the colors, tensile strength and flexibility of the materials mostly found in Chinese market with good reputation, the author offers some recommendations for art designers from different professions in their selection and purchase of 3D printers and materials.

This thesis can also be valuable for manufacturers to design and build new professional 3D printers and printing materials for art designers in the future.

| Keywords: | analysis, 3D printer, printing matrial, China, art designer |
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# 1 INTRODUCTION

## 1.1 Aims and Objectives

As a kind of new hot technology, 3D printing has been widely used both in China and Europe. China is the country with the largest population in the world; although the proportion of the population using 3D printing technology is not higher than that of Europe, the number of the people using 3D printing is rather high. Therefore, in China, 3D printing will surely have a huge market. At present, there are various kinds of 3D printing equipment and materials by different manufacturers in China's 3D printing market. But due to the insufficient popularization of 3D printing knowledge in China, people always get into trouble while purchasing and using 3D printer and printing materials. Art designers constitute the major users of the 3D printer and materials in China. The main objective of this paper is to try to make a comprehensive analysis in the aspects involving operating system, performance, and cost performance specific to some famous printers and printing materials in present China's 3D printing market based on the above fact. Through the comparative analysis on the various specialty features of the designers in different professional fields and the needs of 3D printing, some useful suggestions and references can be provided for the art designs to purchase 3D printers and printing materials. Taking into consideration of the various kinds of 3D printing equipment brands in China's 3D printing market at present, in this paper, the writer will focus on the products of some comparatively famous 3D printing equipment and material manufacturers for analysis and comparison.



*Figure 1. Wedding dress from Xubrance by 3D printing [1]*

## 1.2 Basic Background of Chinese 3D Printing Market

3D printing is one of the newest technologies developing fast nowadays. There are many theses in Europe to compare 3D printing devices, including printers, scanners and materials. But it is hardly to see the theses that write about the 3D printing devices in the Chinese market.



*Figure 2, 3D printed cement lattice window [2]*

To fulfill a 3D printing task, one has to at first transfer one's designed object into a digital file matching the printer's system, and then print the object with a printer, and finally to post process it with some special devices (such as cutters, UV lights and polishers) and some special materials (such as alcohol). Sometimes a 3D scanner is needed to collect the data related to the designed object. For example, a personal body data of the client should be collected if a fashion designer wants to design and 3D print clothes for his client. So broadly speaking, 3D printing devices include printers, printing materials, and some previous devices and post process devices and material, and even the software of drawing. But this thesis will be focused on the printers and printing materials mainly.



*Figure 3, 3D printed picture pancake [3]*

Chinese people started to use the 3D printing technology almost at the same time as Europeans, we can often see the reports or news that some 3D printing has been newly used in different fields in China, including the daily supplies, clothes (Figure 1), ornamentations, mechanical parts, medical supplies such as artificial body organs, building components and even building designs (Figure 2). The students from Tsinghua University at Beijing even use flour as the printing material to print pancakes. They combine the photography skill with 3D printing technology to transfer the customer's portrait to a graphic pattern, and then use a 3D printing machine to print in the pan to cook the pancakes (Figure 3). From this view, 3D printing should be very popular in China; however, since China is a very big country, 3D printing is usually used in some big cities, and is still not popular in some small cities and

towns, much less in countryside areas. The greatest utilization of 3D printing happens in universities or schools, research units, organizations, manufacturing industries and design studios. During the questionnaire survey, many people respond that they do not understand the technological items involved in the questionnaire. This also means that even though 3D printing is very popular nowadays and many people have already heard of 3D printing, they still do not know what 3D printing really is. So 3D printing is in fact still not very popular in the whole of China.
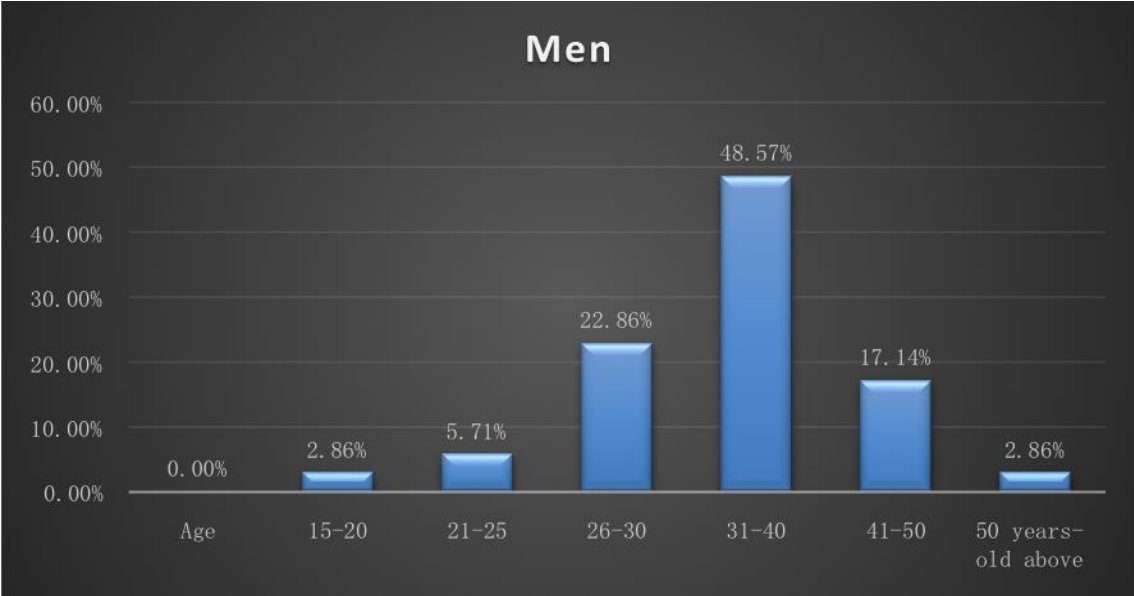


*Figure 4. The percentage of age group for men using 3D printing [4]*
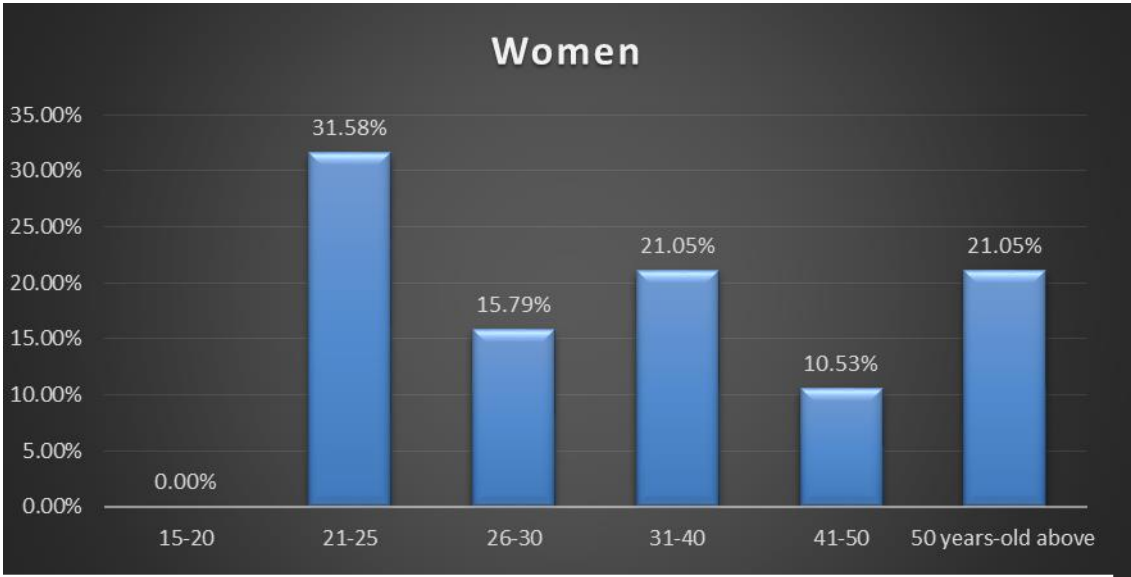


*Figure 5, The percentage of age group for women using 3D printing [5]*

According to the questionnaires that the author made, among the surveyed 3D printing users in China, men comprise 64.29%, while women are 35.71%. The main age of the people using 3D printing is 31~40 years old for men, and the percentage of this age group using 3D printing is 48.57% (Figure 4). The main age for women is 21-25 years old, and the percentage for this age group is 31.58% of all the women using 3D printing (Figure 5).

## 1.3 Art Design - the Main Area in which 3D Printing Is Used in China

Although 3D printing is not so popular in China, people already use it in different fields and different ways. According to the survey, the main 3D printing users in China are art designers. They use 3D printing to print the designed objects in different forms such as study models, prototypes and real products during different design steps. Architects and urban planners utilize 3D printing to print the models of buildings and cities. Sculptors may use 3D printing to print study models or small samples as the medium when discussing with the mandatories of the designs.

In China, the art design field is one of the principal fields with the biggest population using 3D printing. Most of universities have art design disciplines nowadays. According to the statistics, there are 1,951 universities and colleges with art design disciplines, or related departments, representing 67.8% of all the universities and colleges in China [6]. The important market potentialities in China's design field are obvious. Because 3D printing is a new technology, it has not been fully embraced by the designers. For most designers, their understanding of 3D printing is very superficial. Many have never used 3D printers, and, in fact, some elder designers have never seen 3D printers. How to select the correct printer is a difficult problem for most designers. This is the main reason for choosing art designers as the target population in this thesis. The aim is to give art designers concrete references and suggestions that will help them to select the right printers when they plan to buy printers.

# 2 METHODS AND TECHNOLOGICAL PATH OF THE RESEARCH

## 2.1 Methods

The main methods applied in this research include: the method of literature induction, the method of comparative analysis and the questionnaire method.

### 2.1.1 Method of literature induction

Inquire, collect, conclude and summarize various kinds of document literatures, including books, network information, and other forms of product information provided by manufacturers related to 3D printing market and 3D printing users in China, providing enough basis for the comparative analysis later on (Figure 6). Most of the printer and printing material information are from the official websites of the manufacturers and the first-hand data provided by the manufacturers directly.
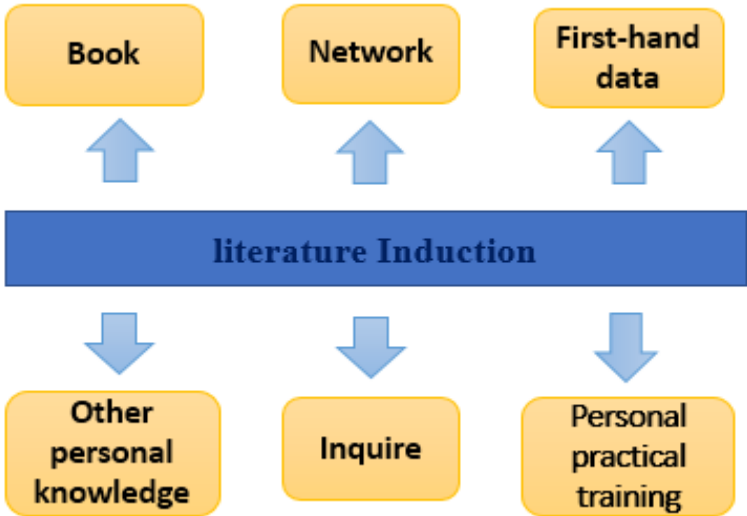


*Figure 6. The illustration of the method of literature induction in the thesis [7]*

### 2.1.2 Method of comparative analysis

The result summarized above is regarded as the basis to make analysis and comparison on the advantages and disadvantages of the products provided by the comparatively famous 3D printing equipment and material manufacturers in Chinese market. And based on the result of

the comparison, useful suggestions and references are provided for the art designers in different professional fields to purchase 3D printers and printing materials. The main factors such as sale price, printing accuracy, printing speed, printable volume, advantages, disadvantages and the majors of art designers were included in the comparative analysis (Figure 7).
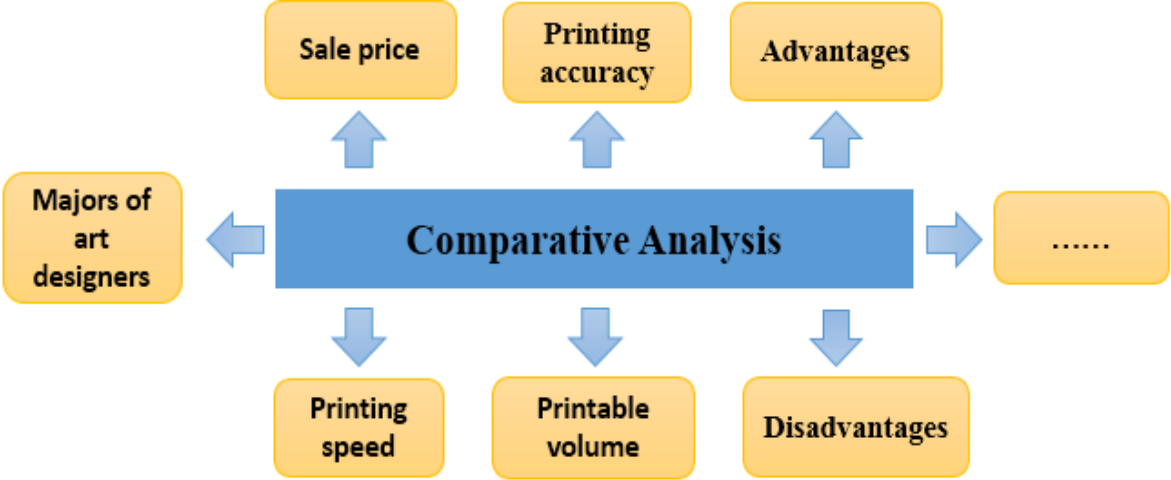


*Figure 7. The illustration of the method of comparative analysis in the thesis [8]*

### 2.1.3 Questionnaire method

To know the major users of 3D printing, the main purposes of using such technique, advantages and disadvantages of the major 3D printing equipment and materials in Chinese market as well as for its user evaluation better, in this paper, some questionnaire surveys focusing on three different emphases are carried out via the "SO JUMP", a professional network questionnaire tool in China (Figure 8). Namely, the three questionnaire surveys include: A Survey of the Application of 3D Printers in China Specific to 3D Printers (Appendix 1), A Survey of the Application of 3D Printing Materials in China Specific to 3D Printing Materials (Appendix 2), and A Survey of Intentio n of 3D printing for Art Designers (Appendix 3). They are all specific for the usage purpose of the art designer planning to use the 3D printer. Furthermore, the collected questionnaires are comprehensively analyzed and applied into the description and research of this paper.

In addition, the writer's various kinds of experience and awareness obtained from practical process are also fully demonstrated in the research of the paper. For example, the data on Polymaker and E-W Lantern are from the personal project of the writer.
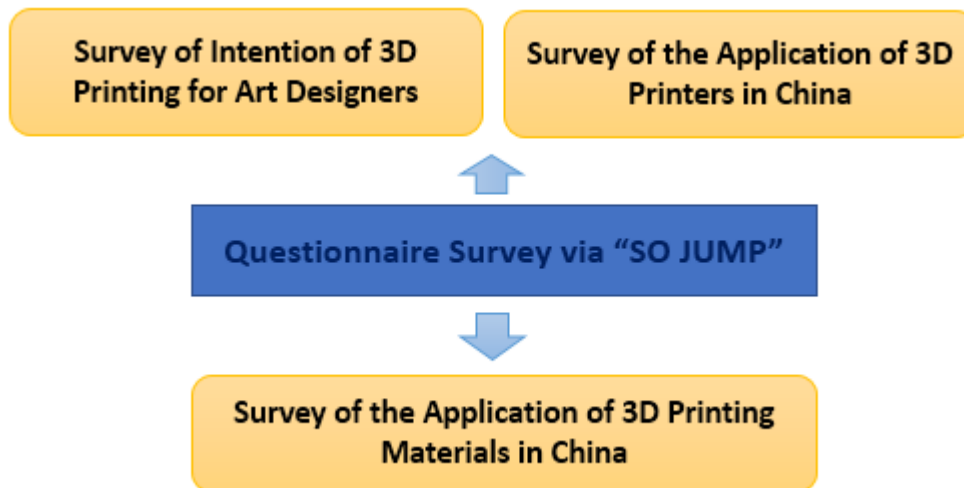
*Figure 8. The illustration of the method of questionnaire survey via "SO JUMP" [9]*

## 2.2 Technological Path and Method of the Research

The technological path of the research in this paper can be summarized below:

- A comprehensive comparative analysis is conducted to the 3D printers and printing materials produced by the comparatively famous printer and printing material manufacturers in Chinese market from the aspects involving operating system, performance, and cost performance.

- An overall analysis is conducted to the users of the 3D printing technology in current China to obtain the following conclusion: art designers have been the main users of the 3D printing technology to form the huge group in the market. Based on the different working characteristics of the art designers in various professional fields, the writer analyzes the characteristics of demands for 3D printing.

- Based on the different needs of the art designers in various professional fields for 3D printers and printing materials, the writer gives useful suggestions and references for people to purchase and use the 3D printers and printing materials，according to the result of the comparative analysis of the 3D printers and printing materials.

# 3 LITERATURE REVIEW

## 3.1 The Role of 3D Printing on Chinese Art Design

### 3.1.1 The Classification of Art Design in China

Like most of European art design schools, the main idea for modern art design in China was from "Bauhaus"（a school of arts and crafts or art design in Germany, and also a pioneer in modern art design education. The discipline divisions, or departments, of art design are similar to those of European schools. From the famous art design educational organization, called the Academy of Arts and Design of Tsinghua University in Beijing, we know that there are ten departments within it: Department of Ceramic Design, Department of Textile and Fashion Design, Department of Art History, Department of Arts and Crafts, Department of Sculpture, Department of Painting, Department of Information Art & Design, Department of Environmental Art Design(Including Interior Design, Landscape Design and Furniture Design), Department of Visual Communication Design(Including Graphic Design), and Department of Industrial Design. There exist four other departments related to art design in the School of Architecture of Tsinghua University. They are Department of Architecture, Department of Urban Planning, Department of Landscape Architecture, Department of Building Science and Technology. Other art universities in China have divisions similar to Tsinghua University's, but they are smaller than Tsinghua University's, so the departments might not be as comprehensive as Tsinghua University. (Table 1)

*Table 1. Art design departments in Tsinghua University, Beijing Forest University and School of Design of Jiangnan University [10], [11], [12], [13], [14]*

| Tsinghua University | Academy of Arts and Design | <ul><li>Department of Ceramic Design</li><li>Department of Textile and Fashion Design</li><li>Department of Art History</li><li>Department of Arts and Crafts</li><li>Department of Sculpture</li><li>Department of Painting</li><li>Department of Information Art & Design</li><li>Department of Environmental Art Design（Including Interior Design, Landscape Design, Furniture）</li><li>Department of Visual Communication Design（Including Graphic Design）</li><li>Department of Industrial Design</li></ul> |
|---|---|---|

| | | |
|---|---|---|
| | School of Architecture | ⬩ Department of Architecture<br>⬩ Department of Urban Planning<br>⬩ Department of Landscape Architecture<br>⬩ Department of Building Science and Technology |
| Beijing Forestry University | College of Arts and Design | ⬩ Digital Media Art<br>⬩ Visual Communication Design<br>⬩ Environment Art Design<br>⬩ Product Design<br>⬩ Animation |
| | Landscape Architecture School | ⬩ Landscape Architecture<br>⬩ Architecture<br>⬩ Urban and Rural Planning<br>⬩ Landscape Plant and ornamental horticulture<br>⬩ Tourist Management |
| Jiangnan University | School of Design | ⬩ Product design<br>⬩ Industrial design<br>⬩ Visual communication design<br>⬩ Environmental design<br>⬩ Public art and fine arts |

In these schools, some smaller disciplines are included in the bigger departments. This thesis uses the way of discipline divisions of Tsinghua University because it is the best representative model for the breakdown of the related disciplines existing in other Chinese schools as well. Among the other disciplines are Art History, known as the discipline of history, Painting, known as the discipline of pure art, Visual Communication Design, which is more about two dimensional graphic design and is hardly related with 3D printing, Information Art & Design, which is more related to computer technology than to 3D printing, and Building Science and Technology, known more as the discipline of engineering and technology. Consequently, these branches will not be included in the proceeding discussion.

## 3.1.2 The Role of 3D Printing on Chinese Art Designers

3D printing is used in variety of areas such as daily life, medical treatment and the industrial process, like in Europe today. But art designers are poised to become one of the main groups using 3D printing in China.

Art design is a very special field because the designer is a combination of artist and engineer. Different designers perform work according to their different specialties. So they have their unique requirements when selecting and using 3D printing devices for their work. Table 2 shows the main applications and demands for art designers in different specialties in China, according to the survey (Table 2).

*Table 2, The main applications of 3D printing for different specialties and their special requirements*

| Fields [10], [11] | Main Applications of 3D Printing during Their Design Processes | Special Requirements |
|---|---|---|
| **Ceramic Design** | Study models printing; Samples printing; Final design works or products printing(Ceramic products or other industrial design products) | • ceramic can be printed |
| **Textile and Fashion Design** | Study models printing; Samples printing; Final design works printing (clothes, shoes, hats, belts, etc.) | • maybe need 3D scanners<br>• high requirements for color<br>• soft flexible materials |
| **Arts and Crafts** | Study models printing; Samples printing; Final design works or products printing (decorations, variety of arts and crafts such as accessories, jewelries, necklaces, etc.) | • high accuracy<br>• high requirements for color<br>• metals can be printed if possible |
| **Sculpture** | Study models printing; Samples printing; Final sculptures printing | • metals and plasters can be printed if possible |
| **Environmental Art Design** | Study or final models printing of buildings, landscapes, furniture | • relatively high accuracy<br>• the bigger the better of printable area |
| **Industrial Design (Product Design)** | Study models printing; Samples printing; Final design works or products printing (industrial products) | • high accuracy<br>• metal can be printed if possible |
| **Architecture** | Study or final models printing of buildings and landscapes | • relatively high accuracy<br>• the bigger the better of printable area |
| **Urban Planning** | Study or final models printing of buildings and urban planning | • The bigger of printing area |
| **Landscape Architecture** | Study or final models printing of buildings and landscape | • relatively high accuracy<br>• the bigger the better of printable area |

As the table shows, different designers have specialized purposes for using 3D printing, but almost all designers will rely on 3D printing to help them in their preliminary design work. During the design process, they often use 3D printers to print their study models, a simple model at different steps. They use their study models to seek the right ways or the right ideas for their designs. They use their study models to modify or improve their art forms and to convey their intentions intuitively when they communicate with their customers the possible artistic effects of their future products. Their customers can put forth their own feedback about the designs through the study models. This is a good way to communicate between designers and customers. It can let designers and customers join in the designing process and share the main ideas to reach the best results. When 3D printing has not been developed, designers generally use the engineering drawings and perspectives to express the idea of their design, but most customers cannot understand the professional engineering drawings, and the perspective can only display some visual effects at a two dimensional level. 3D printed study models can be applied to display the products for customers through three dimensional way. So it is a very effective way that enhances design expression.



*Figure 9, 3D printed chair from Joris Laarman [15]*

Another significant purpose of 3D printing for art designers is to print the final models, prototypes and real products. Once the decision has been finalized about a product, designers can

use 3D printing to print the models, prototypes or real products of their design, such as a building model, an urban planning model, or a prototype of a chair (Figure 9).

Figure 10 is a 3D-printed building model designed by student Mr. Zhu Zichen from Tsinghua University as his assignment (Figure 10). Figure 11 is an example of architectural decoration from Archi Solution Workshop (Figure 11). They used 3D printers to print the decorative outer wall of the building.
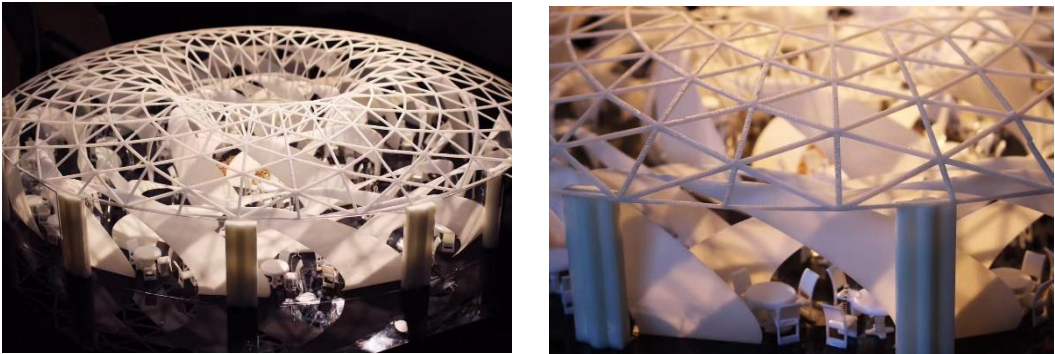


*Figure 10, Graduation project by Zhu Zichen [16]*

Since the printing of the study model is just an intermediate process where the requirements for printed items are not that precise as long as the designer's intention can be conveyed, the printer for printing the study model does not need to be working precisely, yet a relatively high printing speed is required so as to save time. The model is usually a kind of material ob-



*Figure 11. An architectural decoration Cabala from Archi Solution Workshop[17]*

ject that is created as an original or reduced size in proportion after the designer confirms his design scheme. Its proportion, color, and appearance are usually the same as those of the actual products, but the material used itself may be different from that of the actual products. For example, a hand-made building model can be made of plexiglass, cardboard, or another material, and the model of the vacuum cleaner can be made from plaster. 3D printing has the advantages of high speed and precision, and is therefore used as an alternative to time-consuming and labor-intensive handcrafting in the field of art design.

A prototype usually refers to the first work that is made exactly the same as the actual product after the design proposal has been determined. The biggest difference from the model lies in that it is a material and practical piece of work whose internal structure is exactly the same as that of the actual product, such as the first actual piece of furniture used as a sample in furniture design. Since the prototype can be used, it requires the most authentic expression of the design intention. Printers used to print prototypes require as much precision as possible.

An actual product refers to an actual one bulk-printed by a designer or a manufacturer who uses a 3D printer for printing and directly sells it. Therefore, there is an extremely great requirement for the precision of the printer.

The study model, model, prototype, and actual products are some process work that art designers can accomplish by means of 3D printing technology in the whole design and manufacture process. 3D printing can greatly ameliorate the designers' design efficiency and emotional expression in design, which is a feature shared by almost all professional designers. But for the art designers from different specialties, the printed objects are different from each other. For example, the design objects for an architect and a fashion designer are different, so their requirements for printers are also different.

A questionnaire survey concerning the intention of using 3D printers for Chinese designers has been made. From the survey, the objects that designers of various specialties in the Chinese design field prefer to print or are being printed with 3D printers are found. Next, based on this questionnaire, the author will use the professional classification of the Academy of Arts Design of Tsinghua University as a basis to conduct a detailed analysis of the designer's special 3D printing applications in various specialties (Table 2).

## 3.2 The Focus of Attention to 3D Printing by Art Designers in China

There are a lot of factors for 3D printers to which close attention is paid by Chinese designers. These factors are usually the most important ones, which will affect the desired outcome (Figure 12).
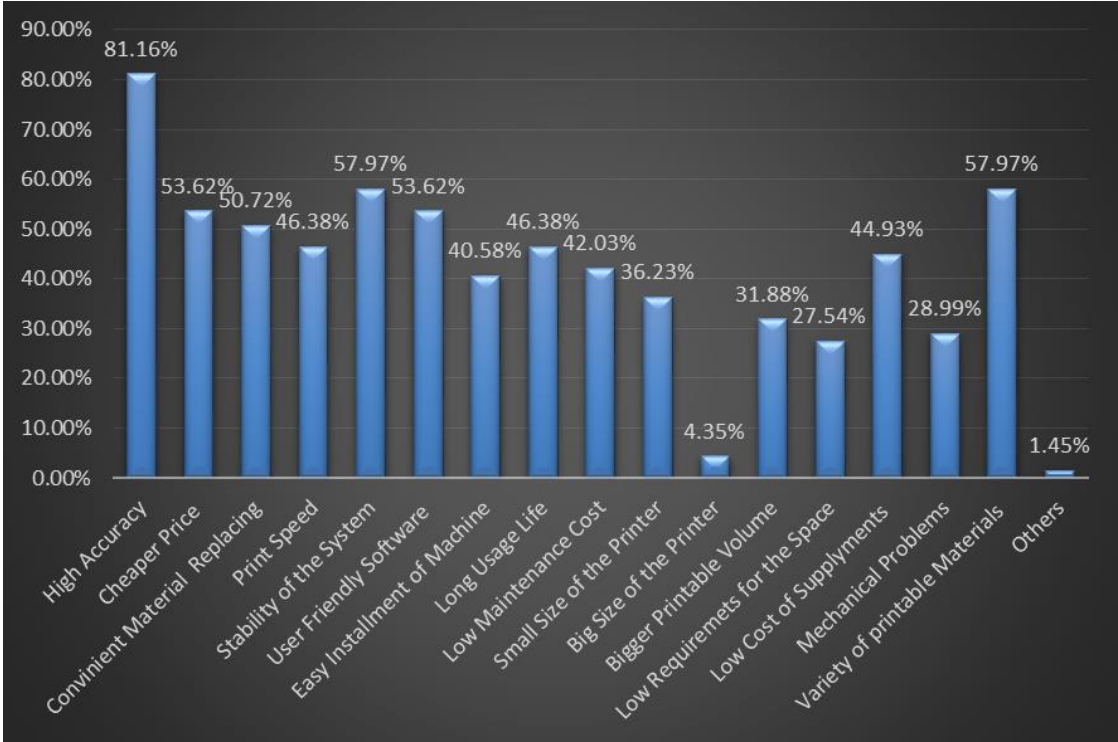


*Figure 12. The factors of 3D printers that clients will pay close attention to [18]*

## 3.2.1 Applicability of 3D Printers

For those who have already had the experience of applying 3D printers, 3D printing technology has been applied to various fields, such as clothing design, architectural design and toys printing.

However, as far as today's 3D printing technology is concerned, there will be some deformation when a thinner object is printed. For example, when the author designed and printed her E-W Lantern during her internship, in consideration of the visual beauty as well as better light transmittance, the lampshade wall itself was designed to be very thin. Although some decorative patterns were designed on it to assure the rigidity of the product itself, the effect of the printed sample of this straight form was not ideal especially when printed with transparent PLA. The



*Figure 13. The deformation of E_W Lantern occurred while printing [19]*

lampshade wall slightly distorted even in the process of printing (Figure 13). Because of this experience, it is concluded that 3D printing technology is more suitable for printing curved surfaces. The irregular curved surfaces are difficult to be manufactured by hand but they can be easily printed with 3D printing technology. Additionally, because of the mechanical properties of curved surfaces, it is generally more stable than straight surfaces. Moreover, for curved surfaces, especially irregular surfaces, even if there is a little deformation, it cannot be spotted, so they impose less impact on the aesthetics of products.

Because most 3D printers are expensive, people hope that different kinds of materials can be dealt with in the same printer. For example, the same machine can both print plastics and metal materials. People even want the same printer to print multiple products at the same time so as to save time. But in fact, most printers can only print one or two materials, and printers that can print more materials like the Stratasys Objet 1000 Plus can be very expensive. Machines like the Stratasys Objet 1000 Plus, which can print a variety of materials into a single product, are even fewer. Integrated printers which can print multiple products at the same time are the best choice for manufacturers, but they are currently rare in the market.

Due to the limitation of the printer's printable volume, there is a big limit to the size of the printed objects. For example, to print a large sculpture, it may be necessary to divide the work

into multiple parts and print it separately, and then manually splice it, thereby greatly reducing the advantages of 3D printing as well as increasing the cost of labor and increasing the complexity of processing of products. Therefore, it is ideal that the larger the printing volume of the 3D printer, the better, so that the printed product can be formed at one time.

Color is one of the most significant elements for designers and artists to express artistic characteristics of their works. The artistic characteristics in clothing, jewelry, decorations and other things all need to be demonstrated through color. So their requirements for color in 3D printing are much higher than those of other kinds of people, such as engineers, with the hope that the 3D printer can print out more realistic and richer color. In the case of today's 3D printers, since most printers can only print a single material, they can only print a single color. If you need to print gradient colors, a multi-nozzle 3D printer will be needed, which is usually very expensive. At present, most printers and printing materials in China's 3D printing market cannot meet the complex needs of designers for color. Therefore, most of the products with high color requirements need to be painted later in order to meet the requirements, which is a shortcoming in the current 3D printing technology.

Most of Chinese art designers work in studios. Usually, the scale of a studio is smaller and its room and fund are also limited. Therefore more art designers prefer to buy table printers than professional printers although table printers' printable volume is smaller, and usually the performance is not as good as professional printers.

## 3.2.2 Performance of 3D Printers

### 3.2.1.1 Printing Accuracy

The purposes of applying 3D printing technology vary from people to people of different fields, so people's demand for printer precision also differs. Although the design objects of the art designers are more arbitrary than those of the engineers, once the shape and color of the works are determined, the designers always hope that the 3D printer is able to print the works precisely as they want. In general, without considering the price, people want 3D printers to be as precise as possible. (Table 3)

### 3.3.1.2 Printing Speed

When designing their works, the art designers usually make their own works from their personal emotion. Once an idea is formed in their mind, they always want to be able to see the actual form of the work as soon as possible, so does the client. Therefore, people always want the printer to print as quickly as possible. It would be unacceptable for people to spend a day or two printing a small model. Therefore, too slow a print speed will also be an important factor affecting printer sales.

Most of the printers' printing speed are not published on their official documents or website; therefore, only some printers' printing speeds are listed in Table 3.

## 3.2.3 Quality of 3D Printers and Ease of Maintenance

People have certain expectations about the quality and the convenience of its maintenance of 3D printer. As can be seen from the previous survey, most people prefer printers with stable systems and long service life. Due to the fact that 3D printers need to supplement or change for different materials frequently, the convenience of material replacement is also an important factor for people. Compared to small-size table 3D printers, professional 3D printer installation will be more difficult.

As a new technology that has been popular recently, there are not many people in China who have a thorough understanding of 3D printers. So the public will hope that the quality of the printer that they bought must be stable, and various problems are not to be expected, such as nozzle clogging or burning out of main control boards. Even if a problem occurs, it can be easily resolved, and it does not take much time or money. It would be better if the malfunctions could be solved effortlessly by themselves. In the event of a problem such as burning out the main control board, or when the parts need to be replaced, convenience in obtaining the replaced parts comes first. Too high a cost of maintaining or repairing a machine is unacceptable for people.

### 3.2.4 Usable Materials for the 3D Printer

As analysis above, when buying a printer, people hope the printer can handle as many different materials as possible so as to print as many kinds of products as possible. If the actual product is to be printed, the quality of the final product should be high enough to be used. It needs to have a series of requirements such as strength, toughness, elasticity, and bending resistance. For example, when printing garments, the printed garments need to have good toughness and elasticity and be soft and comfortable on the texture; if you are printing a plastic shovel, you may expect this shovel to be strong enough and to be as hard as steel. Therefore, it will be better that a printer can use as many different materials as possible to print a large range of products and that the products can fit well for their own functionality.

When buying print consumables, people hope that the same printing material could print as many kinds of products as possible. If a material is too limited in the print product and there is much unsuitability in printing products, people may remove the materials from the shopping list. For people who need high-precision printing, the printable precision with the material is also a focus.

### 3.2.5 Printer Price and Printing Cost

#### 3.2.5.1 Printer Price

A 3D printer is a much more expensive appliance than other household appliances, costing a few thousands to tens of millions of Yuan in RMB. The price of most of the table machines varies from a few thousands to a hundred-odd thousand Yuan, while professional printers cost hundreds of thousands to tens of millions of Yuan (Table 3). As a result, there is no need to buy expensive professional printers if they are used only by individuals, but if the buyers are factories or companies, the budget for purchasing the printer will be much larger than that of individuals. Generally speaking, companies specializing in 3D printing business accept a variety of possible design and printing work. Therefore, high-precision printer's printing products are needed to meet the customer's different requirements. Such companies tend to have higher investment costs and purchase highly adaptable, high-precision printers at higher prices.

**3.2.5.2 Printing Cost**

Since 3D printing requires a large number of printing filaments or other forms of material, the cost of the material should not be too high; otherwise, it would be a huge expense for those who need to print the product for a long time or a big output.

As for the printing cost of 3D printers, in addition to the purchase price of the printer itself and the expense of printing materials, printing time is included, because time actually means the cost. There is generally no particularly high cost in the case that only a sample model is to be printed with ordinary materials. However, if a manufacturer will print their products in bulk then the cost will be very high. Another example is that when customized clothes are to be 3D printed, the overall cost will be much higher because a scanner may be added to collect the detailed data of a customer's body size. Generally speaking, people still expect that it will be better if the cost of printing is kept lower.

## 3.3 An Analysis of Main 3D Printers Commonly Used in China

### 3.3.1 The Main 3D Printers Commonly Used in China

There are so many different types of printers in China and it is impossible that all types of printers made by different manufacturers could be involved in this thesis. Here, in this thesis, only a few main printers in China will be discussed.

Both imported printers and domestic ones are being used in China. Union Tech, a famous domestic 3D printer company, possesses many users in China because its printers are of lower price and good quality. But within the imported printers, both Stratasys and 3D Sytems have a good reputation in China. As the author's personal practical training places and her cooperation companies, Archi Solution Workshop, Zeegine and LinkedFab are more familiar to me. So in this thesis printers will be chosen from Union Tech, 3D Systems, Stratasys, Archi Solution Workshop, Zeegine and LinkedFab as examples.

## 3.3.2 The Technological Systems Commonly Used for 3D Printers in China

There are many different systems for 3D printing such as FDM/FFF (Fused Deposition Modeling/ Fused Filament Fabrication), SLA (Stereo lithography Apparatus), SLS (Selective Laser Sintering), DLP (Digital Light Processing) and Polyjet. But for the Chinese market, people mostly use FDM/FFF and SLA systems to print the products, so in this thesis the technological systems mainly focused on will be SLA and FDM.

### 3.3.2.1 FDM/FFF (Fused Deposition Modeling/ Fused Filament Fabrication)

*3D printing machines that use FDM/FFF Technology build objects layer by layer from the very bottom up by heating and extruding thermoplastic filament. When the thin layer of plastic binds to the layer beneath it, it cools down and hardens. Once the layer is finished, the base is lowered to start building of the next* layer [20].

But some machines build layers by the rising of the nozzle. This FDM/FFF technology prints support structures when printing, and they need cutting off during the post process.

### 3.3.2.2  SLA (Stereo lithography Apparatus)

*Stereo lithography Apparatus is a 3D printing method that can be used to implement your projects that involve 3D printing of objects. SLA printing machines don't work as usual desktop printers which extrude some amount of ink to the surface. SLA 3D printers work with excess of liquid plastic that after some time hardens and forms into solid object [21].*

Like FDM/FFF this SLA technology prints support structures when printing, and they need cutting off during the post process.

### 3.2.2.3 SLS (Selective Laser Sintering)

*Selective Laser Sintering (SLS) is a technique that uses laser as power source to form solid 3D objects. The main difference between SLS and SLA is that it uses powdered material in the vat instead of liquid resin as stereo lithography does [22].*

Different from FDM/FFF and SLA, the printed objects using SLS do not need the support structures.

### 3.3.2.4 DLP (Digital Light Processing)

*Digital Light Processing is another 3D Printing process very similar to stereo lithography. 3D printing DLP as well as SLA works with photopolymers. But what makes SLA and DLP processes unalike is a different source of light. For DLP 3D amateurs generally use more conventional sources of lights such as arc lamps. The other important piece of process is a liquid crystal display panel that is being applied to the whole surface of building material during single run of DLP process. The material to be used for printing is liquid plastic resin that is placed in the transparent resin container. The resin hardens quickly when affected by large amount of light [23].*

Like FDM/FFF and SLA, the printed objects applying DLP do not need support structures either.

### 3.3.2.5 Polyjet

*PolyJet is a powerful 3D printing technology that produces smooth, accurate parts, proto-types and tooling. With microscopic layer resolution and accuracy down to 0.1 mm, it can produce thin walls and complex geometries using the widest range of materials available with any technology.*

*Benefits of PolyJet:*

⬧ *Create smooth, detailed prototypes that convey final-product aesthetics.*

⬧ *Produce accurate molds, jigs, fixtures and other manufacturing tools.*

⬧ *Achieve complex shapes, intricate details and delicate features.*

⬧ *Incorporate the widest variety of colors and materials into a single model for unbeatable efficiency [24].*

### 3.3.3 Printers with FDM System

#### 3.3.3.1 Printers Made by LinkedFab

**F500A**



*Figure 14. The rough finished surface of E-W Lantern printed by LinkeFab F500A [26]*

Printing size: 480 × 480 × 500 (unit: mm, L×W×H)

Machine size: 1280 × 1250 × 1700 (unit: mm, L×W×H)

Weight:750kg

Advantages: The price of F500A is cheaper than the same level printers made by Union Tech. The cost is also lower for products running. Filaments are easily changed with F500A, and a variety of filaments can be used too. Surroundings requirements are not strict [25].

Disadvantages: The print speed is pretty slow (print speed: 9.6g/h). It normally needs a longer time to complete a printing job. For example, it took 48.5 hours to print the lamp shade of the author's E-W Lantern the author designed during her personal practice training. The total weight of the lamp shade is 465 grams. The accuracy of good printers is normally about 0.1mm, but the accuracy of F500A is 0.5mm. Another disadvantage is that the quality of printing is not good, and the finished surface of the product is rather rough. Thus some precision parts may not be accurately printed out with a nice finished surface (Figure 14) [27].

#### 3.3.3.2Printers Made by Archi Solution Workshop

**MEGA** (Figure 15）

Printing Size: 500×400×400 (unit: mm, L×W×H)

Machine size: 800×600×800 (unit: mm, L×W×D)

Weight: 75kg

The gross weight: about 100kg
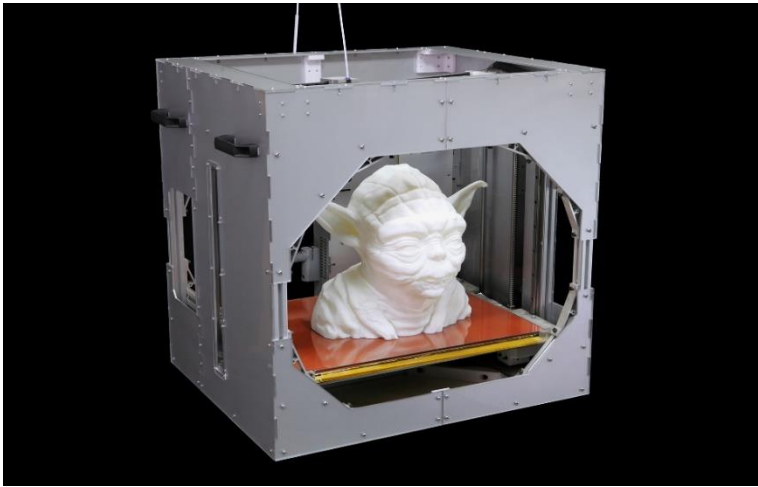


*Figure 15, MEGA made by Archi Solution Workshop [28]*

MEGA is a professional printer produced by Archi Solution Workshop in Beijing. This printer is smaller and is convenient to be placed. The printing accuracy is 0.1mm – 0.8mm. The length of output from the printer can reach half meter. Because it is convenient to be placed and it fits for both Windows and Mac it is good for home, office or factory. The Archi Solution Workshop set the specialized exhaust fans for printers so there is no need to worry about the bad odor while printing. Another extra service is that the engineer from the company will install the printer for you at your home and teach you how to use it. One year guarantee will be included in the service [28].

**MPP** (Figure 16)

Printing Size: $200 \times 200 \times 200$ (unit: mm, $L \times W \times H$)

Machine size: $410 \times 410 \times 550$ (unit: mm, $L \times W \times H$)

Weight: 18kg

The gross weight: about 25kg



*Figure 16, MPP made by Archi Solution Workshop [29]*

MPP is a table printer which is easy to be placed. The accuracy of the printer is 0.1mm to 0.8mm. Both Windows and Mac systems are suitable for the printer. The working surrounding temperature for the printer should be between 15℃ to 45℃. One year guarantee will be included in the service [29].

**GRANDY** (Figure 17)

Printing Size: 1100×1100×1100 (unit: mm, L×W×H)

Machine size: 1550×1550×1600 (unit: mm, L×W×H)

Weight: 280kg

Gross weight: about 380kg

GRANDY is the biggest printer from Archi Solution Workshop which has 1.1 meters output.



*Figure 17. GRANDY made by Archi Solution [29]*

The accuracy of the printer is 0.1mm– 1.5mm. GRANDY is suitable for industry printing and suitable to use at the factory instead of home. One year guarantee will be included in the service [29].



*Figure 18. The outer wall Arachne designed and printed by Archi Solution Workshop [30]*

Compare the differences between MEGA, MPP and GRANDY, MPP is more suitable to use at home and has the smallest machine size. GRANDY has the biggest size of machine and the output size is also the biggest comparing with MPP and MEGA, so it is suitable to use in the factory to print the big size objects. MEGA can print the middle size products, such as E–W Lantern. If necessary clients can ask the engineer from Archi Solution Workshop to do the designing for them. The picture shown in Figure 18 is the outer decoration wall of a building named Arachne, which is designed and produced by Archi Solution Workshop. It was printed by GRANDY with PLA. The separate pieces were printed first and then were assembled together into a whole.

### 3.3.3.3 Printers Made by Zeegine

**Zeemaker** (Figure 19)

Printing size: 25×32 (unit: mm, Diameter×H)

Machine size:  450×420×870 (unit: mm, L×W×H)

Weight: 21Kg

Zeemaker is a FDM printer which is made by Zeegine. The print speed is 30 mm/s– 300 mm/s. The printing head can be changed. Variety of diameters of printing head can be chosen, the diameter of the printing head include: 0.2mm, 0.4mm and 0.8mm. Printing heads are made from copper. The thickness of each layer is 0.1mm–0.4mm. The maximum heat temperature of the machine is 240℃ and the maximum temperature of heat plate is 100℃. The materials ABS, PET, PVA and HIPS can be used to print, but PLA is the most suitable filaments for Zeemaker printers. The operating systems for the machine are windows 7 or higher versions and Mac OS 10.7 or higher [31].



*Figure 19. Zeegine Zeemaker[31]*



*Figure 20.The Moon Light from Zeegine [32]*

Zeegine is a company which is professional at lamp printing. Some of author's E–W Lantern were printed by Zeegine. Zeegine has two factories in two different cities, one in Tian Jin and another one in Chang Zhou. Zeegine uses Zeemaker printer to print PLA filament in Tian Jin and uses Union Tech 450 printer to print the photosensitive resin in Chang Zhou. The most famous lamps from Zeegine are different sizes of the lamp Moon Lights (Figure 20). The most important thing for the lamp is the transmittance of light, so Zeegine has its own PLA fila-

ments to print lamps, which have higher transparency than normal PLA. But, unfortunately, Zeegine does not have any official document to introduce their PLA filament.

## 3.3.4 Printers with SLA System

### 3.3.4.1 Printers Made by Union Tech

**Lite 600HD** (Figure 21)

Printing size: 600×600×400 (unit:mm, L×W×D)

Machine size: 1570×1310×1935 (unit:mm, L×W×D)

Weight: 1400kg



*Figure 21. Lite 600 HD made by Union Tech [33]*

Lite 600 HD is a SLA printer. The print speed of Lite 600HD is 20.2g/h. The accuracy of the printer is 0.2mm. The layer thickness of each layer is 0.05 mm – 0.25 mm. Only photosensitive resin can be printed. Printing materials are not easy to change. Surrounding requirements are very strict. The operating system for the printer is Windows 7. The software for the Lite 600 HD is called UnionTech™ RSCON[33].



*Figure 22. PILOT 450 made by Union Tech [34]*

**PILOT 450** (Figure 22)

Printing size: 450×450×400 (unit:mm, L×W×D)

Machine size: 1331×1368×2140 (unit:mm, L×W×D)

Weight: 1085kg (including material weight:160kg)

PILOT 450 is a SLA printer which is made by Union Tech. The layer thickness of each layer is 0.05mm– 0.25mm, depending on the exact size of

the products. The working age for the laser head is 5000 hours or 15 months. The laser scanning speed is 12 m/s which is the same as PILOT 250. Windows 7 and Windows 10 are the operating system for the printer. UnionTech™ RSCON is the software for the printer. One year guarantee is included in the service.

Compare the differences between PILOT 250 and PILOT 450, PILOT 450 has bigger print size (450×450×400 mm) than PILOT 250 (250×250×250 mm).. The PILOT 450 has bigger printing size, this causes the initial material in it heavier (160kg) than the initial material in the PILOT 250 (48kg) [34].

**RSPro 800** (Figure 23)

Printing size: 800×800×550 (unit:mm, L×W×D)

Machine size: 1798×1602×2118 (unit:mm, L×W×D)

Weight: 2000kg (including material weight: 560kg)

The accuracy of the printer when its part size is less than 100 mm is±0.15 mm. When the part size is equal or bigger than 100 mm the accuracy is ± 0.15% ×length. The layer thickness for each layer is 0.07mm – 0.25mm. But the print speed of the RSPro 800 is the same as the RSPro 600. The operating systems for RSPro 800 are windows 7 and Windows 10. The operating environmental temperature range is 22℃– 26℃. One year guarantee is included in the service [35].



*Figure 23, RSPro **800** made by Union **Tech** [35]*



**FM 700** (Figure 24)

Print size: 700×350×350 (unit:mm, L×W×H)
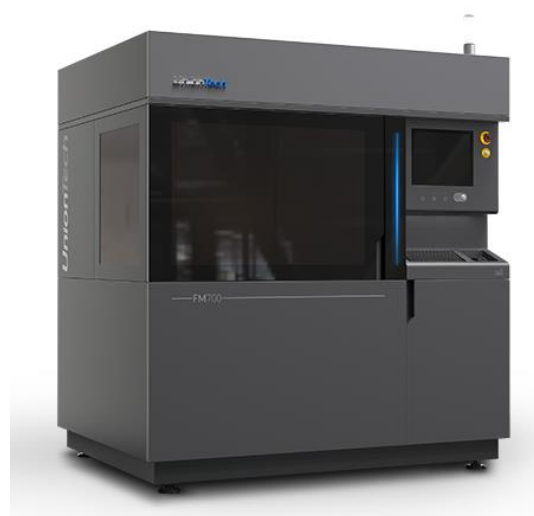
*Figure 24. FM 700 made by Union Tech [36]*

Machine size: 1790×1320×1950 (unit:mm, L×W×H)

Weight: 1447kg (including material weight:182kg)

FM 700 is designed especially to fit to print shoes mold. The laser wave length is 255nm and the wave power is 1000 mW. When the length of the printed object is less than 100 mm， the accuracy is ± 0.06 mm, when the length is bigger or equal to 100 mm，the accuracy is ± 0.06% ×length. The operating systems for FM 700 are Windows 7 and Windows 10. One year guarantee is included in the service [36].

**FL 700** (Figure 25)

Printing size: 700×350×350 (unit:mm, L×W×H)

Machine size: 1800×1195×2260 (unit:mm, L×W×H)

Weight: 1440kg (including material weight:182kg)

FL 700 is designed especially to fit to print shoes mold. The laser wave length is 355nm and the wave power is 1500 mW. The operating system for FL 700 is Windows 7. One year guarantee is included in the service [37].

Conclusion for Union Tech: Union Tech is a famous company producing 3D printers and scanners with great quality in China. The printing quality of their printers is good. All printers from



*Figure 25. FL 700 made by Union Tech [37]*

Union Tech are SLA printers. 3D printers from Union Tech are divided into Lite series, Lite HD series, PILOT series, RSPro Series, FL series and FM series. Lite, Lite HD and RSPro are all suitable to print medical, architectural, and aviational parts, as well as car parts. Only the FM series and FL Series are suitable to print shoes. The PILOT series is suitable for educational organization and jewellery printing.

In this section, Lite 600HD, PILOT 450, RSPro 800 and FM 700 are chosen to be introduced because they are all the higest version in each series.

One of the author's E–W Lanterns  was printed with a Union Tech Lite 600HD printer. It used 424g of  photosensitive resin and it took 21 hours to print it. It took  3 hours for the post process including polish, UV light solidify, structure support removal and alcohol wash.

### 3.3.4.2 Printers Made by 3D Systems

**ProX 800** (Figure 26)

Printing size: $650\times750\times550$ (unit: mm, L×W× D)

Machine size: $137\times160\times226$ (unit: mm, L×W× D)

Weight: 1724Kg



*Figure 26.  ProX 800 made by 3D Systems  [38]*

3D Systems ProX 800 is a SLA 3D printer which has the highest print speed and high accuracy (accuracy: 0.025mm–0.5mm). Because the working life of the laser device has been extended, the maintaining fee of the printer will be lower. One year guarantee is included. The operating system for ProX 800 is Windows 7 or higher versions. [38]



**ProX 950** (Figure 27)

Printing size: $1500\times750\times550$ (unit: mm, L ×W×D)

Machine size:  $220\times160\times226$ (unit: mm, L ×W×D)

*Figure 27. ProX 950 made by 3D Systems [39]*

Weight: 1951Kg

ProX 950 is a SLA 3D printer which has two lasers to work at the same time. The accuracy of the ProX 950 is the same as ProX 800 (0.025mm–0.5mm). The sale price for ProX 950 is higher than 641,025.64 €. One year guarantee is included in the service. The operating system for the ProX 950 is Windows 7 or higher versions. [39]

Comparing the ProX 800 and ProX 950, ProX 950 has faster printing speed because ProX 950 has two lasers. ProX 950 is more suitable for printing big products. But consider the size of the printer, it is more suitable to be used in a factory, instead of an office or home. For home and office ProX 800 is better. ProX 800 also has the lower sale price (half a million dollars) compared to ProX 950 (641,025.64 €).

## 3.3.5 Printers with Polyjet System

### 3.3.5.1 Printers Made by Stratasys

**Objet 1000 Plus** (Figure 28)

Printing size: 1000×800×500 (unit: mm, L×W×D)

Machine size: 1960 × 2868 ×2102 (unit: mm, L×W×D)

Weight: 2200Kg

Objet 1000 Plus is the printer from Stratasys which has eight print heads. This printer can offer impressive multi– material capabilities with the power of digital materials. Fourteen dif-



*Figure 28. Objet 1000[ Plus made by Stratasys [40]*

ferent materials can be printed in one product. Materials which can be used for the printer are Model materials and digital materials.

Objet 1000 Plus has two rooms (waterjet and printer can be in the same room), but ProX 800/950 have three rooms (Printer + Manual support removal + Post process equipment). The post process equipment for the Objet 1000 Plus is only waterjet. The sale price for the printer is 550,000 dollars. The accuracy of the Objet 1000 Plus is 0.015mm. The operating systems

for the Objet 1000 Plus are Windows 7, 64 bit, and Windows 8. One year guarantee is included in the service.

*Model materials:*

*• Transparent rigid (VeroClear™)*

*• Rubber–like (TangoPlus™ and TangoBlackPlus™)*

*• Rigid Opaque (Vero family)*

*• Simulated Polypropylene (Rigur™)*

*Digital materials:*

*• Transparent shades and patterns*

*• Rigid Opaque shades*

*• Rubber–like blends in a range of Shore A values*

*• Simulated Polypropylene blends in rigid and flexible options*

*• Digital ABS Plus™ simulates ABS plastics by combining high–temperature resistance with toughness Digital ABS2 Plus™ matches those properties and provides enhanced dimensional stability in walls thinner than 1.2 mm (.047 in.)*

*• Rigur–based Digital Materials in a range of Shore A values and shades in rigid and flexible options*

*−<Objet 1000 Plus>* [40]

**Objet Eden260VS Dental Advantage** (Figure 29)

Printing size: $255 \times 252 \times 200$ (unit: mm, L×W×D)

Machine size: $870 \times 735 \times 1200$ (unit: mm, L×W ×D)

Weight: 410Kg

Stratasys Objet Eden260VS Dental Advantage is a dental 3D printer which can be used in the dental field. This printer offers the customers an essential materials package:



*Figure 29. Objet Eden260VS Dental Advantage made by Stratasys [41]*

*• Clear Bio–compatible (MED610)*

*• VeroDentPlus™(MED690)*

*• VeroDentTM (MED670)*

*• VeroGlazeTM (MED620)*

All open intraoral scanners are supported by Stratasys. The accuracy of Objet Eden 260VS Dental Advantage is 0.015mm. For the post process, there are two ways that clients can select: quick support removal by using waterjet or the soluble material (SUP707) can be used (alcohol soluble). The operating system for the Objet Eden 260VS Dental Advantage is Windows 7, 32/ 64 bit. One year guarantee is included in the service. [41]

*Table 3. The properties of all 3D printers involved in this thesis*

| Company Name | Printers Name | Machine Size ( mm) | Weight (kg) | Printing Size (mm) | Accuracy ( mm) | Printing Speed | Sale Price (€) | Comment |
|---|---|---|---|---|---|---|---|---|
| LinkedFab | F500A [25] | | | 480×480×500 | 0.50 | 9.6 g/h | 19,230.77 | • Low saling price<br>• Printing speed is slow<br>• Suitable for model printing and study model printing |
| Archi Solution Workshop | MEGA [28] | 800×600×800 | 75 | 500×400×400 | 0.1-0.8 | | 4,871.79 | • simple apperance<br>• low saling price<br>• normal accuracy |
| | MPP **[29]** | 410×410×550 | 18 | 200×200×200 | 0.1-0.8 | | 1,282.05 | • simple apperance<br>• low saling price<br>• normal accuracy<br>• table printer |
| | GRANDY [30] | 1550×1550×1600 | 280 | 1100×1100×1100 | 0.1-1.5 | | 10,256.41 | • big printing size<br>• simple apperance<br>• low saling price<br>• suitable for urban planning, architecture and lanscape designers |
| Zeegine | Zeemaker [31] | 450×420×870 | | 25×32 (diameter×height) | 0.30 | | 1538.50 | • table printer<br>• professional lamp printing<br>• low saling price |
| Union Tech | Lite 600HD [33] | 1570×1310×1935 | 1400 | 600×600×400 | <100 mm is ±0.15 mm, ≥ 100 mm is ±0.15% ×length. | 20.2 g/h | 64,102.56 | • good printing speed<br>• machine is heavy and big, but printing sixe is small<br>• SLA printer, photosensitive can be used only |
| | PILOT 450 [34] | 1331×1368×2140 | 1085 | 450×450×400 | <100 mm is±0.15 mm, ≥ 100 mm is ±0.15% ×length | 16 m/s | | • Small print size compared with other professional printers |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | RsPro 800 [35] | 1798×1602×2118 | 2000 | 800×800×550 | <100 mm is ±0.15 mm, ≥ 100 mm is ±0.15% ×length | 6-8 m/s | | • bigger printing size<br>• SLA printer, photosensitive can be used only |
| | FM 700 [36] | 1790×1320×1950 | 1447 | 700×350×350 | <100 mm is ±0.15 mm, ≥ 100 mm is ±0.15% ×length. | 18 m/s | | • high UV llight scanning speed<br>• SLA printer, photosensitive can be used only |
| | FL 700 [37] | $1800 \times 1195 \times 2260$ | 1440 | $700 \times 350 \times 350$ | <100 mm is ±0.15 mm, ≥ 100 mm is ±0.15% ×length. | | | • long laser wave length<br>• wave power is 1500 mW |
| 3D Systems | ProX 800 [38] | 1370×1600×2260 | 75 | 650×750×550 | 0.025-0.5 | | higher than 641,025.64 | • high accuracy<br>• expensive saling price<br>• can change to metalic printing system<br>• suitable for sculptors, industry designers and fashion designers |
| | ProX 950 [39] | 2200×1600×2260 | 150 | 1500×750×550 | 0.025-0.5 | | higher than 641,025.64 | • high accuracy<br>• expensive saling price<br>• can change to metalic printing system<br>• two lazer heads can save time while printing<br>• suitable for sculptors, industry designers and fashion designers |
| Stratasys | Objet 1000 Plus [40] | 1960×2868×2102 | 2200 | 1000×800×500 | 0.02 | | Higher than 897,435.90 | • big printing size<br>• polyjet system<br>• suitable for urban planning, architecture and lanscape designers<br>• high accuracy<br>• expensive saling price |
| | Objet Eden 260VS Dental Advantage [41] | $870 \times 735 \times 1200$ | 410 | 252×252×200 | 0.02 | | 230,769.23 | • table printer<br>• can print plastics fashion accessories<br>• suitable for fshaion designers<br>• can print small accessories, such as earings and necklace |

**Exchange rate: 1Euro =7.8RMB**

## 3.4 The Main 3D Printing Materials In China

### 3.4.1 Status of Development of 3D Printing Materials in China

At the very beginning poly plastics are the basic materials for 3D printing, such as PLA, ABS,
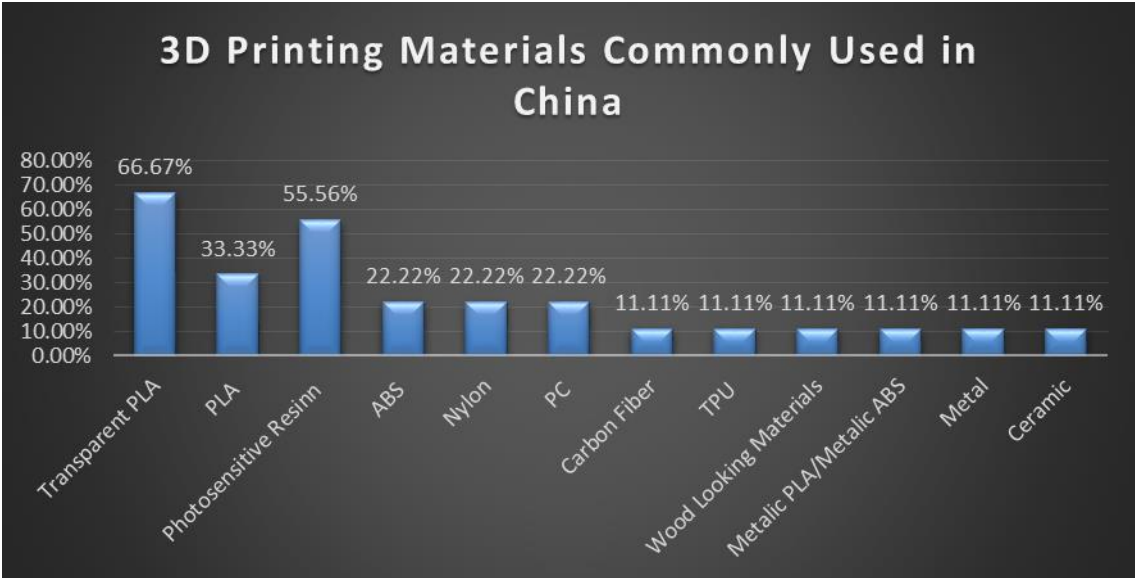


*Figure 30. The comparison of the usage of 3D printing materials commonly used in China [42]*

and photosensitive resin. Later as the technology gets rapidly developed，ceramics, metals (e.g. stainless steel) and metal alloys (e.g. aluminum alloy) can be printed too. The forms of materials become increasingly diversified, from filament to powder and liquid resin today. But most popular materials are still PLA, ABS and photosensitive resin because of their reasonable cost and wide adaptation both for printers and printed objects (Figure 30).

PLA and ABS are suitable for almost all table machines and professional machines using FDM/FFF technology. They are very popular materials for 3D printing and they can be found very easily.

Photosensitive resin is also popular for 3D printing, and the finished surface of the production is usually smoother than PLA and ABS.

For improving the printing quality of normal PLA and ABS, some new types of PLA have been exploited, such as PC Max and PC Plus. Some companies have their own special prod-

ucts to print, so they have some special requirements for printing materials so as to print their lamp shades well. For example, the Zeegine company's main printed products are various lamp shades, so they have developed some special PLA which is a little different from normal PLA in the ingredients.



There are some new developed materials used in China, like PolyWood and Sandstone. PolyWood, developed by Polymaker, is a newly developed filament material, with which a printed object has a wood appearance (Figure 31). Sandstone is a powdered material which is based on parquet. The products printed with it have sandstone-like appearances and textures.

Ceramics, metals and metal alloys are only used in some special fields in China. It can hardly be seen in folk.

*Figure 31. A Polywood product [43]*

## 3.4.2 Polymer Plastics

### 3.4.2.1 Normal Polymer Plastics

**Normal PLA （Polylactic Acid）**

PLA (Polylactic Acid) is a material which is odorless and insoluble in water. The density of the material is 1.210–1.430 g/cm3. Melting point of PLA is around 150℃ - 160℃[44]. Tensile strength is about 37 MPa. PLA is not an elastic material; this can be seen from tensile strength at break (37 MPa) [45].

PLA is the most basic filament that is used in 3D print. PLA is suitable for most 3D printers, whatever it is table printers or professional printers. In the world every year the yield is over 10,000 tons. It was found in a wide range, depending on printing conditions. The finished surface of the printed product was always with filiform lines. The quality of printing is not good enough because the surface is quite rough, and the print head of the printer easily gets jammed. Considering the marketing price (1 ¥/g, about 0.13 €/g) [46], **it** is really low, and the filaments are easy to get. Normal PLA is good for beginners to do practice in 3D printing.

The main advantage of PLA is its low cost for filaments. It is also suitable for most 3D printers and good for amateurs to practice with. Because PLA can be used in a wide range, it is one of the most popular materials used in factories, organizations, schools, and homes to print objects.

Low heat resistance and low printing quality are the main disadvantages of PLA. While the surrounding temperature is about 55℃ (Figure 34), the product will easily get deformed. Because all the PLA products' surfaces have filiform lines, polish is needed after printing.

**Photosensitive Resin**

Photosensitive resin is a popular 3D printing material, and the material is liquid at room temperature. Photosensitive resin is odorless and soluble in alcohol. While using the material to print, UV light should be used (Figure 32). Otherwise, products cannot solidify. The printed
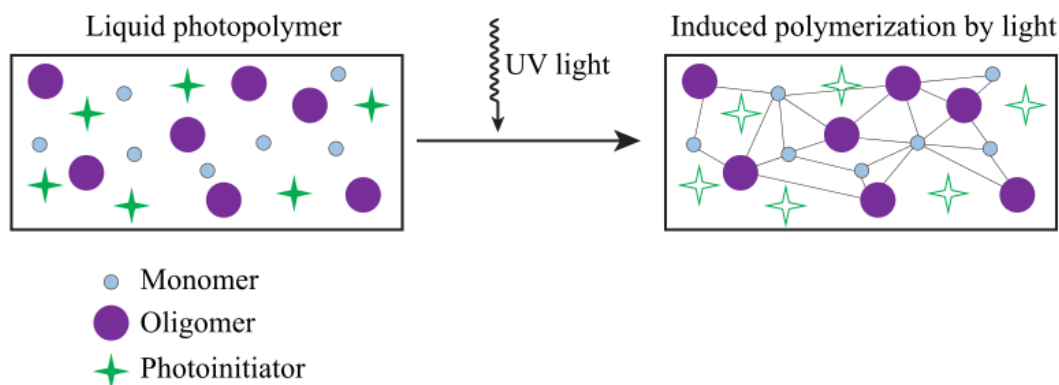


*Figure 32. Photosensitive resin under the UV light [47]*

objects need support structures. They need longer time for the post process compared to PLA. After printing, the photosensitive resin products should be put into industrial alcohol to remove the viscosity. UV light may be used again to make the structure solidify adequately, but to save steps and time, the polisher can be used – this is the author's personal suggestion – the product can be put into the Polisher to be polished, and the viscosity can be removed.

The advantages of this material are low price for normal photosensitive resin (Chinese marketing price: 3.5 ¥/g， about 0.45€/g [73]) . Its transparency is better than PLA. The finished surface is smoother than PLA, and the printing quality is higher than PLA too.

The disadvantage of photosensitive resin is the low heat resistance, which renders it easy to soften and deform if the surrounding temperature is over 40℃. For example, when the author was having her personal practical training last summer at Nanjing in southern China , the daily highest temperature  was about 40 ℃ . The author's E-W Lantern was printed in Nanjing with photosensitive resin. Its lampshade was put into the car trunk when taken from one place to another. Two hours later, the lampshade was strongly deformed (Figure 33). Since the photosensitive resin is a liquid material at room temperature, it is not easy to change like filament. Some ancillary tools may be need while changing the material, such as goggles and gloves.  It should be stored carefully. Because the photosensitive resin is in a liquid state at room temperature, it should be stored in a cool, dry place.



*Figure 33. The deformation of the lamp shade printed with photosensitive resin, under the high temperature of summer[48]*

Compared to other normal filament material, such as PLA and ABS, the post process needs more steps. The product should be put into the alcohol to remove the viscosity. This step normally needs about half an hour.

**ABS (Acrylonitrile butadiene styrene)**

ABS (Acrylonitrile butadiene styrene) is a common thermoplastic polymer. It is a kind of amorphous material. ABS has no exact melting temperature. The density of ABS is 1.060–1.080 g/cm³ . The material is almost odorless and insoluble in water. [49]

Compared to PLA, ABS has a low ratio of molding and has more chances of causing a jam in the nozzle. Compared to other materials such as PLA, the heat resistance is very low. ABS is easy to design, thus the material is suitable for most printers and good for beginners to practice with, similar to PLA.

**Nylon**

Nylon is a generic designation for a family of synthetic polymers. The density of nylon is 1.15 g/cm$^3$. The melting point is 190–350 °C. Nylon is a thermoplastic silky material which can be used in a variety of applications. [50]

**TPU**

TPU (Thermoplastic polyurethanes) is any of a class of polyurethane plastics with many properties. The material possesses good elasticity and oil resistance [51]. The suggested printing temperature for 3D printing is 200 - 220 °C [52]. TPU can be used in many different fields.
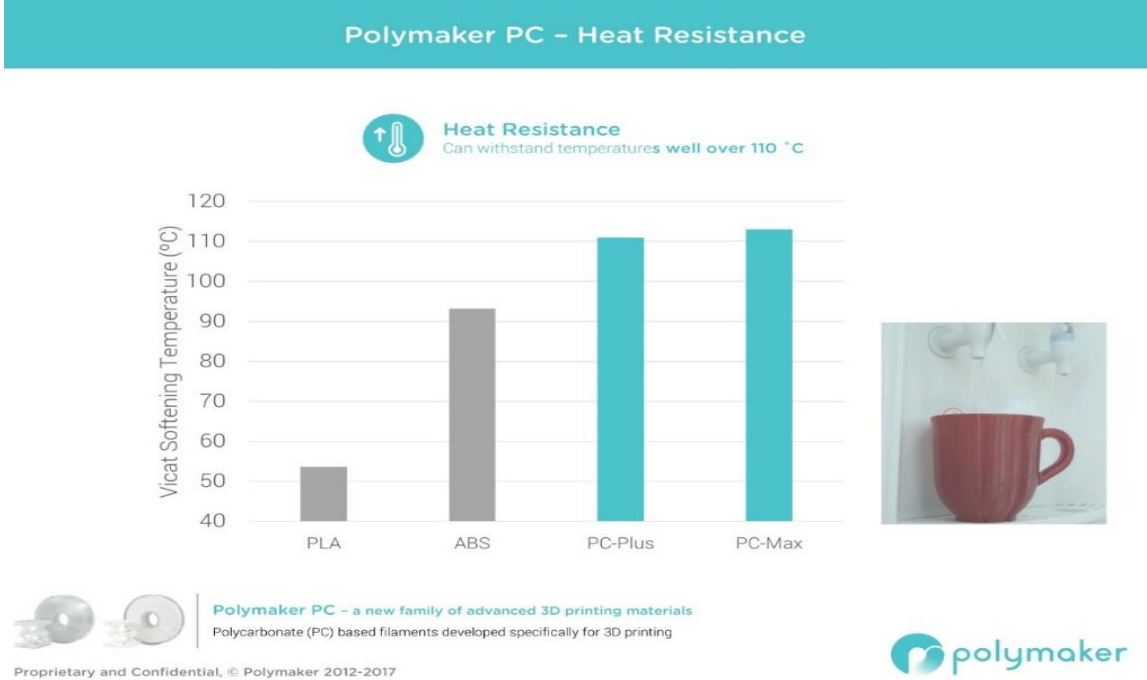


*Figure 34. The comparison of the heat resistances of Polymaker-PC to PLA and ABS [53]*

## PC (Polycarbonates)

PC (Polycarbonates) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. The density is 1.20-1.22 g/cm$^3$ [54]. The melting temperature of PC is 270℃[55]. The heat resistance of PC is higher than PLA and ABS (Figure 34).

## Other Comparatively Commonly Used Polymer Plastics in China

In addition to PLA, Photosensitive resin and ABS, there are some other comparatively commonly used 3D printing materials such as nylon, TPU, PC and Carbon Fiber materials in China. But their popularity of use is not as high as that of PLA, Photosensitive resin and ABS (Figure 30).

## The Main Properties of the most commonly used 3D Polymer Plastics in China

As an entry-level 3D printing material, PLA, ABS and photosensitive resin, are well received
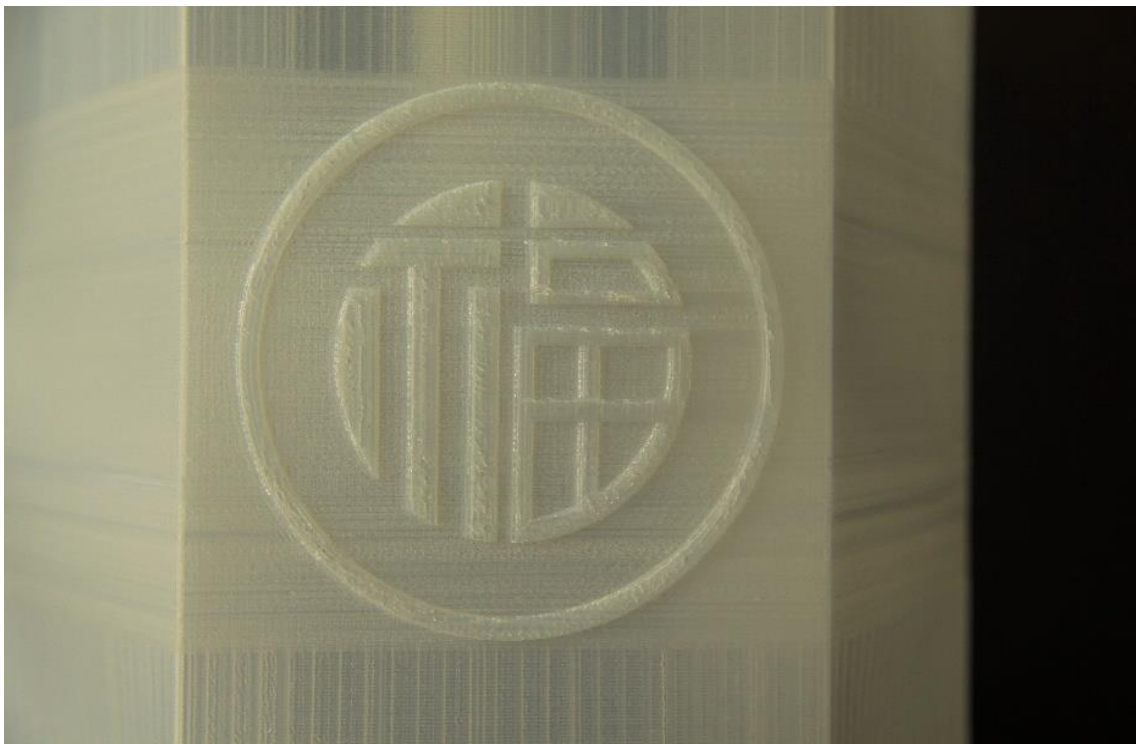


*Figure 35. The obvious printing venations of transparent PLA on the lampshade of E -W Lantern [56]*

by users because of their low cost and high plasticity. They are the most commonly used 3D printing material.

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The author once used PLA and photosensitive resin to print the lampshade of her own design work, E-W Lantern, during her personal practical training in the summer of 2017.

As a basic material for 3D printing, PLA is cost-effective and is widely applied. Because of its low cost, it is widely used in study models or sample printing and in schools. The drawback is that there are obvious printing structure venations on the printed objects, and the surfaces need to be polished after print to smooth them out. But it does not work for the objects printed with transparent PLA even if the surfaces are polished after print, because the printing structure venations exist inside the objects as an intrinsic printing structure（Figure 35）.

The photosensitive resin printed lampshade of the author's E-W Lantern has very low thermal resistance. Due to the high summer temperature in China during the author's internship, the lampshade deformed in transit. Photosensitive resin is one of the few liquid materials in 3D printing materials that needs to be irradiated with a laser or an ultraviolet light for molding.

After being printed, it is required to be soaked in industrial alcohol for about another half an hour. If it can be fixed with an ultraviolet light again, the effect will be better. The E-W Lantern's lampshade has also been printed with a photosensitive resin, but the thermal resistance of the photosensitive resin is much lower than that of PLA, and deformation was also caused by high temperature in that summer. Usually, it will get deformed at about 40°C. In terms of aging caused by exposure to light, when compared with the same lampshade printed with the PLA, under the same position and time of exposure, as well as the same intensity of light, photosensitive resin will yellow and discolor earlier than PLA. The original white lampshade becomes light yellow half a month later (Figure 36). The impact is very obvious,
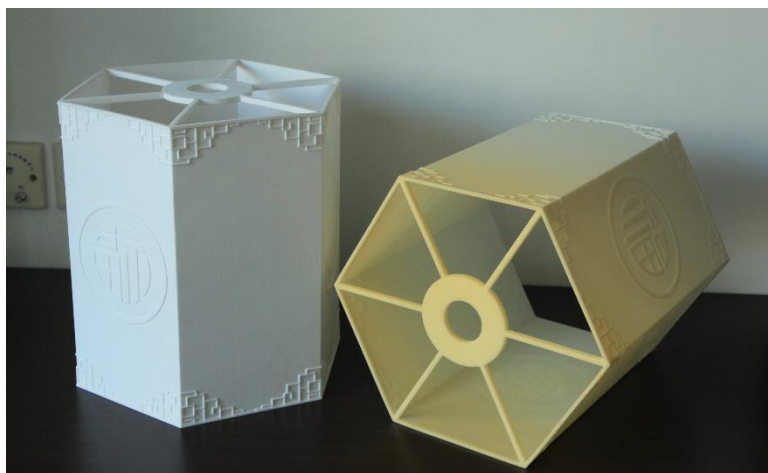


*Figure 36. The lampshade of E-W Lantern printed with PLA and Photosensitive resin. Photosensitive resin became yellow easily under nature light [57]*

and the intensity decline is also very obvious, and it becomes more easily broken. Therefore,

it is practically not suitable for printing lampshades. As a kind of engineering material, photo-sensitive resin has slight toxicity and is unfit for printing indoor decorations and for long-term indoor use.

In terms of environmental protection, PLA, as a degradable material, is more environmental friendly than photosensitive resin. Most manufacturers have now developed some special PLA with better intensity and heat resistance (such as PC Max and PC Plus from Polymaker's mentioned above). Newly developed special PLAs have higher tensile strength and bending strength than ordinary PLA materials, and the accuracy is relatively higher. Of course, the cost will also increase.

ABS, like PLA, has relatively low printing precision, but it is suitable for beginners. The cost price of ordinary ABS is not different from that of PLA, and the tensile strength is similar to that of PLA. However, ABS has a lower melting point and is more fluid at melting status. When printing ABS, the printing platform needs to be glued, and the odor emitted when the printer and the print platform heat up are large, so ABS is not often used to produce actual products compared to PLA and photosensitive resin.

### 3.4.2.2 Polymer Plastics Made by Polymaker

There are some new polymer plastics materials developed by Polymaker. Here, the author just take some new polymer plastics materials used in LinkedFab Company in Nanjing as examples, where the author finished her personal practical training in the summer of 2017. These materials are the newest filaments or powder materials for 3D printing with good quality. From Table 4 one can find some testing data of Polymer Plastics by Polymaker, including physical properties and mechanical properties.



*Figure 37. PC Plus filaments and its product [59]*

**PC Max**

PC Max is a tough but lightweight and flexible material. It is transparent with glowing. This material is now widely used all over the world. PC Max, which is break proof, light weight and with high resistance, is mostly used in our daily life, e.g. the cup. The total annual value in 2014 was approximately 5 million metric tons. In 2015, the material passed the European Food Safety Authority (EFSA).

The safety factor of PC Max is 150, heat resistance >110℃. Young's modulus (unit: MPa) of the material is 2048±66. The average diameter of filaments is 1.75mm or 2.85mm (<±0.05mm to ±0.02mm). The printing temperature for PC Max is recommended to be 250-270℃. [58]

**PC Plus** (Figure 37)

PC Plus is a filament which has excellent impact resistance and fracture toughness, good chemical/solvent resistance. The heat resistance is >110℃. This filament can be used to print translucent objects. It can be seen in Figure 38 that PC Plus has higher strength than other materials in the chart. Another important point is that the material has more clarity than normal
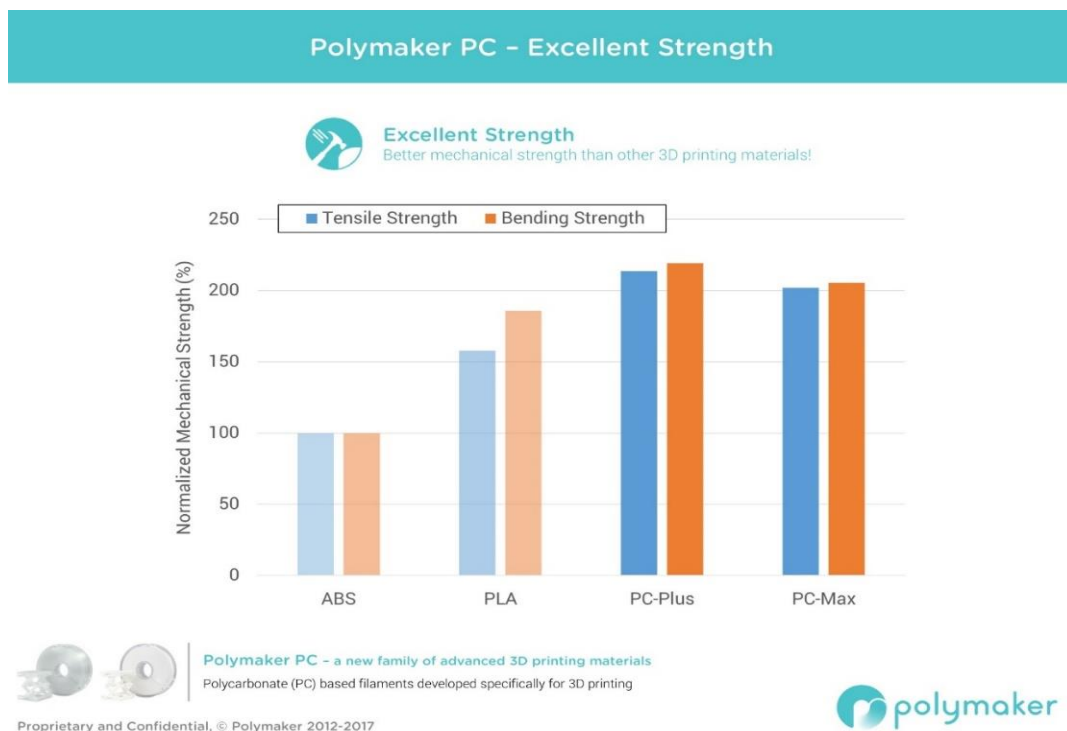


*Figure 38. The tensile strength and bending strength of normal ABS, normal PLA, PC-Max and PC-Plus [59]*

PLA and ABS. The recommended temperature for printing is 250-270℃.

Addition: PC Max and PC Plus all belong to PLA but better quality than normal PLA. The printer requires a heated built plate.

Figure 38 shows the tensile strength and bending strength of normal ABS, normal PLA, PC Max and PC Plus. [59]

**PolyFlex** (Figure 39)
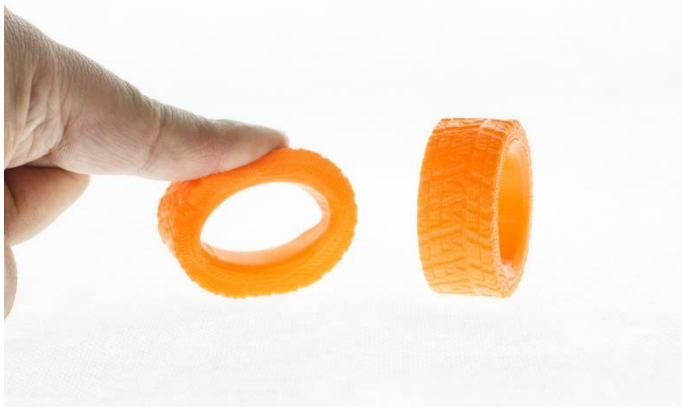


*Figure 39. A PolyFlex product which has a good extensibility [60]*

PolyFlex is a material which is almost odorless and insoluble in water. The hardness is shore A (95A). Moisture content <0.1%. PolyFelx is a good choice to make flexible objects. From the Table 4 one can know the value of elongation at break is the highest compared with other materials (330.1 ± 14.9). As the value shows, the PolyFlex has a good extensibility. [60]

*PolyMax*

The material PolyMax is almost odorless and insoluble in water. PolyMax has strong impact strength. Its impact strength is 9 times stronger than PLA and 20% better than ABS, so it can be used to print the bones for medical use (Figure 40). The recommended printing temperature for 1.7mm filament is 190-220℃, for 2.85mm is 200-220℃. Young's Modulus of this material is 1879 ± 109. [61]
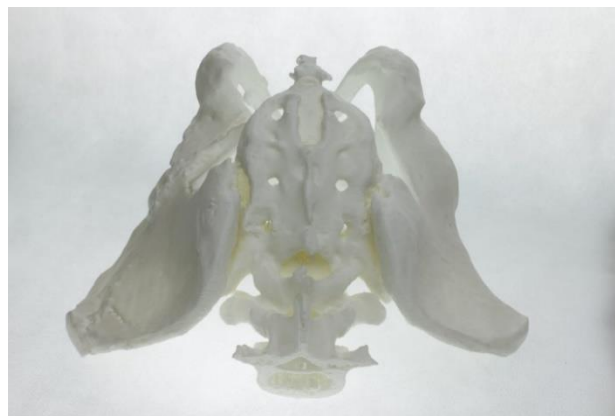


*Figure 40. A bone printed with PolyMax [61]*

## PolyPlus

PolyPlus (Figure 41) has higher Young's modulus than other materials in the Table 4. The Young's modulus of PolyPlus is 2636 ± 330. The bending modulus of this filament is also higher than other materials: 3283 ± 132. But compared with PolyFlex, PolyPlus has a low extension (1.90 ± 0.21), and is the lowest of all the materials in the table. [62]



*Figure 41, PolyPlus filament made by Polymaker [62]*



*Figure 42. A polisher called Polysher made by Polymaker [64]*

## PolySmooth

Polysmooth is the first free post process material. It is solvent in alcohol and almost odorless. Polysmooth is especially developed to work with their own developed special Polysher (Figure 42). It is suitable for working with table printers. This material also exhibits a minimal residual stress but with normal strength [63].

## 3.4.3 Polymer Plastics Made by ESun

### 3.4.3.1 EASA

Best print temperature: 220-260℃

Bed temperature: 70-110℃

Feed rate: 20 - 90mm/s

Idling speed: 90 - 150mm/s



*Figure 43. EASA made by eSUN [65]*

EASA (Figure 43) is a filament printing material which has a similar structure to ABS. This material has good weather resistance, high temperature resistance, and anti-static and anti-UV performance. EASA is stable enough to be applied in cars, gardening, electronic, architecture, furniture and other areas. From the Table 4 one can see the material has low density and low percentage of the elongation at the break. So this material has lower bad tear resistance. Customers should not twist or drag too much. [65]

### 3.4.4 Somos EvoLVe128 Made by DSM

Somos is a very popular photosensitive resin series from DSM Company. Many 3D printing companies use the photosensitive resin from Somos. Table 4 shows some basic properties for Somos EvoLVe128. Compared with other materials in *5.2.10 Shenzhen ESUN Industrial Co., Ltd*, the Somos EvoLVe128 has higher strength (tensile strength: 2964 Mpa). Somos EvoLVe128 is a medium hardness polymer. Its hardness is hardness Shore D and the value is 82. [66]

### 3.4.5 Wood-looking & Bamboo-looking Polymer Plastics
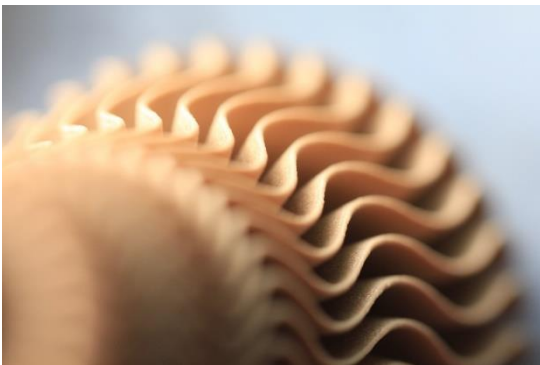


*Figure 44, Polywood product details [67]*

#### 3.4.5.1 PolyWood Made by Polymaker
PolyWood (Figure 44) is manufactured with a foam technology. The material has a wood-like look but is not a real wood. This material is also very lightweight (density: 0.8g/cm³ ). It is 35% lighter than regular PLA. The products printed with PolyWood look like real natural wood. [67]

#### 3.4.5.2 EBamboo Made by ESUN
Best print temperature: 200-220℃
Bed temperature: 25-70℃
Feed rate: 20-90mm/s
Idling speed: 90-150mm/s



*Figure 45, eBamboo made by ESUN. [68]*

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EBamboo (Figure 45) (Table 4) has a matte surface and frosted texture. While printing, the filament is smooth and sustains no stripping. The bamboo texture and bamboo aroma are included in the material. EBamboo is a renewable material with a long-use age. EBamboo can be printed with sprayed way too. The material remained on the nozzle head should be removed as soon as possible after print; otherwise, it will burn. EBamboo can be applied in building industry, automobile industry, package and transport industry, storage, furnishing and other areas [68].

### 3.4.5.3 Wood Made by ESUN

Wood (Figure 46) is a filament material which is produced by eSUN 3D. Because the filament has wood powder in it, the printing temperature and the bed temperature should be lower than normal polymer materials (printing temperature: 190 ℃ - 220 ℃ ). The ideal bed temperature for Wood is 80℃ or without heating. If the temperature is too high, the material will burn. Wood material has better strength



*Figure 46. Wood made by ESUN [69]*

than normal PLA (Table 4). This filament also has a small shrinkage rate. [69]

## 3.4.6 Metal

### 3.4.6.1 Bronze Made by ESUN (Figure 47)

Bronze has the stronger strength than other filaments mentioned before. The tensile strength of this filament is 66 and the bending strength is 106 (Table 4). Bronze filament from eSUN Company is an environmentally friendly material in that the material can be recycled. The low process temperature and the nice liquidity is



*Figure 47. Bronze made by ESUN [70]*

good for the printing process. The products made by Bronze will have the bronze color and perfect metallic out-looking. [70]

Because the printing technique of metal material is not well developed and the printing cost is relatively expensive in China. There are few factories which produce metal printing materials in the Chinese market. This thesis will not take the metal material as emphasis and just take Bronze as an example.

Because in China, metals 3D printing is not so successful or popular. Because the material manufacturers do not produce metal printing materials normally. In this thesis, Bronze from eSUN is the only metal material which has been noticed.

### 3.4.7 Ceramic

Because the printing technique of ceramic material is not well developed and the printing cost is relatively expensive in China too, there are few factories which produce ceramic printing materials in the Chinese market. This thesis will not include it.

### 3.4.8 Other 3D Printing Materials

There are many other materials for 3D printing in China. Most of these materials are specially developed and produced by some companies for some special uses. For example, some kinds



*Figure 48. A 3D printed house in Su Zhou in China [71]*

of special concrete for building printings (Figure 48). But these special printers and printing

materials are almost all in the experimental stages. They do not exist, at least, in the Chinese markets. So this thesis will not include them too.

**3.4.8.1 Color-changing Filaments Made by ESUN** (Figure 49)



*Figure 49, Color-Changing filaments' product made by eSUN [72]*

There are many different color-changing materials made by eSUN. But the properties of them are all the same except for the colors (Table 4). The color-changing filaments include: temperature color-changing filaments and light color changing filaments. The diameters for filaments have two different diameters: 1.75mm and 3.00mm. When put under high temperature or UV light, the filaments will change color, but the new color will return to the original color when the filaments lose the UV light and high temperature. The storage condition for the filaments should be a cool place with the room temperature at 23℃. Here are the usage life of color-changing filaments:

• Under the UV light 10 minutes per day, the filaments can be used for two years.

• Under the UV light 15 minutes per day, the filaments can be used for one and half years.

•Under the UV light 20 minutes per day, the filaments can be used for one year.

•Under the UV light 25 minutes per day, the filaments can be used for three months.

•The usage life values above are all theoretical. The actual value will depend on the actual way the filaments are used. [72]

## 3.4.9 A Comparison of Commonly Used 3D Printing Materials' Prices

In general, ceramic and metal printing materials are more expensive than polymer plastics. The prices of the three normal polymer plastics materials mentioned in 5.2 are as follows:

PLA: 0.13 €/g (1¥/g)

Photosensitive Resin: 0.36€/g (2.8¥/g)

ABS: 0.26 €/g (2¥/g)

The prices of several other polymer plastics mentioned in 5.1 are roughly:

Nylon: 0.58-0.77 €/g (4.5-6¥/g)

TPU: 0.38 €/g (3¥/g)

PC: 0.64 €/g (5¥/g) [73]

These are the approximate market prices, which vary slightly from year to year, but the change is not significant. To sum up, ABS, PLA and photosensitive resins are more cost-advantageous, and their precision is sufficient for products that do not require too high precision for printing models, small samples, and the like. So these three materials are better received by consumers.

*Table 4. The properties of all 3D printing materials involved in this thesis*

| Company Name | The Name of Materials | Tensile Strength | Young's modulus (Mpa) | Bending Strength | Density (g/cm3) | Bending Modulus (Mpa) | Elongation at Break (%) | Odor | Sale Price Euro/Piece |
|---|---|---|---|---|---|---|---|---|---|
| **Polymaker** | **PC-Max** [58] | >200 | 2048±66 | >200 | 1.18-1.2 | 2044 ± 55 | 12.24 ± 1.44 | Almost odorless | 41.03 € |
| | **PC-Plus**[59] | >200 | 2307 ± 60 | >200 | 1.19 - 1.20 | 2477 ± 159 | 3.15 ± 0.35 | Almost odorless | 44.74 € |
| | **PolyFlex**[60] | 29.0 ± 2.8 | / | / | 1.17 - 1.24 | / | 330.1 ± 14.9 | Almost odorless | 55.90 € |
| | **PolyMax**[61] | 28.1 ± 1.3 | 1879 ± 109 | 48.0 ± 1.9 | 1.17 - 1.24 | 2119 ± 60 | 1.36 ± 0.30 | Almost odorless | 42.95 € |
| | **PolyPlus**[62] | 46.6 ± 0.9 | 2636 ± 330 | 85.1 ± 2.9 | 1.17 - 1.24 | 3283 ± 132 | 1.90 ± 0.21 | Almost odorless | 44.87 € |
| | **PolyWood**[67] | 23.2 ± 0.4 | Not available | 52.9 ± 0.3 | ~ 0.8 | 2607 ± 50 | 8.21 ± 0.87 | Almost odorless | 57.44 € |
| | **PolySmooth**[63] | 41.32 ±2.6 | 1925± 65 | 71.01 ± 5.7 | 1.15 - 1.17 | 1156 ± 200 | 5.20 ± 0.56 | Almost odorless | 38.21 € |
| **ESun** | **eASA**[65] | 50 | / | 35 | 1 | 4300 | 30 | / | / |
| | **Wood**[69] | / | / | / | 0.7 | / | / | / | 10.26 € |
| | **eBamboo**[68] | 28 | / | 35 | 10-18 | 2000 | 3-7 | / | / |
| | **Bronze**[70] | 66 | / | 106 | 1.27 | / | 16 | / | 10.26 € |
| | **Color Change Filaments**[72] | 65 | / | 97 | 1.24 | / | 6 | / | 10.26 € |
| **DSM** | **Somos EvoLVe128** [66] | 2964 | / | / | 1.12 | / | 11 | / | 705.13 € |

**Exchange rate: 1Euro =7.8RMB**

# 4 RESULTS

## 4.1 Suggestions for Purchase 3D Printers and Materials for Art Designers in China

As mentioned above, designers of different arts design professions have different requirements for 3D printing devices on account of their different professional characteristics. If you have a suitable 3D printing device, you may be halfway through your career. Some suggestions to purchase printing devices will be given below based on the work characteristics of different specialties and the characteristics of the 3D printers and printing materials in China.

### 4.1.1 Ceramic Art Design

For Ceramic art designers, their main design scope is ceramic decorations, daily used ceramic objects, and the like. The main material of these products is mostly ceramic. So the main requirement for the printer is that it can print ceramic. These ceramic products normally have small sizes and usually are viewed and used directly by people, so high printing accuracy is needed.

It is most preferable to purchase a machine that combines the ability of printing with polishing. For printed ceramic materials, attention should be paid to their performance, such as tensile strength, filament precision and so on. If the FDM printer is to be chosen, attention should be paid to the quality of the filament. For example, uneven thickness can easily cause the nozzle jam. If there are restrictions on funding, then the cost of late polishing should also be taken into account when purchasing.

## 4.1.2 Textile and Fashion Design



*Figure 50. 3D printed cloth for the Beijing opera Farewell My Concubine [74]*

The main job for textile and fashion designers are the design of textile and clothing, including shoes, hats, and accessories. 3D printers with SLS technology are more suitable for clothing printing, because this technology applies laser solidifying of materials to print the designed fabric, the product can be folded when printed. After the printing is completed, the excess powder can be cleaned up and the printed fabric can be manually unrolled to obtain the actual product (garment). As a result, although the overall size of the garment is relatively large, it is entirely possible to print with a smaller printer, and the printed product is more precise (Figure 50). As more and more soft materials can now be employed to print clothing, it is also feasible to use different printing systems to print garments depending on the material, such as the SLA system. Because printing clothing has high requirements on the printing system, printing materials and printing precision, even if it is ordinary printing clothing, the expense will be much higher than other products. If clothing customization is needed, the 3D scanner is essential. The desired scanner is preferably a handheld 3D scanner with the feasibility to scan the human body flexibly. Professional printers are usually applied to print clothing. To meet the needs of the human body, fashion and shoes that come into contact with the skin need to have a soft touch, so the used plastic materials shall be as flexible as possible. The printed clothing and shoes should be thin and soft enough. Thus the high accuracy of the printer should be the most important requirements. Another requirement is that the printer can meanwhile print different materials with different colors too. Meanwhile, the materials should be chosen carefully so that they will not impact people's health. The price of this kind of printer will be expensive, and the materials will also be much more expensive than normal PLA and ABS, such as Objet 1000 Plus.

### 4.1.3 Arts and Crafts Design

The Arts and Crafts designers are mainly engaged in the design of jewelry, ornaments, handicrafts, and the like. Since the craftworks are usually very small and most of them have small decorations on them, the printers should have a higher accuracy.

The metal is an important material for these jobs, so the selected printer is best able to print the true metal, which usually costs a lot choosing a printer that can print metal PLA or metal ABS would be a wise choice. It would be better if there were machines that could print a variety of materials. Printing jewelry requires high precision, but the printing volume does not have to be large, so the table printer can meet the requirements. Some special-purpose professional printers can also be used to print handicrafts such as jewelry. The Stratasys Eden 260VS Dental Advantage printer mentioned above, for example, can be used to print jewelry because it is a medical printer with a very high precision, which is exactly in line with the requirements for high printing precision of such things as craftsmanship and jewelry.

In terms of materials, if metal PLA filament materials are used, the cost of investment will be much higher than that of ordinary PLA or ordinary ABS plastics. Because there are very fine details on the surface of jewelry, handicrafts, and the like. The need exists for very smooth surfaces; thus, it will require manual polishing after the completion of the printing. The price of an ordinary 3D printer that can print plastic on the Chinese market is roughly 100,000 RMB (35578Euro), while a medical printer, like the Stratasys Eden 260VS Dental Advantage, will reach about one million RMB (177514 Euro). It is more expensive to print pure metal materials, so one way to save money is to print the inner core of the work with a cheap alternative material, and then gilding or silvering the surface. This is an efficient way to save money.

### 4.1.4 Sculpture

Sculptors may use 3D printers to print the small samples or study models when designing. Sculpture is usually ornamental, so the accuracy of the printers should be considered. Since metals are normal sculpture materials, it will be better if the printers can print metals. If printers can print more special materials like cement and parquet, it will be the best.

Although the sculptures also require higher printing precision, the precision requirements are slightly lower than those of fashion design and jewelry design. Moreover, there is more room for improving the surface precision of the works through post processing. A printer capable of printing large-scale products with metal PLA or metal ABS can meet the basic requirements. Of course, if there are sufficient funds, purchasing a 3D printer that can print true metal is an option. The market price of such large-printing metal printers in China is usually more than 1 million RMB (177514Euro). For the Pro 800 and Pro 950 of 3D Systems mentioned above, internal parts can be replaced with those suitable for metal. The retail price is approximately 3 million RMB (384615Euro) and the printing precision is high. Sculptors can consider buying machines similar to these two printers.

## 4.1.5 Industrial Design (Product Design)

In most universities in China, Industrial Design and Product Design are similar, only a few universities set them separately. The main work for industrial designers is the shape design of industrial products. 3D printing can be used to print study models or models and some simple final products without complex inner structure such as glasses, pots, and the like. This field also has a high requirement for accuracy.

Industrial designers' demand for 3D printers is basically the same as that for sculpture printing, but since the products involved are mostly models or real products, there is a high requirement for precision. As mentioned above, 3D Systems' Pro 800 and Pro 950 can also be used by industrial design professionals.

## 4.1.6 Environmental Art Design (Landscape Design, Interior Design, Furniture Design) and Landscape Architecture

In China, Environmental Art Design usually includes Landscape Design and Interior Design, and sometimes even Furniture Design. 3D printing in this field will be used to print the site models of landscape (terrains, rivers, buildings, pavilions, stairs, rails, bridges, flower beds, and the like.), furniture and street furniture as well as other landscape facilities. This field

does not need such high accuracy for printing, but the print size should be as big as possible. Landscape Architecture at the School of Architecture in Tsinghua University is similar to the Landscape Design at the Environmental Art Design Department of the Academy of Arts and Design in the same university. But Landscape Architecture tends to design the landscape from the engineering perspective and it is more rational in the design method. Landscape Design prefers to design more from a visual perspective and is more emotional in the design method. The main requirement for both is almost same. Polymer plastics are the main printing materials.

### 4.1.7 Architecture

Designing the individual buildings is the main job for architects. It normally includes the outer appearance and the indoor space design. Sometimes the structures of the building should be expressed. The building design is more complex than sculpture, ceramic product, textile and clothing, and industry product. Architects mainly use the engineering drawings and perspectives to communicate with their clients, but ordinary people usually do not understand the engineering drawings. This causes the communication trouble between designers and their clients. Perspectives waste more time and manpower. 3D printed Building models can solve these problems completely. The 3D building models can show the clients the actual feature of a building. Thus, it is an efficacious way for architects to communicate with their clients. In China, 3D printing is also used in the real estate field to print the site and building models. It can give the building buyers a general layout as a reference. Because a building model is a scaled-down version of a building, it is more closed to the real situation. The accuracy of the printer does not need to be so high, but the print size should be as big as possible. For the printing materials, usually normal polymer plastics are enough.

### 4.1.8 Urban Planning

The job for an Urban Planer is similar to Architect, but the difference between architecture and urban planning is that the urban planner's work is more focused on the planning work for a much larger area such as a village, a city or even a large district. It normally does not in-

clude the design of individual buildings. An urban planner mainly focuses on presenting the relations between different parts or different buildings in the city, or the relations between the city elements such as roads, railways and rivers. So the models for urban planning do not need very high accuracy. There are not many special requirements for urban planning, but the print size should be as big as possible.

The above are some specific suggestions for the purchase of 3D printers according to the special needs arising from the working characteristics of different specialties in art design.

# 5 DISCUSSION

For environmental designers, landscape architects, architects, and urban planners, their needs are roughly the same with the purpose of printing architectural or city models. They may be the study models or the final solution models. The architect mainly designs individual buildings, so his model needs to better represent the details of the building; therefore, it is hoped that the printer will have relatively better precision. The landscape architect usually designs landscape sites that are larger than the architecture's, such as a large plaza or a park, but also needs to design landscape buildings or facilities within the site, such as steps and railings, pavilions, outdoor furniture, and the like. Thus, the requirements for precision are relatively high. Therefore, when buying 3D printers, architects should pay more attention to the printing precision and volume of printers. Of course, budget permitting, a larger printable area would be better. However, since the printable area of printers currently on the market is generally below 1000mm×1000mm, if large-scale architectural and landscape models are needed, it is often necessary to print the models in smaller blocks and then stitch them together later. Architects and landscape architects can consider Union Tech's printers at their discretion. Union Tech's printers generally have lower prices but with fine precision. The urban planner can consider purchasing printers like the Grandy printer from the Archi Solution Workshop with a large output area of 1100mm x 1100mm, but the price is low, about 80,000 RMB (10256 Euro).

Usually, a printer suitable for an architect is suitable for either a landscape designer or urban planner.

Among the table 3D printers mentioned in this thesis, the printers like the Archi Solution Workshop MPP mentioned in the text can be used for general architects to print small models and samples. Archi Solution Workshop printers are generally low in price and material cost. Printing precision is sufficient for students majoring in general design and architecture to print model samples. Because Archi Solution Workshop printers are cheap, schools can buy them in large quantities.

When purchasing a 3D printer, in addition to considering the professional needs of the design, the actual use of the 3D printing by the printer user should also be taken into account. Depending on the use and purpose, the factors to be considered when purchasing a 3D printer will vary. For example, if a 3D printer is purchased for the art design school's workshop (or laboratory), it also needs to consider the characteristics of the students' use. The students' purpose for using 3D printing is generally to print their designs' study models in the process of designing exercises to deliberate their design schemes, and meanwhile to understand the basic knowledge of 3D printing and learn the basic operation methods of the 3D printer through actual operation practice. Rather than really hoping to print an actual final product, students are optimizing their design through 3D printing in the design process, so the requirements such as the precision, printable area, type of printable material, etc. of a 3D printer for this kind of purpose can all be slightly lower. In case students want to print the final design product, they can do so on a more professional printer.

Of course, the printing price of a printing device is also a factor that must be taken into account when selecting a printer. The price is often closely related to the printer's printable volume, printing precision, printing speed, the type of printable material, the complexity of the printable product, and the quality of the printer itself. Therefore, how to consider the price of the printer when purchasing depends on the actual situation of the buyer. For example, even in the same school, the emphasis of the consideration when buying a printer for the design students to print study models is different from that to print the final models of their designs. Since students who use printers are often novices, failures and damage caused by improper operations are often much more than those of professionals. A table printer which is convenient to operate and whose basic performance in terms of precision, speed, etc. can be guaranteed but with a smaller footprint and low price should be a better choice. It would be far better if the printer had faster printing speed under the above premise. Those very expensive professional printers are not very suitable for students' use. Of course, if a school needs to buy a printer for teachers and students to print the final design model or prototype and actual product, it is of great necessity to purchase a better printer in accordance with the professional characteristics and unique needs of the previously mentioned specialties. At this time, the price may not be a major issue.

For another example, if it is a company/factory that specializes in receiving print orders, the main purpose of the printer purchase is to conform to the customer's print order, so the requirement for precision is very strict. Due to the needs of printing products, such companies/factories will require some different printers with different printing systems and different forms, both table and professional printers. A large printer like Objet 1000 Plus, which is highly precise and contains a water tank in it so as to eliminate the need to transfer products after printing, can print multiple materials at the same time. Although this type of printer is expensive, it has wide applicability and can be used efficiently. Therefore, it is a good choice for this kind of company/factory. However, such printers are bulky, heavy and expensive, so they are not suitable for use in small studios.

For general art design studios, the number of people is generally smaller, and the room is smaller. If the main purpose of purchasing a printer is to print study models during the design process, the requirements for the printer can be lower. If the room is not spacious, a table printer with a smaller size and normal precision may be enough.

The overall size of a professional printer can be either big or small. Generally, large-sized printers come with a material storage cabinet. If no storage cabinet is required, printers without storage cabinets can be purchased. This professional printer, like the Grandy of the Archi Solution Workshop without a storage cabinet, still has a larger output volume than a table printer, and is cheaper than many large printers. It not only satisfies the requirements for size but also meets the requirements for funding.

Purchasing table printers may save more money, but table printers are generally less precise than professional printers, and its systems are not as stable as large printers, but they are sufficient for daily printing, such as study model printing and small product printing.

Stratasys Objet Eden 260VS Dental Advantage can be applied if designers are in need of printing models with high precision with small size. This printer was originally mainly used

for dental printing in the medical industry, so the printing precision is higher. The market price is more than RMB 1.8 million, which is much higher among those of table printers.

## 6 CONCLUSION

There is a large population of art design in China and the group composed of art designers is becoming one of the biggest. As 3D printing is becoming more and more popular in China, more and more art designers start to recognize the importance of 3D printing for their work and have already applied, or are trying to apply, 3D printing technology in aiding their design work. The aid of 3D printing for an art designer can mainly be summarized as 4 aspects. The first aspect is to 3D print his study models during the design process to deliberate and improve his design schemes. The second one is to use study models to communicate with his clients to exchange opinions about the design scheme from each other for improving the design. The third one is to print the design's final model after the confirmation of the design as a sample for reference for future use. The fourth one is to print the final real jobs or the products in bulk for sale.

Although the purpose of 3D printing is basically the same for all the designers from the art design field, there are still many differences between different specialties because of their different work duties, service objects and the special requirements from their different clients. Therefore, the art designers from different professions have their own special purposes and requirements for 3D printing, such as the printers' performance (printing accuracy, printing speed, printable materials, printable volume, etc.) and materials' properties (color and strength, etc.).

There are various 3D printing-related products such as printers, printing materials, datum collecting devices and post process devices and materials in the Chinese market. But the widely used better products that have a good reputation and big market shares are not so many. The devices and materials which are especially suitable for art designers are almost hardly to be found. Most art designers can only use normal 3D printers and materials to print their art design works. For this reason it is a very troublesome problem for art designers without enough knowledge of 3D printing to select the correct 3D printers and materials. According to the special characteristics and requirements of different specialties in China, this thesis recommends some suitable 3D printers and materials for Chinese art designers after the analyses of

some main 3D printers and materials found in the Chinese market. Moreover, the work done by the author and the recommendations for art designers when they select and purchase their 3D printers and materials are, hopefully, useful as a reference for manufacturers to design and build some new 3D printing devices and materials especially suitable for Chinese art designers in the future.

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# APPENDICE

Appendix 1

## 中国 3D 打印机市场调研

## A Survey of the Application of 3D Printers in China

因为研究的需要，本人正在做一个关于中国 3D 打印机的问卷调查。本调查没有任何商业用途，更不会泄露您的隐私。 问卷中涉及的题目没有对错之分，只需根据您的实际情况填写，无需署名，问卷只耽误您一点点时间。非常感谢您的支持。

In need of my research, I am now asking your help to finish a questionnaire on 3D printing utilized in China. This questionnaire has not any commercial object and will not reveal your privacy. The answers for the questions within the questionnaire is not Wrong or Correct. What you need to do is to answer the questions according to your own practical situation without your name on it. It will take you some minutes for your answering the questionnaire. Thank you for your support.

1 您的性别 [单选题] Your gender [Single choice]

□ 男 Male                                          □ 女 Female

2 您的年龄 [单选题] Your age [Single choice]

□ 15-20                    □ 21-25                    □ 26-30

□ 31-40                    □ 41-50                    □ 50 以上 Above 50

3 您的工作机构 [多选题]   What is your organization? [Multiple choice]

□ 生产（制造）企业 Manufacture Enterprise

□ 贸易商务 Business Company

□ 学校 School

□ 科研机构 Scientific Research Institution

□ 医院 Hospital

□ 实验室 Laboratory

□ 政府机关 Government Office

□ 传媒 Media Organization

□ 房地产 Real Estate Company

□ 其他 Others _____


4 您的职业 [多选题]  What is your occupation? [Multiple choice]

□ 学生(Student)

□ 老师 **Teacher**

□ 工程师 **Engineer**

□ 设计师 **Designer**

□ 研究人员 **Researcher**

□ 医生 **Doctor**

□ 艺术家 **Artist**

□ 建筑师 **Architect**

□ 其他 Others _____


5 您所使用的 3D 打印机型号及购买时的价格 （填写格式：型号、价格，价格请尽可能精确，如不记得精确价格请填写大致价格） [填空题]

The names and types of the 3D printers you are using and their sale prices (For example: Name, price. Please write down the price accurately, if you cannot remember the price of the printer, you can write down the approximate price) [Gap filling]

□ 型号 Printer 1 _____

□ 型号 Printer 2 _____

□ 型号 Printer 3 _____

□ 型号 Printer 4 _____

□ 型号 Printer 5 _____

□ 型号 Printer 6_____

6 您的这些打印机是否仍在使用中？请勾选正在使用的打印机型号并告知已经使用的时间，以"年"为单位（型号顺序请务必与上一题一致）[填空题]

Are your printers still in use? If yes, please write down the using time. The unit is Year. [Gap filling]

□ 型号 Printer 1_____

□ 型号 Printer 2 _____

□ 型号 Printer 3 _____

□ 型号 Printer 4_____

□ 型号 Printer 5_____

□ 型号 Printer 6_____

7 如果您的某些打印机已经停止使用，请说明原因 [多选题]

If your 3D printer is not in use, please choose the reason. [Multiple choice]

□ 运行系统不稳定 Unstable operation system

□ 材料堵塞喷头 Nozzle jam

□ 打印精度不够 Low printing accuracy

□ 打印机激光波长不够长 Wavelength of the laser printer is not long enough

□ 紫外线长度不够 The length of the UV light is not enough

□ 维修费太贵 High maintenance cost

□ 容积不够大 The printing volume is not big enough

□ 打印材料种类少 Fewer types of printing materials

□ 每层厚度不均匀 The thickness of each printing layer is not uniform.

□ 每层太厚或太薄 Each layer is too thick or too thin

□ 打印速度太慢 Low printing speed

□ 散热不好 Cooling system not good

□ 喷头拉丝 Nozzle wiredrawing problem

□ 所打印的产品不坚固 Printed products not strong enough

□ 材料更换不方便 Inconvenience of material replacement

□ 层错位 Printing layer dislocation

□ 层断裂 Layer fracture

□ 实际打印温度低于设定温度 The actual printing temperature lower than the setting temperature

□ 实际打印温度高于设定温度 The actual printing temperature higher than the set temperature

□ 填充轮廓之间有缝隙 Gap between the contour filling

□ 打印中途无故自动停止 Automatically stop halfway without a reason

□ 经常烧坏主控板、拓展板等 The main control board and expansion board often burn out

□ 软件不好操作 The operation software is not user-friend

□ 机械系统不稳定或损坏 Mechanical system instability or damage

□ 其他 Others _____

8 您的 3D 打印机如果还在使用中，使用用途是 [多选题]

  If your printer is still in use, what is its main usage? [Multiple choice]

□ 打印建筑或设计模型 Printing building models

□ 打印人体器官(例如:牙齿、耳朵、义肢等) Printing body organs

□ 打印零配件 Printing spare and accessory parts

□ 打印人体模型 Printing body models

□ 打印实际产品 Printing real products

□ 其他 Others _____

9 您的打印机如果还在使用中，让您满意的是什么 [多选题]

  If your printer is still in use, what are the things that satisfy you? [Multiple choice]

□ 运行系统稳定 Stable system

□ 用户操作软件使用方便 User-friend of its operation system

□ 打印精度高 High printing accuracy

□ 材料更换方便 Convenient Material  Replacing

□ 打印材料喷出均匀 Material printed uniformly

□ 每层厚度均匀 Uniform of thickness of each layer

□ 光斑面积大 Light spot is bigger enough

□ 光波够长 Wavelength is long enough

□ 散热好 Good cooling system

□ 成本低 Low maintenance cost

□ 后续加工不废时间 Less post process time

□ 机械系统稳定 Mechanical system is stable

□ 其他 Others_____

10 您认为您使用的上述打印机性价比如何？（型号顺序请务必与上面顺序一致。（请按等级填写优、良、中、差）[填空题]

   How are the cost performances of the printers in use? (great, good, normal, bad) [Gap filling]

□ 型号 Printer 1 _____

□ 型号 Printer 2 _____

□ 型号 Printer 3 _____

□ 型号 Printer 4 _____

□ 型号 Printer 5 _____

□ 型号 Printer 6 _____

11 您是否会再次购买您正在使用的打印机？（型号顺序请务必与上面顺序一致，请填写是或否）[填空题]

Will you buy the printers that you are using again? Please write Yes or No. [Gap filling]

□ 型号 Printer 1 _____

□ 型号 Printer 2 _____

□ 型号 Printer 3 _____

□ 型号 Printer 4 _____

□ 型号 Printer 5_____

□ 型号 Printer 6_____

12 如果您要购买新的不同于之前使用的打印机，您会选择哪一款打印机？请提供生产厂家及打印机型号并简要说明其优缺点 [填空题]

If you want to buy a new printer different from your previous one you ever used, which printer you will choose. Please write the name of the new printer, the manufacture's name. Please write the advantages and disadvantages of the printer briefly. [Gap filling]

□ 型号 Printer A _____

□ 型号 Printer B _____

□ 型号 Printer C _____

□ 型号 Printer D _____

13 对您现在使用的打印机您有什么改进建议，请简短描述 [填空题]

What suggestions you will give for improving the printers that you are using now. [Gap filling]

_____

14 您使用的打印机可使用什么材料及材料形态？[多选题]

What kind of materials can be used for you 3D printers? [Multiple choice]

□ 塑料线圈 Polymer plastics filaments

□ 塑料粉末颗粒 Polymer plastics powder

□ 液态材料 Liquid printing material

□ 金属线圈 metal filaments

□ 金属粉末 Metal powder

□ 木质成分线圈 Wood filaments

□ 木质成分粉末 Wood powder

□ 烧结打印 Sintering

□ 其他 Others_____

# Appendix 2

# 中国市场 **3D** 打印材料应用调查

# **A Survey of the Application of 3D Printing Materials in China**

因为研究的需要，本人正在做一个关于中国市场 3D 打印材料的问卷调查。本调查没有任何商业用途，更不会泄露您的隐私。 问卷中涉及的题目没有对错之分，只需根据您的实际情况填写，无需署名。问卷会耽误您一点点时间，但您所提供的信息对我的研究将会非常重要，衷心感谢您的支持！

In need of my research, I am now asking your help to finish a questionnaire on 3D printing utilized in China. This questionnaire has not any commercial object and will not reveal your privacy. The answers for the questions within the questionnaire is not Wrong or Correct. What you need to do is to answer the questions according to your own practical situation without your name on it. It will take you some minutes for your answering the questionnaire. Thank you for your support.

1 请勾选您的 3D 打印机所使用的材料的形态 [多选题]

Please choose the forms of your 3D printing materials. [Multiple choose]

□ 粉末 Powder

□ 线圈 Filament

□ 液体 Liquid

□ 颗粒 Grains

2 请勾选您正在使用的 3D 打印材料，并写出大致价格（例如：透明 PLA 1 元/克） [多选题]

Please choose the 3D printing materials used for your 3D printers and write down their prices. (For example, Transparent PLA 1RMB/g）[Multiple choice]

□ A. 透明 PLA Transparent PLA

□ B. 不透明 PLA Opaque PLA

□ C. 光敏树脂 Photosensitive Resin

□ D. ABS

□ E.尼龙 Nylon

□ F. PC

□ G. 碳纤维材料 Carbon Fiber

□ H. TPU

□ I. 木质感材料 Wood looking material

□ J. 金属 PLA(PLA 混合金属粉末)/ 金属 ABS(ABS 混合金属粉末) Metal PLA

□ K. 金属材料 Metal _____

□ L. 陶瓷 Ceramic _____

□ M 其他（如果有其他材料，请回答问题 3）Others（If you have some other materials please read question 3)

3 如果您使用过上题中 A~L 材料以外的其他 3D 打印材料，请写出其名称及大致价格 （例如：透明 PLA 1 元/克）

If you used or are using the materials besides materials A to L in question 2, please write down the name and the approximately price. (For example, transparent PLA, 1RMB/g)

| 材料 Material 1 | _____ |
| --- | --- |

| | |
|---|---|
| 材料 Material 2 | _____ |
| 材料 Material 3 | _____ |
| 材料 Material 4 | _____ |
| 材料 Material 5 | _____ |
| 材料 Material 6 | _____ |
| 材料 Material 7 | _____ |

4-1 请写明您使用的上述 3D 打印材料的生产厂家 （请在每种材料后面写出对应的厂家，例如：A. 透明 PLA 后面可以这样填写： 厂家 1xxx 厂家、厂家 2xxx 公司、厂家 3xxx 工厂；B. 不透明 PLA 后面可以这样填写：厂家 1xxx 公司、厂家 2xxx 厂家）

Please write the manufacturers' names of your 3D printing materials (For example, A Transparent PLA: Manufacturer 1 xxx, Manufacturer 2 xxxx, Manufacturer 3 xxxx. B Opaque PLA: Manufacturer 1 xxx, Manufacturer 2 xxxx, Manufacturer 3 xxxx.)

| | |
|---|---|
| A. 透明 PLA Ttransparent PLA | _____ |
| B. 不透明 PLA Opaque PLA | _____ |
| C. 光敏树脂 Photosensitive resin | _____ |
| D. ABS | _____ |
| E. 尼龙 Nylon | _____ |
| F. PC | _____ |
| G. 碳纤维材料 Carbon fiber | _____ |

| | |
|---|---|
| H. TPU | _____ |
| I. 木质感材料 Wood looking material | _____ |
| J. 金属 PLA（PLA 混合金属粉末）/ 金属 ABS（ABS 混合金属粉末）Metal PLA/ metal ABS | _____ |
| K. 金属材料 Metal | _____ |
| L. 陶瓷 Ceramic | _____ |
| 材料 1 Material 1 | _____ |
| 材料 2 Material 2 | _____ |
| 材料 3 Material 3 | _____ |
| 材料 4 Material 4 | _____ |
| 材料 5 Material 5 | _____ |
| 材料 6 Material 6 | _____ |
| 材料 7 Material 7 | _____ |

4-2 请问以上厂家的透明 PLA 与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the PLA material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| | |
|---|---|
| 透明 PLA 厂家 1<br><br>Transparent PLA's Manufacturer 1 | _____ |
| 透明 PLA 厂家 2<br><br>Transparent PLA's Manufacturer  2 | _____ |
| 透明 PLA 厂家 3<br><br>Transparent PLA's Manufacturer 3 | _____ |

4-3 请问以上厂家的不透明 PLA 与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Opaque PLA material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| | |
|---|---|
| 不透明 PLA 厂家 1<br><br>Opaque PLA 's Manufacturer 1 | _____ |
| 不透明 PLA 厂家 2<br><br>Opaque PLA's Manufacturer 2 | _____ |
| 不透明 PLA 厂家 3<br><br>Opaque PLA's Manufacturer 3 | _____ |

4-4 请问以上厂家的光敏树脂与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Photosensitive resin material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| | |
|---|---|
| 光敏树脂 厂家 1<br><br>Photosensitive resin's Manufacturer 1 | _____ |
| 光敏树脂 厂家 2<br><br>Photosensitive resin's Manufacturer 2 | _____ |
| 光敏树脂 厂家 3<br><br>Photosensitive resin's Manufacturer 3 | _____ |

4-5 请问以上厂家的 ABS 与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the ABS material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| | |
|---|---|
| ABS 厂家 1<br><br> ABS's Manufacturer 1 | _____ |
| ABS 厂家 2<br><br>ABS's Manufacturer 2 | _____ |
| ABS 厂家 3<br><br>ABS's Manufacturer 3 | _____ |

4-6 请问以上厂家的尼龙与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Nylon material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 尼龙厂家 1<br><br>Nylon's Manufacturer 1 | _____ |
| --- | --- |
| 尼龙厂家 2<br><br>Nylon's Manufacturer 2 | _____ |
| 尼龙厂家 3<br><br>Nylon's Manufacturer 3 | _____ |

4-7 请问以上厂家的 PC 与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the PC material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree))

| PC 厂家 1<br><br>PC's Manufacturer 1 | _____ |
| --- | --- |
| PC 厂家 2<br><br>PC's Manufacturer 2 | _____ |
| PC 厂家 3 | _____ |

| PC's Manufacturer 3 | |
|---|---|

4-8 请问以上厂家的碳纤维材料与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）[输入 1 到 10 的数字]

How is the matching degree between the Carbon fiber material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 碳纤维材料 厂家 1<br><br>Carbon fiber's Manufacturer 1 | _____ |
|---|---|
| 碳纤维材料 厂家 2<br><br>Carbon fiber's Manufacturer 2 | _____ |
| 碳纤维材料 厂家 3<br><br>Carbon fiber's Manufacturer 3 | _____ |

4-9 请问以上厂家的 TPU 与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the TPU material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| TPU 厂家 1<br><br>TPU's Manufacturer 1 | _____ |
|---|---|
| TPU 厂家 2 | _____ |

| | |
|---|---|
| TPU's Manufacturer 2 | |
| TPU 厂家 3<br><br>TPU's Manufacturer 3 | _____ |

4-10 请问以上厂家的木质感材料与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Wood looking material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| | |
|---|---|
| 木质感材料 厂家 1<br><br>Wood looking material's Manufacturer 1 | _____ _____ |
| 木质感材料 厂家 2<br><br> Wood looking material's Manufacturer 2 | _____ |
| 木质感材料 厂家 3<br><br>Wood looking material's Manufacturer 3 | _____ |

4-11 请问以上厂家的金属 PLA（PLA 混合金属粉末）/ 金属 ABS（ABS 混合金属粉末）与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Metal PLA material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| | |
|---|---|
| 金属 PLA（PLA 混合金属粉末）厂家 1<br><br>Metal PLA's Manufacturer 1 | _____ |
| 金属 PLA（PLA 混合金属粉末）厂家 2<br><br>Metal PLA's Manufacturer 2 | _____ |
| 金属 PLA（PLA 混合金属粉末）厂家 3<br><br>Metal PLA's Manufacturer 3 | _____ |
| 金属 ABS（ABS 混合金属粉末）厂家 1<br><br>Metal PLA's Manufacturer 1 | _____ |
| 金属 ABS（ABS 混合金属粉末）厂家 2<br><br>metal ABS's Manufacturer 2 | _____ |
| 金属 ABS（ABS 混合金属粉末）厂家 3<br><br>Metal PLA's Manufacturer 3 | _____ |

4-12 请问以上厂家的金属材料与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Metal material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| | |
|---|---|
| 金属材料 厂家 1<br><br>Metal's Manufacturer 1 | _____ |
| 金属材料 厂家 2 | _____ |

| Metal's Manufacturer 2 | |
|---|---|
| 金属材料厂家 3<br><br>Metal's Manufacturer 3 | _____ |

4-13 请问以上厂家的陶瓷与您正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

 How is the matching degree between the Ceramic material mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 陶瓷厂家 1<br><br>Ceramic's Manufacturer 1 | _____ |
|---|---|
| 陶瓷厂家 2<br><br>Ceramic's Manufacturer 2 | _____ |
| 陶瓷厂家 3<br><br>Ceramic's Manufacturer 3 | _____ |

4-14 请问以上厂家的材料 1 与正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Material 1 mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 材料 1 厂家 1 | _____ |
|---|---|

| 材料 1 厂家 1<br>Material 1's Manufacturer 1 | |
| --- | --- |
| 材料 1 厂家 2<br>Material 1's Manufacturer 2 | _____ |
| 材料 1 厂家 3<br>Material 1's Manufacturer 3 | _____ |

4-15 请问以上厂家的材料 2 与正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between Material 2 mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 材料 2 厂家 1<br>Material 2's Manufacturer 1 | _____ |
| --- | --- |
| 材料 2 厂家 2<br>Material 2's Manufacturer 2 | _____ |
| 材料 2 厂家 3<br>Material 2's Manufacturer 3 | _____ |

4-16 请问以上厂家的材料 3 与正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

 How is the matching degree between the Material 3 mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 材料 3 厂家 1<br><br>Material 3's Manufacturer 1 | _____ |
|---|---|
| 材料 3 厂家 2<br><br>Material 3's Manufacturer 2 | _____ |
| 材料 3 厂家 3<br><br>Material 3's Manufacturer 3 | _____ |

4-17 请问以上厂家的材料 4 与正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Material 4 mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 材料 4 厂家 1<br><br>Material 4's Manufacturer 1 | _____ |
|---|---|
| 材料 4 厂家 2<br><br>Material 4's Manufacturer 2 | _____ |
| 材料 4 厂家 3<br><br>Material 4's Manufacturer 3 | _____ |

4-18 请问以上厂家的材料 5 与正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Material 5 mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 材料 5 厂家 1 Material 5's Manufacturer 1 | _____ |
|---|---|
| 材料 5 厂家 2 Material 5's Manufacturer 2 | _____ |
| 材料 5 厂家 3 Material 5's Manufacturer 3 | _____ |

4-19 请问以上厂家的材料 6 与正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Material 6 mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 材料 6 厂家 1<br><br>Material 6's Manufacturer 1 | _____ |
|---|---|
| 材料 6 厂家 2<br><br>Material 6's Manufacturer 2 | _____ |
| 材料 6 厂家 3<br><br>Material 6's Manufacturer 3 | _____ |

4-20 请问以上厂家的材料 7 与正在使用的 3D 打印机的匹配程度如何（比如打印机生产商生产的原厂打印材料一般比其他厂家生产的替代材料的匹配度就要好得多）（1-10 分，1 分最低，10 分最高，可拖动拉条评分。厂家序号务必与第 4-1 题相一致）

How is the matching degree between the Material 7 mentioned above and your 3D printer? Please use the slider to choose the grade 1- 10 (1 is the lowest, 10 is the highest. Normally the materials from the same company as your printer's manufacturer has the best match degree)

| 材料 7 厂家 1<br><br>Material 7's Manufacturer 1 | _____ |
|---|---|
| 材料 7 厂家 2<br><br>Material 7Factory 2 | _____ |
| 材料 7 厂家 3<br><br>Material 7's Manufacturer 3 | _____ |

5-1 如果您使用的是透明 PLA，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using the Transparent PLA, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |

| 挥发性 Evaporation | _____ |
|---|---|
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-2 如果您使用的是不透明 PLA，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using the Opaque PLA, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |

| 水溶解度 Solubility in Water | _____ |
|---|---|
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-3 如果您使用的是光敏树脂，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using the Photosensitive resin, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, | _____ |

| etc.) | |
|---|---|

5-4 如果您使用的是 ABS，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using ABS, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-5 如果您使用的是尼龙，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）If you are using the Photosensitive resin, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| | |
|---|---|
| 抗拉伸强度 Tensile Strength | _____ |
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-6 如果您使用的是 PC，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using PC, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| | |
|---|---|
| 抗拉伸强度 Tensile Strength | _____ |
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-7 如果您使用的是碳纤维材料，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Carbon fiber, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| | |
|---|---|
| 抗拉伸强度 Tensile Strength | _____ |
| 抗弯曲强度 Bending Strength | _____ |

| 弹性 Elasticity | _____ |
|---|---|
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-8 如果您使用的是 TPU，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using TPU, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |

| 耐热程度 Heat Resistance | _____ |
|---|---|
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-9 如果您使用的是金属 PLA（PLA 混合金属粉末），请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Metal PLA, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |

| 变色性 Discolor | _____ |
|---|---|
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

5-10 如果您使用的是金属 ABS（ABS 混合金属粉末），请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Metal ABS, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |

| | |
|---|---|
| 气味大小 Odor | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 水溶解度 Solubility in Water | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |

5-11 如果您使用的是金属材料，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Metal, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| | |
|---|---|
| 抗拉伸强度 Tensile Strength | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 抗弯曲强度 Bending Strength | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 弹性 Elasticity | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 坚硬程度 Hardness | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 耐热程度 Heat Resistance | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 形变程度 Deformation | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 变色性 Discolor | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 挥发性 Evaporation | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 气味大小 Odor | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 水溶解度 Solubility in Water | ＿＿＿＿＿＿＿＿＿＿＿＿＿＿ |

| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| --- | --- |

5-12 如果您使用的是木质感材料，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Wood Looking Material, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| --- | --- |
| 抗弯曲强度 Bending Strength | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 弹性 Elasticity | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 坚硬程度 Hardness | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 耐热程度 Heat Resistance | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 形变程度 Deformation | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 变色性 Discolor | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 挥发性 Evaporation | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 气味大小 Odor | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 水溶解度 Solubility in Water | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |

5-13 如果您使用的是陶瓷，请对用此材料所打印的产品的性能表现进行评价 （1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Ceramic, please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| | |
|---|---|
| 抗拉伸强度 Tensile Strength | _____ |
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

6-1 如果您使用的是第 3 题其他材料中的材料 1 (见第 3 题答案），请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Material 1 from Others in question 3 (see the answers in question 3), please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

6-2 如果您使用的是第 3 题其他材料中的材料 2 (见第 3 题答案)，请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Material 2 from Others in question 3 (see the answers in question 3), please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|

| 抗弯曲强度 Bending Strength | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
|---|---|
| 弹性 Elasticity | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 坚硬程度 Hardness | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 耐热程度 Heat Resistance | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 形变程度 Deformation | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 变色性 Discolor | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 挥发性 Evaporation | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 气味大小 Odor | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 水溶解度 Solubility in Water | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |

6-3 如果您使用的是第 3 题其他材料中的材料 3（见第 3 题答案），请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Material 3 from Others in question 3 (see the answers in question 3), please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
|---|---|
| 抗弯曲强度 Bending Strength | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |
| 弹性 Elasticity | ＿＿＿＿＿＿＿＿＿＿＿＿＿ |

| 坚硬程度 Hardness | _____ |
|---|---|
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

6-4 如果您使用的是第 3 题其他材料中的材料 4(见第 3 题答案)，请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Material 1 from Others in question 3 (see the answers in question 3), please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |

| | |
|---|---|
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

6-5 如果您使用的是第 3 题其他材料中的材料 5 (见第 3 题答案），请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Material 5 from Others in question 3 (see the answers in question 3), please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| | |
|---|---|
| 抗拉伸强度 Tensile Strength | _____ |
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |

| 挥发性 Evaporation | _____ |
|---|---|
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）<br><br>Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

6-6 如果您使用的是第 3 题其他材料中的材料 6 (见第 3 题答案），请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Material 6 from Others in question 3 (see the answers in question 3), please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |

| 水溶解度 Solubility in Water | _____ |
|---|---|
| 特殊液体溶解度（例如：酒精，汽油等）Solubility in Special Liquids (like Alcohol, Gasoline, etc.) | _____ |

6-7 如果您使用的是第 3 题其他材料中的材料 7 (见第 3 题答案)，请对用此材料所打印的产品的性能表现进行评价（1-10 分，1 分最低，10 分最高，可拖动拉条评分）

If you are using Material 7 from Others in question 3 (see the answers in question 3), please give the score 1 -10 for the quality of the products printed with this material. (1 is the lowest and 10 is the highest)

| 抗拉伸强度 Tensile Strength | _____ |
|---|---|
| 抗弯曲强度 Bending Strength | _____ |
| 弹性 Elasticity | _____ |
| 坚硬程度 Hardness | _____ |
| 耐热程度 Heat Resistance | _____ |
| 形变程度 Deformation | _____ |
| 变色性 Discolor | _____ |
| 挥发性 Evaporation | _____ |
| 气味大小 Odor | _____ |
| 水溶解度 Solubility in Water | _____ |
| 特殊液体溶解度（例如：酒精，汽油等）Solubility in Special Liquids (like Alcohol, Gasoline, | _____ |

| etc.) | |
|---|---|

7 请您写出您心目中最好的 3D 打印材料并告知其生产厂家 （例如：透明 PLA，xxx 公司）

Please write down the best 3D printing materials you think and their manufacturers (e.g. transparent PLA, company name).

| 1 | _____ |
|---|---|
| 2 | _____ |
| 3 | _____ |
| 4 | _____ |
| 5 | _____ |

Appendix 3

# 设计师、艺术家 3D 打印意向调查

# A Survey of Intention of 3D Printing for Art Designers

因为研究的需要，本人正在做一个关于中国 3D 打印机的问卷调查。本调查没有任何商业用途，更不会泄露您的隐私。 问卷中涉及的题目没有对错之分，只需根据您的实际情况填写，无需署名，问卷只耽误您几分钟时间。非常感谢您的支持！

In need of my research, I am now asking your help to finish a questionnaire on 3D printing utilized in China. This questionnaire has not any commercial object and will not reveal your privacy. The answers for the questions within the questionnaire is not Wrong or Correct. What you need to do is to answer the questions according to your own practical situation without your name on it. It will take you some minutes for your answering the questionnaire. Thank you for your support.

1. 作为一名设计师或艺术家，您所从事的具体领域是什么? [多选题]

As an Art designer, what is (Are) your main major(s)? [Multiple choice]

□ 产品设计 Products Design (Industrial Design)

□ 交互设计 Interaction Design

□ 视觉传达设计 Visual Communication Design

□ 染织与服装设计 Textile and Fashion Design

□ 景观设计 Landscape Design

□ 建筑设计 Architecture Design

□ 室内设计 Interior Design

□ 家具设计 Furniture Design

□ 陶瓷设计 Ceramic Design

□ 工艺美术设计 Arts and Crafts Design

□ 玻璃设计 Glass Design

□ 园艺设计 Gardening Design

□ 信息艺术设计  Information Art & Design

□ 动漫设计 Animation Design

□ 绘画 Painting

□ 雕塑 Sculpture

□ 其他（请填写您的专业领域）Others (Please fill in your major) _____

2. 如果您想要购买一台 3D 打印机，您更偏向于专业打印机还是桌面打印机 [单选题]

If you want to buy a 3D printer, do you want to choose the table printer or a professional printer? [Single choice]

□ 桌面机（一般指放在桌面上的小型打印机，一般只能打印小型物品）

  Table printer (Usually a small printer which can be put on a table and can print small size objects only.)

□ 专业机（通常为落地式，可以打印较大的物品）

  Professional printer (Usually a bigger printer to be put on the ground and can print bigger size objects)

3. 如果您拥有或想要添置一台 3D 打印机，您正在或将用于什么具体用途 （例如：打印建筑模型，装饰品，服饰等）(请写下您的打印用途)

If you have or want to buy a 3D printer which purpose is it or will it be? (E.g. to print building models, decorations, cloths, etc.) (Please write down your purposes)

| 1 | _____ |
|---|---|
| 2 | _____ |
| 3 | _____ |
| 4 | _____ |
| 5 | _____ |
| 6 | _____ |
| 7 | _____ |
| 8 | _____ |
| 9 | _____ |
| 10 | _____ |

4. 如果您将要购买一台新的 3D 打印机，您将更侧重于它的哪方面特性？ [多选题]

If you will buy a 3D printer which characteristics will you pay more attention to? [Multiple choice]

□ 打印精度高 High Accuracy

□ 打印机价格便宜 Cheaper Price

□ 材料更换时操作方便 Convenient Material Replacing

□ 打印速度快 Fast Printing Speed

□ 系统稳定 Stability of the System

□ 用户操作软件使用方便 User Friendly Software

□ 易安装 Easy Installment of the Machine

□ 机器寿命长 Long Usage Life

□ 维修和维护费用低 Low Maintenance Cost

□ 机器体积小 Small Size of the Printer

□ 机器体积大 Big Size of the Printer

□ 可以打印体积较大的物品 Bigger Printable Volume

□ 对环境要求不高 Low Requirements for the Space

□ 配套耗材成本低 Low Cost of the Printing Material Supplements

□ 机械问题少 Less Mechanical Problems

□ 可以打印多种材料 More Printable Materials

□ 其他 Others_____