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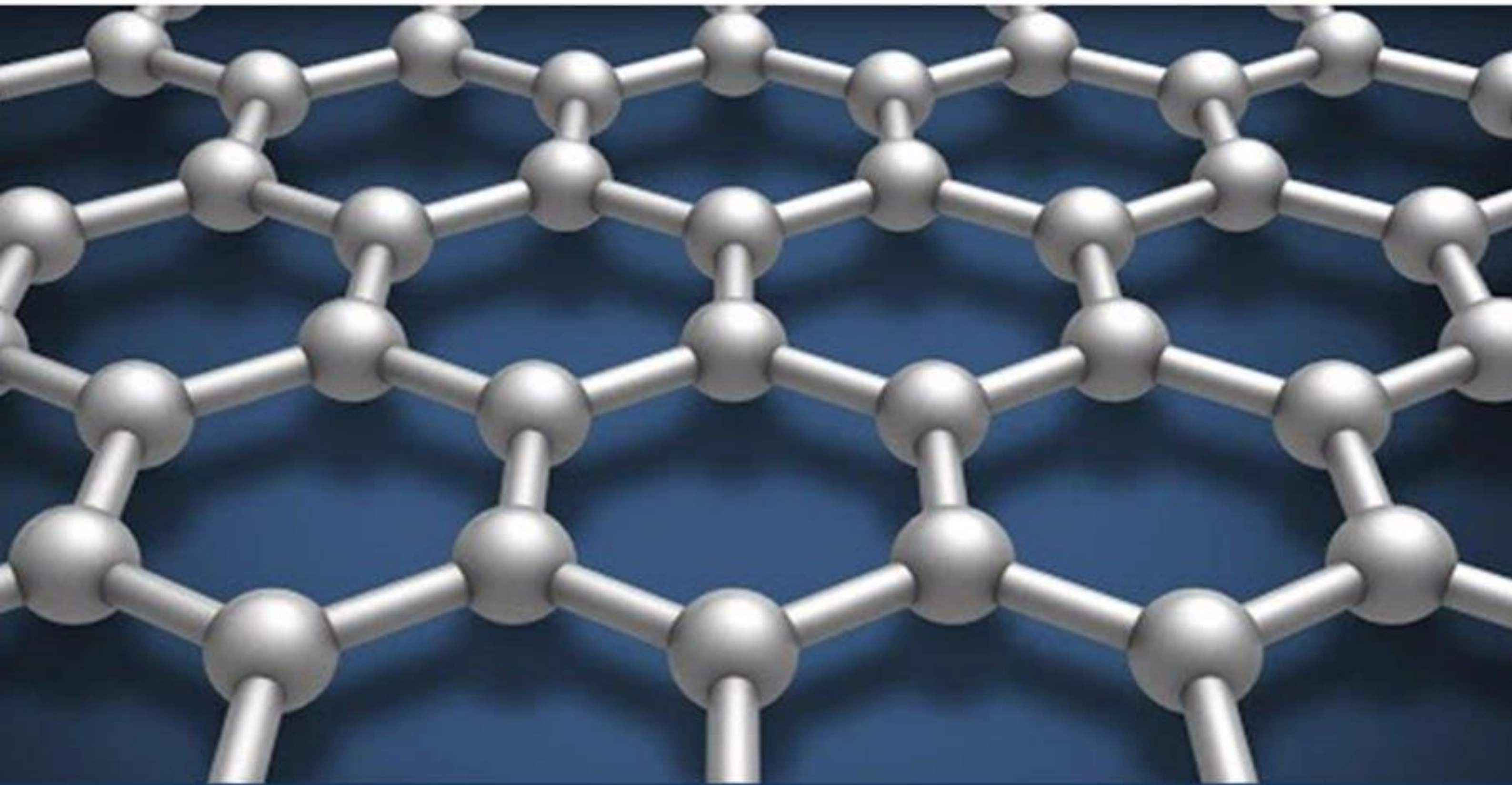

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Композиционные материалы

ADVANTAGES AND CHARACTERISTICS OF TPU FILAMENT OVER PLA FILAMENT WHEN USING 3D PRINTING TECHNOLOGY IN CLOTHES

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Introduction. TPU (Thermoplastic Polyurethane) filament is an optimal material for 3D printers. It possesses a range of advantages and characteristics that make it suitable for various types of applications. TPU filament is well-known for its complex flexibility and elasticity compared to other filaments. Objects made by this filament can bend, stretch, and compress without losing their shape. This enables the creation of flexible and elastic objects. Additionally, TPU filament has high impact resistance, meaning it can withstand external forces and maintain durability. Therefore, it is commonly used in the production of protective or functional models. TPU filaments are available in different hardness levels, with 85A TPU being softer and more flexible compared to 95A TPU filament.

The utilization of filament highly depends on the purpose of the object and the characteristics of 3D printers. One crucial aspect to consider when producing models with 3D printers is the proper bonding of layers, which ensures the structural integrity of the 3D model. If the layers do not adhere correctly to each other, the printed model may become weak and brittle.

When it comes to TPU filament demonstrates strong layer adhesion during the printing process. This ensures good bonding and structural integrity between the layers of the printed objects, reducing the risk of layer separation or expansion. Furthermore, one of the advantages of TPU filament is its chemical resistance, allowing it to withstand exposure to a wide range of chemical substances without significant mechanical degradation or deterioration. Making it endurable for a wide range of substances without deforming its mechanical characteristics. 3D models printed with TPU filament can be post-processed to enhance their external appearance and functionality, such as through polishing, dyeing, or heat treatment. It is important to note that TPU filament requires specific precision and attention during the 3D printing process. Factors such as the printer's speed, adequate cooling, and proper layer bonding techniques must be considered. By adhering to these considerations, 3D-printed models can achieve overall strength and quality. In general, TPU filament offers versatility, flexibility, and durability [1].

Objects and methods of research. In addition to its other benefits, TPU filament is an excellent material for creating fashion designs in 3D printing. Its high flexibility, elasticity, and wide range of available colors offer designers unique and innovative possibilities in creating garments. Specifically, TPU filament is a preferred choice for producing clothing, accessories, and footwear that demand comfort, flexibility, resilience, and a high degree of convenience. It allows for the creation of personalized, customized garments tailored to individual body shapes and measurements, enhancing the aesthetics of clothing. TPU filament opens up avenues for creating visually appealing and well-fitted ensembles for customers.

Indeed, in the 3D printing process, TPU filament can be used to create various textured surfaces and patterns. This allows for the production of highly appealing, and unique designs that can not be replicable. Additionally, it enables designers to cater to the interests of customers who appreciate intricate details and express their own individuality through their clothing and accessories. TPU filament offers a wide range of available colors, providing fashion designers with the opportunity to experiment with different color schemes, gradients, and multicolored prints to bring their creative visions to life. Another benefit of TPU filament in fashion design is its compatibility with other traditional fabric materials. By combining TPU filament with conventional textiles used in regular garments that designers can achieve stunning aesthetics. They can create captivating combinations of structure, texture, and flexibility in their fashion creations.

In the fashion industry, TPU filament can be used not only for garments but also for accessories such as jewelry components, buttons, various types of fasteners, necklaces, and trims. The flexibility and customization possibilities of the filament make it a suitable choice for creating intricate and patterned surface elements for complex and embellished costumes. It is important to note that when using TPU filament for fashion design, attention should be given to the settings of the 3D printing machine and the unique properties of the filament itself, such as ensuring strong layer adhesion and appropriate printing techniques.

It is important to emphasize that TPU filament opens up new possibilities for fashion designers. It allows them to leverage the advantages of 3D printing technology and create innovative, customized, and visually stunning fashion pieces that are tailored to individual preferences and styles. By harnessing the capabilities of 3D printing with TPU filament, designers can explore new avenues in fashion design, combining traditional manufacturing with modern technology to produce unique and personalized garments and accessories.

PLA (Polylactic Acid) filament is one of the most commonly used materials for 3D printing. It is a biodegradable thermoplastic polymer derived from renewable sources such as cornstarch or sugarcane. PLA filament possesses several characteristics. Firstly, it offers ease of printing with good dimensional accuracy, low warping, and minimal shrinkage during the printing process. Additionally, PLA filament has a relatively low melting temperature, typically ranging from 180 to 220 degrees Celsius, making it compatible with various types of 3D printers. PLA is well-known for its high-quality prints and excellent layer adhesion, resulting in smooth and precise prints [2].

The obtained results and discussion. PLA filament is indeed known for its biodegradable nature, making it an environmentally friendly material. Under the right conditions, such as high temperature and humidity, it can be broken down by microorganisms. PLA filament is available in a wide assortment of colors and various models for printing. Also, models printed with PLA filament can be post-processed through sanding and painting to achieve the desired design. This type of filament is commonly used for larger-scale models that do not require high-temperature resistance, such as functional parts, sculpture-making, decorative objects, educational models, and various consumer products. PLA filament is hygroscopic, meaning it absorbs moisture from the surrounding environment. To maintain its quality during 3D printing, it is recommended to store this material in airtight containers. Generally, while each type of filament has a recommended storage period when stored properly, they can be stored for up to two years.

It is important to highlight that while PLA filament has many advantages, it also has certain limitations and drawbacks for fashion design. It is not recommended for models that require high-temperature resistance because PLA can soften and deform at temperatures above 60-70 degrees Celsius. Additionally, PLA's biodegradability makes it less suitable for long-term outdoor use in open environments. PLA filament is not as compatible with other materials commonly used in fashion design, such as TPU or nylon. It is susceptible to external forces and can be easily fractured or torn. Therefore, it may not be suitable for fashion modals that require long-term durability or high resistance to external forces. Furthermore, its low heat resistance makes it an inappropriate choice for garments or accessories that will be exposed to direct sunlight or heat sources in close proximity. While PLA filament is relatively flexible compared to other solid filaments, it may not provide the necessary level of flexibility for certain fashion designs and models. When designing clothes, the flexibility and stretchability of the material is ultimately important.

Although this filament is available in a wide range of colors, it may not offer the same color consistency as other materials. If the designer requires a unique and vivid color for their project, using a different filament may be more advantageous and convenient. While the biodegradable nature of PLA filament can be beneficial for certain objects and items, it may present limitations for garments and accessories that require long-term structural integrity and intactness. The filament can degrade and discolor over time, especially when exposed to moisture or ultraviolet light, which can lead to 2 times faster changes in texture and appearance.

It can be understood that it can have many harmful effects on both the human body and clothing, and it is certainly not suitable for long-term fashion models. It is important for designers to consider these limitations when choosing materials for their designs. Depending on the specific requirements of the fashion piece, TPU, nylon, and other flexible filaments can be among the best choices.

Table 1

Name	TPU filament	PLA filament
Density g/sm^3	From 1,1 to 1,2	1,2 g/sm^3
Moistureness	From 0,1% to 0,5%	0,2-0,5%
Hygroscopicity	0,5-3%	1-2%
The permeability of a material to moisture and gases g/m· h· mm Hg. st	TPU possesses moderate gas permeability, meaning it allows the passage of water vapor or gases only to a limited extent through its structure	PLA typically has higher moisture and gas permeability compared to TPU. The moisture and gas permeability values of PLA can vary depending on the conditions.
Thermal conductivity. Vt/m*K.	0.1-0.2 Vt/m*K.	0.1-0.2 Vt/m*K.
Thermal diffusivity. m^2/s	0.1-0.3 m^2/s	0.1-0.2 m^2/s
Specific heat capacity kkal/kg·°C.	1,5-2,5 kkal/kg·°C.	1,0-1,5 kkal/kg·°C.
Heat absorption. kkal/m^2·h·°C.	0,01-0,04 kkal/m^2·h·°C.	0,02-0,05 kkal/m^2·h·°C.
Expansion and contraction	From -2% to +2%	From -5% to +5%
Thermal stability °C	100-200 °C,	150-160 °C
Mechanical strength MPa	From 20 MPa to 70 MPa	From 50 MPa to 70 MPa
Biological stability	TPU (Thermoplastic Polyurethane) has good biocompatibility. It is compatible with the human body without eliciting significant negative reactions due to its non-toxic nature.	PLA also has good biocompatibility. It is a biodegradable material that can undergo biological degradation in certain conditions and environments.
Elasticity	From 300% to 800%	From 5% to 10%
Thermal resistance °C	From -30°C to +80°C	From 60°C to 70°C

In summary, TPU (thermoplastic polyurethane) typically has a density ranging from 1.1 to 1.2 g/cm³. This means that 1 cubic centimeter of TPU has an approximate volume of 1.1 to 1.2 grams. PLA (polylactic acid), on the other hand, has a density of approximately 1.2 g/cm³. This means that 1 cubic centimeter of PLA has an approximate volume of 1.2 grams. The moisture content of TPU and PLA is an important parameter because both materials can absorb moisture from the surrounding environment. Moisture affects the quality and characteristics of the material. The moisture content is typically expressed as a percentage and indicates the amount of water the material can absorb from the environment. It is generally recommended to store and use TPU and PLA in dry conditions. TPU has a relatively high moisture absorption capability, but its moisture absorption rate might be as low as that of nylon. The moisture content of TPU is typically specified in the range of 0.1% to 0.5%. This means that TPU can increase its weight by 0.1% to 0.5% when exposed to moisture over an extended period Additionally, different types of TPU can have varying levels of moisture absorption. However, to achieve optimal results when printing with TPU filament, it is best to use it in a dry environment. PLA, on the other hand, can absorb moisture from the environment over time. If exposed to high levels of moisture or stored for an extended period, PLA can further degrade and result in printing issues. The moisture content of PLA is typically specified in the range of 0.2% to 0.5%. This means that PLA can increase its weight by 0.2% to 0.5% when exposed to moisture over an extended period [3].

Hygroscopicity refers to the ability of a material to absorb and retain moisture from the surrounding environment. The hygroscopicity of TPU may be relatively insignificant compared to some other materials, typically ranging from approximately 0.1% to 0.5%. This means that TPU can absorb moisture and increase its weight by approximately 0.1% to 0.5% in a specific humid environment. The hygroscopicity of PLA, on the other hand, typically ranges from 0.2% to 0.5%. This means that PLA can absorb moisture and increase its weight by approximately 0.2% to 0.5% in a specific humid environment.

The permeability of a material to moisture and gases is measured in g/m²·h·mmHg and indicates the material's ability to transmit water vapor or gases through its structure. TPU has moderate permeability, meaning it can only allow the passage of limited amounts of water vapor or gases under controlled conditions. The permeability of PLA to water vapor and gases can vary depending on its composition and manufacturer. PLA generally has lower permeability to water vapor and gases compared to TPU.

The mechanical strength of a material is measured in megapascals (MPa) and indicates its ability to withstand mechanical loads. TPU typically has good mechanical strength, particularly in terms of its elasticity and flexibility. The mechanical strength of TPU can vary depending on its specific type and composition, ranging from approximately 20 MPa to 70 MPa or even higher. PLA, on the other hand, generally has lower mechanical strength compared to TPU. Typically, it ranges from approximately 50 MPa to 70 MPa, depending on the specific PLA filament and its processing. PLA is known for its good stiffness, but it may be more brittle compared to TPU, especially at lower temperatures

The elasticity of a material is typically measured as a percentage and indicates its ability to return to its original state after undergoing mechanical deformation. TPU generally has high elasticity and resilience, allowing it to deform under load and return to its original state when the load is removed. The elasticity of TPU can be expressed as a percentage of deformation that it can undergo without permanent damage. Depending on the specific type and composition of TPU, it can exhibit elasticity ranging from 300% to 800% or even higher. PLA, when compared to TPU, has lower elasticity that the elasticity of PLA ranges from approximately 5% to 10%,. it is generally less elastic compared to TPU. PLA is stiffer and has a more brittle structure, which limits its ability to undergo elastic deformation.

"Thermal resistance" refers to a material's ability to withstand prolonged exposure to high temperatures. Heat-resistant 3D printing materials exhibit superior mechanical properties and chemical resistance at high temperatures compared to non-heat-resistant materials. Additionally, they can maintain their properties over extended periods at elevated temperatures. TPU possesses good thermal resistance and, depending on the specific type of TPU, can withstand temperatures ranging from approximately -30°C to +80°C or even higher. In comparison, PLA has lower thermal resistance when compared to TPU.

Thermal insulation materials typically exhibit expansion and contraction during heating and cooling, as well as a change in their crystalline structure, which results in a change in volume and contraction during drying. This property is known as thermal shrinkage. Shrinkage that occurs during the material's solidification phase is referred to as solidification shrinkage. Total or linear shrinkage is expressed as a percentage relative to the initial sample dimensions and is influenced by various physical and chemical processes during drying and cooling. TPU may undergo slight expansion or contraction with temperature changes. However, the expansion and contraction effects of TPU are generally lower compared to other materials like PLA. The expansion and contraction of TPU with temperature changes can range from -2% to +2%. PLA, when compared to TPU, tends to exhibit more significant expansion and contraction effects. It may shrink during cooling and expand during heating. The expansion and contraction of PLA are specific to its composition and the cooling or heating conditions and can range from -5% to +5% or even higher.[3]

Thermal conductivity is a physical property that measures a material's ability to conduct heat. It is typically expressed in units of watts per meter-kelvin (W/(m·K)). TPU generally has low thermal conductivity. Typical average values for thermal conductivity of TPU range from approximately 0.1 to 0.2 W/(m·K). This indicates that TPU has a relatively low ability to conduct heat. PLA also has low thermal conductivity. Typical average values for thermal conductivity of PLA are similar to TPU, ranging from approximately 0.1 to 0.2 W/(m·K). Therefore, both TPU and PLA have relatively low heat conduction abilities.

Thermal diffusivity is a physical property that measures a material's ability to conduct heat through diffusion over a given temperature difference and is typically expressed in square meters per second (m^2/s). TPU generally has low thermal diffusivity. Typical average values for the thermal diffusivity of TPU range from approximately 0.1 to 0.3 m^2/s. This indicates that TPU has a relatively low ability to conduct heat through a unit area. PLA also has low thermal diffusivity. Typical average values for the thermal diffusivity of PLA are similar to TPU, ranging from approximately 0.1 to 0.2 m^2/s.

Specific heat capacity is a physical property that measures the amount of heat energy required to raise the temperature of a unit mass of material by one degree Celsius. Specific heat capacity, also known as specific heat, is a physical property that measures the amount of heat energy required to raise the temperature of a unit mass of material by one degree Celsius. It is typically expressed in kilocalories per kilogram-degree Celsius (kcal/(kg·°C)). TPU has a specific heat capacity typically ranging from approximately 1.5 to 2.5 kcal/(kg·°C). This indicates that TPU requires a relatively higher amount of heat energy to raise its temperature compared to other materials. PLA has a specific heat capacity typically ranging from approximately 1.0 to 1.5 kcal/(kg·°C). This indicates that PLA requires a relatively lower amount of heat energy to raise its temperature compared to TPU [4].

Thermal stability refers to a material's ability to withstand high temperatures without undergoing significant changes or degradation. TPU is generally not thermally stable. It can melt and become molten, and after solidification, it can continue its melting process. The melting point of TPU typically ranges from 100 to 200 °C, and upon heating, it can melt and resume the melting process. PLA is also not highly thermally stable. It has a lower melting point (approximately 150-160 °C) and can melt and decompose at high temperatures. However, when compared to TPU, PLA tends to have better thermal stability. It exhibits a higher resistance to melting and can maintain its solid state at higher temperatures.

Biological stability refers to the ability of a material to maintain its structure and functionality when in contact with a biological environment, such as the human or animal body. TPU generally exhibits good biocompatibility. It indicates the compatibility of the material with the tissues and organs of the body without causing adverse reactions or inflammation. Due to its good biocompatibility, TPU is commonly used in medical applications such as implants and medical tools. PLA also possesses good biostability. It is a biodegradable material that can break down under specific conditions in the surrounding environment. Due to its biocompatibility and biodegradability, PLA finds extensive use in biomedical and pharmaceutical applications, including sutures and implants [5].

Conclusion. Indeed, both TPU and PLA have their own physical and chemical properties that make them convenient for use in 3D printing technology. However, when considering certain physical properties in tables and when designing garments, TPU filament has several advantages over PLA filament for fabric design. TPU filament is valued for its flexibility, elasticity, heat resistance, and durability, which are well-suited for garment design in terms of its compatibility with external mechanical forces and resilience.

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Key words: 3D, print, TPU PLA, flexsibility, elastic.

Annotation: The article examines the advantages and disadvantages of TPU filament, which is one of the fabrics used in 3D printing technology, as well as its physical and chemical properties in comparison with PLA filament. Some physical parameters for TPU and PLA filaments have been studied. In addition, the effect of using this filament in the design of clothes was analyzed.

Tayanch so‘zlar: 3D, bosma, TPU, PLA, filament, moslashuvchanlik, egiluvchanlik.

Annotatsiya: Maqolada 3D bosma texnologiyasida foydalanildigan matolardan biri bo`lgan TPU filamentining afzalliklari va kamchiliklari, fizik-kimyoviy xususiyatlari PLA filament bilan solishtirgan holatda ko`rib chiqilgan. TPU hamda PLA filamentlari uchun ba`zi fizik kattaliklar o`rganib chiqilgan. Bundan tashqari liboslarni loyihalashda ushbu filamentdan foydalanishning samarasi tahlil qilingan.

Ключевые слова: 3D, печать, ТПУ, ПЛА, нить, гибкость.

Аннотация: В статье рассмотрены преимущества и недостатки нити ТПУ, которая является одной из тканей, используемых в технологии 3D-печати, а также ее физические и химические свойства по сравнению с нитью PLA. Изучены некоторые физические параметры нитей ТПУ и ПЛА. Кроме того, был проанализирован эффект от использования этой нити в дизайне одежды.

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