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# Additive technologies in amber production: comparative analysis of properties and quality of products

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**Abstract**

The article presents the results of an empirical study carried out on two 3D printers using pressed amber as a raw material for making small-scale jewelry. The purpose of the study was to compare the quality and properties of the final amber products produced using additive technologies. The results obtained allowed the author to conclude that with the help of additive technologies it is possible to reduce the production cycle at the stage of material processing by half, as well as to obtain a product that, in terms of its properties and quality, is not inferior to amber products produced by traditional methods. The use of additive technologies reduces the time for the primary processing of amber: grinding, washing and soaking (wet processing); avoids fragility and cracks in the product; allows you to reduce the production time of the finished product. The amber item produced for three days of printing is not inferior in properties and quality to the item produced using traditional technology. Because of this, it is possible to recommend the use of additive technologies in the industrial production of amber. The development of additive technologies will make it possible, in a strategic perspective, to make a technological revolution in the jewelry industry in terms of the quality, speed and properties of the final amber products. The results of the empirical research presented in the article prove that additive technologies can significantly intensify the production cycle and reduce material losses during the processing of finished products.

**For citation**

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**Keywords**

Amber, additive technologies, jewelry industry, 3D printing, jewelry products.

## Introduction

The relevance of the research topic is due to the fact that the production of jewelry from amber is a large international market, comparable in scale to the diamond market. The share of different countries of the world in the amber market varies greatly in scale: 90% of world reserves are concentrated in Russia, in the Kaliningrad region [Baranov, Kirin, 2018, 102]. In the world market of finished amber products, Russia occupies 22% of the market share [Hirwell, 2021, 104]. One of the methods for classifying amber by color and transparency. This criterion corresponds to the optical classification of amber varieties. Amber colors include yellow, orange, red, white (see example below), brown, green, bluish and "black" (darker shades of other colors) [Hye Jin Lee, Hyung Kyu Lee, 2021, 401].

Modern additive technologies trace their history back to 1986, when the first commercial stereolithography machine (SLA) was patented, which was developed by 3D Systems. Until the mid-1990s, the main field of application was R&D for the defense industry. The first laser 3D printers were extremely expensive, but the set of used model materials was very limited [Jun Xing, Jin-Xin Zhao, Jun Dud, 2017, 31]. Nevertheless, in order to understand the level of quality of amber products produced using additive technologies, it is necessary to analyze the properties and quality of the products. To this end, we have conducted an empirical study of the quality assessment of products produced on two types of SLA and DLP printers.

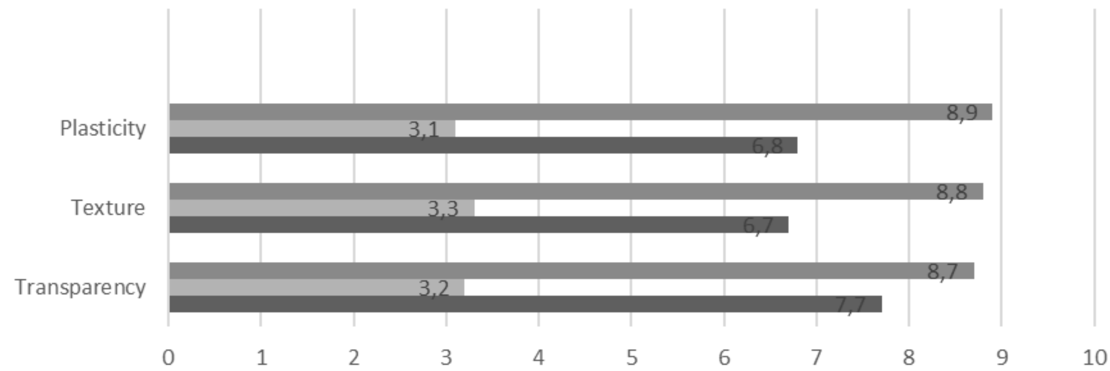
## Materials and methods

The choice of pressed amber as a research material is due to several reasons. Due to the ability to press amber, we can get completely new shades of stone in jewelry. Beads, bracelets and rosary beads are made of pressed amber (which are lower in price, although not at all worse), in this way we even make accessories for rings. Shaped amber expands the possibilities of making various exclusive jewelry and amber products. The research methodology is based on a systematic approach and includes methods for analyzing statistical data, a method for translating qualitative data into quantitative ones, a method of observation, a method of scientific generalization. For the study, we identified the following criteria for assessing the quality of amber products produced using two different 3D printers: plasticity, transparency, texture (homogeneous or layered). Based on the selected criteria, we evaluated the quality of products on a 10-point scale using two printers. The obtained data were processed using the Neural Designer program, which made it possible to more clearly display the research results.

## Results

In 3D printers based on LFS technology, the optical components are located in a light processing unit (LPU). Inside the LPU, a galvanometer positions a high-density laser beam in the Y-direction, passes it through a spatial filter, and directs it to a deflecting and parabolic mirror so that the beam always remains perpendicular to the plane of the platform, ensuring print accuracy and reproducibility. As the LPU moves in the X-axis direction, the printed model is carefully detached from the flexible bottom of the reservoir, which can significantly reduce the forces acting on the model during the printing process.

Light is reflected on a digital micromirror screen (DMD), a dynamic mask made up of microscopic mirrors that are located in an array on a semiconductor chip. Quickly switching these tiny mirrors between lenses directing light to the bottom of a tank or radiator determines the coordinates at which the liquid polymer must solidify to form the current layer.




| | Transparency | Texture | Plasticity | |
|---|---|---|---|---|
| DLP printer | 8,7 | 8,8 | 8,9 | |
| Traditional technology | 3,2 | 3,3 | 3,1 | |
| SLA printer | 7,7 | 6,7 | 6,8 | |

**Figure 1 - SLA and DLP technologies: comparison of 3D printers using pressed amber as consumables**

Since the projector is a digital screen, the image of each layer is composed of square pixels, resulting in a three-dimensional layer of rectangular cubes called voxels. The basic units of SLA and DLP processes are of different forms, which makes it difficult to compare printers only by numerical characteristics. In 3D printing, we considered three dimensions: two planar two-dimensional dimensions (X and Y) and the third vertical dimension Z, with which three-dimensional printing is carried out. The Z measurement resolution is determined by the thickness of the layer that the 3D printer can print.

For example, the Form 3 LFS-based 3D printer has a laser with a spot size of 85 microns, but thanks to the continuous linear scanning process, the laser can move in smaller steps, and the printer can consistently print models with an XY resolution of 25 microns.

Since 3D printing is an additive process, disruptions can potentially occur in every layer. The layer formation process affects the level of precision and correctness of each layer. In general, SLA and DLP printers are among the most accurate. Differences in print fidelity are often more noticeable between printers from different manufacturers than between the technologies themselves.

Both stereolithography and DLP printers are renowned for printing models with the best surface quality compared to other technology solutions. When we talk about differences, in most cases they are only visible on very small parts and models with a high degree of detail. Since 3D printing is done in layers, finished models often have noticeable horizontal lines.

And due to the fact that digital light processing technology uses rectangular voxels, the effect of vertical lines can also be observed. DLP printers use rectangular voxels to render images, which can result in vertical lines. In this image, vertical voxel lines are shown as they appear after printing, and highlighted for better visibility.

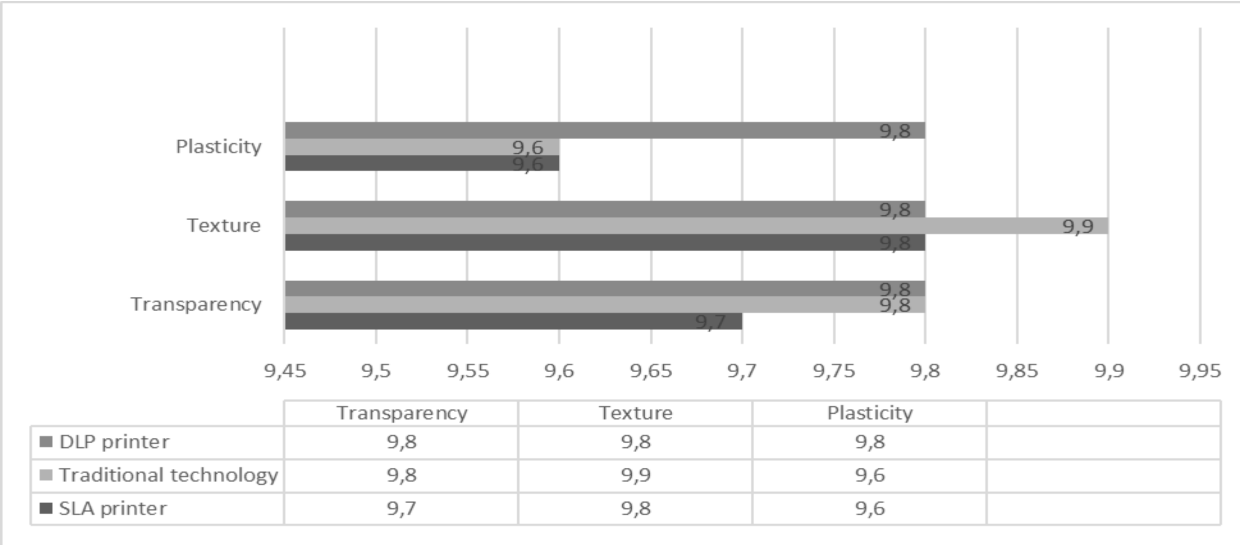



**Figure 2 - The quality of the final product on the SLA and DLP printer (compiled by the author using the Neural Designer program)**

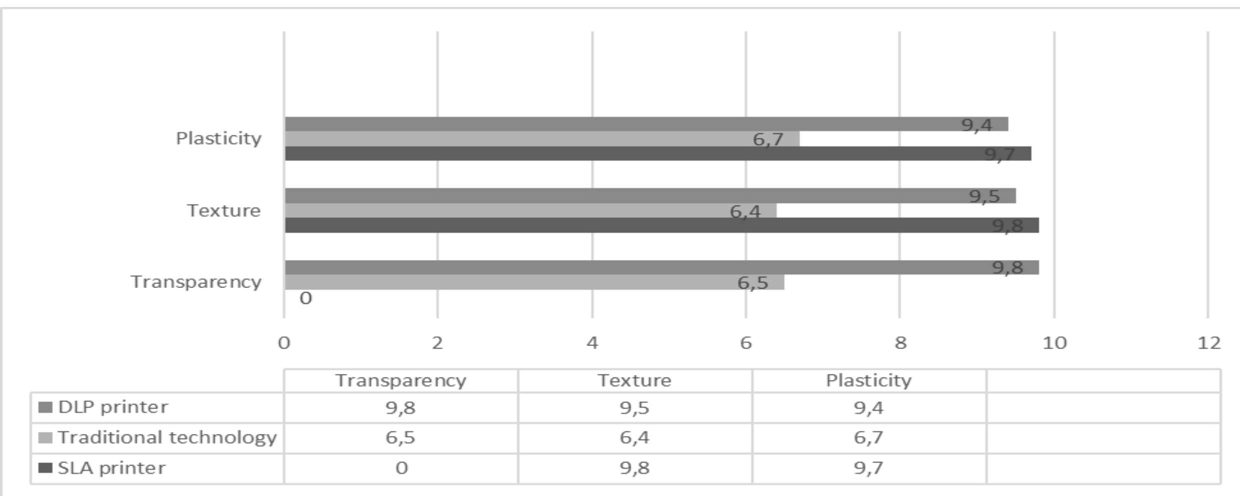



**Figure 3 - The quality comparison of small products on a 3D printer (compiled by the author using the Neural Designer program)**

## Discussion

Our results confirm the theoretical theses presented in the works by P. Baranov and R. Kirin [Baranov, Kirin, 2018], F. Demarco, F. Bertacchini, C. Scuro, E. Bilotta, P. Pantano [Demarco et al., 2020] and H. Tiago, L.P. Rocha, F. Silva [Tiago, Rocha, Silva, 2018]. In particular, the results obtained confirm the idea that the strength and transparency of amber products produced using additive technologies are indistinguishable from products produced using traditional soaking technology and preliminary manual grinding [Di Nicolantonio, Rossi E., Stella, 2020, 89].

Our results also confirm the thesis by F. Bertacchini, E. Bilotta, F. Demarco that additive technologies can reduce the production cycle at the stage of material processing by almost half [Demarco et al., 2020, 67]. Moreover, at the stage of primary processing by hand grinding, from 3 to 5% of the useful amber powder is lost [Bouju, Feldberg, 2021, 94].

Our results also confirm by V.S. Doroshenko [Doroshenko, 2021] and A.S. Elakkad [Elakkad, 2019], who suggested that when using a DLP printer in jewelry production, you can get a higher quality texture – an amber item does not crumble or flake, has a full-color mass. At the same time, according to R. Falabella [Falabella, 2020], D. Hirwell [Hirwell, 2021] and G. Lawton [Lawton, 2019], using additive technologies, it is possible to obtain high precision of layers in articles made of pressed amber, which do not require wet wrapping, in contrast to traditional production methods [Hye Jin Lee, Hyung Kyu Lee, 2021, 394]. Such researchers as M.A. Iturralde-Vinent, R. D. MacPhee [Iturralde-Vinent, MacPhee, 2019] and Jun Xing, Jin-Xin Zhao and Jun Dud [Jun Xing, Jin-Xin Zhao, Jun Dud, 2017] are in solidarity with their opinion.

The quality of the initial mass texture, poured into a 3D printer, is written in works by such authors as O.A. Kazachkova, O.A. Zyabneva, I.Y. Mamedova, E.A. Kulishova [Kazachkova et al., 2018]. Our results also confirm the thesis by V. McCoy, H. Jonas, B. Arnoud, B. Enrique, P. Martínez-Delclòs that layer-by-layer 3D printing for a mass of pressed amber is especially effective in the production of small jewelry items [McCoy et al., 2021, 107]. Our results also confirm the theses by A. Mitchell, B. Hukawng [Mitchell, Hukawng, 2018], E. Mychko [Mychko, 2020], M.A. Perepelkin, V.V. Tyutyunin, V.I. Sklyanov, M.V. Kozlov [Perepelkin et al., 2020], P. Prapitpongwanich [Prapitpongwanich, 2016], who state that the use of additive technologies also makes it possible to obtain a denser structure of the final product, with higher strength for pressed amber. Our results also refute the thesis by E. Salmela, I. Vimm [Salmela, Vimm, 2018] and S.M. Stockton [Stockton, 2019], that the use of additive technologies for the production of jewelry from amber is not suitable for an industrial scale, since new 3D printers have a higher speed of forming and printing a product than traditional jewelry machines.

## Conclusion

The results obtained in the course of empirical research allow us to draw the following conclusions:

1) The use of additive technologies reduces the time for the primary processing of amber: grinding, washing and soaking (wet processing); avoids fragility and cracks in the product; allows you to reduce the production time of the finished product. The amber item produced for three days of printing is not inferior in properties and quality to the item produced using traditional technology. Because of this, it is possible to recommend the use of additive technologies in the industrial production of amber.

2) The development of additive technologies will make it possible, in a strategic perspective, to make a technological revolution in the jewelry industry in terms of the quality, speed and properties of the final amber products. The results of the empirical research presented in the article prove that additive technologies can significantly intensify the production cycle and reduce material losses during the processing of finished products.

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# Аддитивные технологии в производстве янтаря: сравнительный анализ свойств и качества продукции

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**Аннотация**

В статье представлены результаты эмпирического исследования, проведенного на двух 3D-принтерах, использующих прессованный янтарь в качестве сырья для изготовления небольших ювелирных изделий. Целью исследования было сравнение качества и свойств конечных изделий из янтаря, произведенных с использованием аддитивных технологий. Полученные результаты позволили сделать вывод, что с помощью аддитивных технологий можно вдвое сократить производственный цикл на стадии обработки материала, а также получить продукт, который по своим свойствам и качеству не уступает по качеству изделиям из янтаря, произведенным традиционными методами. Использование аддитивных технологий сокращает время первичной обработки янтаря; позволяет избежать хрупкости и трещин на изделии; позволяет сократить сроки изготовления готовой продукции. Изделие из янтаря, изготовленное за три дня печати, по свойствам и качеству не уступает изделию, изготовленному по традиционной технологии. В связи с этим можно рекомендовать использование аддитивных технологий в промышленном производстве янтаря. Развитие аддитивных технологий позволит в стратегической перспективе совершить технологическую революцию в ювелирной отрасли с точки зрения качества, скорости и свойств конечных изделий из янтаря. Результаты эмпирического исследования доказывают, что аддитивные технологии позволяют значительно интенсифицировать производственный цикл и снизить материальные потери при переработке готовой продукции.

**Для цитирования в научных исследованиях**

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**Ключевые слова**

Янтарь, аддитивные технологии, ювелирная промышленность, 3D-печать, ювелирные изделия.

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