Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 01, Issue 09, December, 2025
Website: usajournals.org

DIGITALIZATION OF TAX ADMINISTRATION AND ITS IMPACT ON TAX DISCIPLINE OF COMPANIES

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Abstract
This article examines the main applications of nanotechnology in the jewellery industry: physical vacuum deposition (PVD), diamond-like carbon (DLC) coatings, and transparent nanobarrier layers. Their advantages over traditional rhodium and gold plating are highlighted, including increased wear resistance, corrosion resistance, luster and color retention, and the potential for creating new aesthetic effects.

Keywords: Nanotechnology, jewelry coatings, PVD, DLC, nanocomposites, wear resistance, corrosion resistance, decorative properties.

Introduction

Scientific Novelty. This article systematizes the application of nanotechnology (PVD, DLC, electroless, nanobarrier coatings) in the jewelry industry, evaluates their impact on wear resistance, corrosion protection, and decorative properties, and examines multifunctional coatings with combined mechanical, antibacterial, and aesthetic effects, expanding the possibilities for creating durable and innovative jewelry.

The modern jewelry industry is undergoing a technological transformation driven by the introduction of nanotechnology into processing and finishing processes. Key requirements for jewelry coatings include durability, wear resistance, corrosion resistance, hypoallergenicity, and aesthetic preservation. Traditional methods, such as electroplating or rhodium plating, often prove insufficient, as the coatings are susceptible to rapid abrasion, tarnishing, and color loss under environmental and chemical influences [1].

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Nanotechnology offers fundamentally new possibilities, enabling control of the structure and properties of coatings at the atomic and molecular level. The use of advanced methods such as physical vapor deposition (PVD), electroless chemical vapor deposition, and diamond-like carbon (DLC) and nanocomposite systems makes it possible to form ultra-thin coatings (from nanometers to hundreds of nanometers) with specified characteristics, ranging from color to microhardness [2] .

PVD technologies enable the application of highly adhesive and wear-resistant nitride and carbonitride layers (e.g., TiN, ZrN, CrN). These coatings impart stable, long-lasting gold, silver, or dark hues to items, while significantly reducing the consumption of expensive precious metals. Their high abrasion resistance is especially important for jewelry subject to constant friction (rings, bracelets).Diamond-like carbon (DLC) coatings combine exceptional hardness, chemical inertness, and biocompatibility. Furthermore, the inclusion of silver nanoparticles in the DLC matrix provides an additional antibacterial effect without compromising the strength of the protective layer [3].

Sol-gel and nanoceramic approaches are also actively developing, which are used to create transparent protective layers on the surface of silver and copper alloys, effectively preventing their darkening and corrosion, while preserving the natural shine of the metal [4].

Thus, the introduction of nanotechnology is transforming jewelry production, enabling a shift from purely decorative to functional and protective coatings. This not only improves the durability and performance of jewelry but also reduces material consumption and opens up opportunities for the creation of new, previously unattainable color and texture effects.

In the modern jewelry industry, innovative methods that enable the application of thin coatings with the ability to precisely control their functional properties are in high demand. These technologies include physical vapor deposition (PVD), diamond-like carbon (DLC) coatings, electroless cladding with nanoparticles, and nanobarrier transparent coatings.

1. Physical vacuum deposition (PVD). PVD methods (including magnetron and ion sputtering, as well as electron beam evaporation) are used to form thin metal-

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ceramic layers such as titanium (TiN), zirconium (ZrN), and chromium (CrN) nitrides.

Characteristics: the coatings range in thickness from 100 to 1000 nm. They exhibit high adhesion and exceptional wear resistance.

Functionality: PVD coatings provide a wide range of colours, from vibrant gold to deep black, without the need for expensive precious metals.

Property control: precise adjustment of process parameters (temperature, pressure, speed) allows for precise control of the microstructure and, consequently, the optical and mechanical properties of the final coating [1].

2. Diamond-like carbon coatings (DLC). DLC is an amorphous carbon with a high concentration of sp^3 bonds, which provides the material with unique mechanical properties.

Properties: DLC coatings are characterized by extremely high hardness (up to 80 GPa) and a low coefficient of friction, which is important for increasing the wear resistance of frequently used jewelry (rings, watches, bracelets). They also provide chemical inertness and biocompatibility.

Innovation: the introduction of silver nanoparticles (Ag/DLC) allows the creation of a coating with additional antibacterial properties without reducing its mechanical strength [5].

3. Electroless cladding with nanoparticles. Autocatalytic (electroless) deposition methods allow for the production of homogeneous metallic coatings on complex-shaped objects, as well as on non-conductive (dielectric) surfaces, without the use of external electric current.

Functionalization: the introduction of nanoparticles (silver, copper or metal oxides) into the deposited layer allows not only to improve adhesion and mechanical properties, but also to impart special functions to the coating, such as enhanced antibacterial properties or increased conductivity [4].

4. Nanobarrier transparent coatings (sol - gel, nanoceramics). Sol - gel and electrochemical varnish coatings are widely used to protect silver and copper alloys from corrosion and tarnish.

Functionality: these technologies form ultra-thin transparent coatings (50–200 nm thick) that act as a nanobarrier, effectively preventing oxidation and darkening of the metal.

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Advantages: coatings preserve the original aesthetic appearance and natural shine of the base metal, while providing long-term protection from moisture and aggressive chemicals [3].

Table 1 - Comparison of the main nanotechnological methods for applying jewelry coatings

Method	Coating thickness	Color options	Strength/Wear Resistance	Corrosion protection	Functional effects	Price
PVD	100–1000 nm	Golden, black, rainbow	High	Medium-high	Color control, decorative effects	Medium-high
DLC	50–500 nm	Black, graphite	Very high	High	Low friction, antibacterial additives	High
Electroless with nanoparticles	1–10 µm	Golden, silver	Average	Average	Antibacterial, conductive	Average
Sol-gel / nanoceramics	50–200 nm	Transparent	Average	High	Protection against darkening and oxidation	Low-medium

Nanotech coatings offer a number of significant performance and aesthetic advantages over traditional methods (such as electroplating and rhodium plating), making them the new standard in the jewelry industry:

- Increased wear resistance. PVD coatings (TiN, ZrN, CrN) and DLC (diamond-like carbon) significantly increase the abrasion resistance of jewelry. DLC layers can increase surface hardness to 80 GPa, ensuring exceptional durability of jewelry (rings, bracelets, watches) under constant friction. PVD coatings, in addition to high strength, guarantee the preservation of the original color and luster over a long lifespan.
- Improved corrosion resistance. Nanocoatings create an effective barrier protecting jewelry alloys from oxidation and tarnishing. Transparent nanobarrier layers (sol-gel, nanoceramics) prevent direct contact of the base metal (especially silver and copper) with oxygen and moisture. This allows jewelry to retain its decorative properties even after prolonged contact with skin, sweat, and harsh chemicals found in cosmetics.

- expanded aesthetic possibilities. Nanotechnology opens new horizons in design, offering visual effects unachievable with traditional coatings. PVD and DLC allow for stable and uniform color shades – from bright gold to deep graphite and black. Multilayer systems enable the creation of unique decorative effects, including iridescent shimmer, thanks to precise control of the thickness and structure of the applied layers.
- antibacterial and functional properties. The incorporation of silver or copper nanoparticles into DLC or electroless coatings provides products with a long-lasting antibacterial effect. This functionality is especially important for jewelry that comes into contact with the skin (earrings, piercings). Moreover, the mechanical properties of the coatings are not impaired, and the risk of allergic reactions is reduced due to the chemical inertness of the nanolayer.
- Cost-effectiveness and environmental friendliness. Nanotechnology methods contribute to more environmentally friendly production and resource conservation. They significantly reduce the consumption of expensive precious metals by forming uniform and ultra-thin layers. Furthermore, compared to traditional galvanic processes, PVD and other nanotechnologies often require less toxic chemicals.

Current research and development shows that nanotechnology in the jewelry industry continues to develop in several key areas:

1. The combination of PVD and DLC with the introduction of nanoparticles allows for the creation of coatings that simultaneously offer high wear resistance, antibacterial properties, and decorative effects. These coatings are suitable for rings, bracelets, and watches that require protection from friction and skin contact.
2. The development of nanocoatings with minimal use of toxic reagents (for example, modernized sol-gel and electroless processes) reduces the environmental impact and ensures safety for production workers.
3. Nanostructuring of surfaces opens up new possibilities for controlling light, color, and shine. Coatings with iridescent effects, variable transparency, and unique color schemes are emerging without the use of expensive metals.
4. Nanocoatings provide long-term protection against corrosion, discoloration, and wear, which is especially important for mass production and premium

products. The use of transparent barrier layers and DLC reduces the need for recoating and repairs.

Table 2 - Promising areas of application of nanocoatings

Direction	**Core technologies**	**Main advantages**	**Application examples**
Multifunctional coatings	PVD + DLC + nanoparticles	Wear resistance, antibacterial properties, decorative properties	Rings, bracelets, watches
Eco-friendly processes	Sol-gel, electroless with nanoparticles	Minimal use of toxic reagents, safety	Silver, copper alloys
Optical effects	PVD, DLC with nanostructuring	Rainbow shimmer, changing shine, unique colors	Designer products, limited edition
Extending service life	DLC, transparent nanobarrier coatings	Protection against darkening, corrosion and abrasion	Mass and premium jewelry

Thus, the use of nanotechnology in the jewelry industry opens new horizons for the creation of durable, resilient, and aesthetically pleasing coatings. The use of PVD, DLC, and transparent nanobarrier technologies enhances the performance properties of products and ensures innovative development in the industry.

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