Transmission spectra of transparent electrodes based on oriented platinum nanowires at various concentrations of the metal used

G R Nizameeva 1, I R Nizameev 1,2 and M K Kadirov 2

1 Kazan National Research Technological University, Kazan 420015, Russia
2 Arbuzov Institute of Organic and Physical Chemistry, FRC Kazan Scientific Center, Russian Academy of Sciences, Kazan 420088, Russia

guliya.riv@gmail.com

Abstract. The paper investigates the optical transparency dependence of a coating based on an oriented network of platinum nanowires on the amount of metal used. Oriented platinum nanowires on a glass surface are produced by chemical deposition from an aqueous hexachloroplatinic acid solution. The topography of the deposited metal layer on glass is visualized using atomic force microscopy. Optical transparency was investigated with a spectrophotometer. In almost the entire region of optical radiation, the transparency is approximately 98%. The absorption spectrum shows that the absorption coefficient increases sharply in the near UV region.

1. Introduction
Transparent electrodes have received significant attention due to their importance in electronics. They are an integral part of many optoelectronic devices such as touch displays and sensors, bright windows, solar panels, etc. Today, transparent electrodes are made of solid indium and tin oxides. The material is highly transparent and conductive. However, the material has such disadvantages as fragility, complexity of production technology and high cost. Therefore, scientists from all over the world are looking for an inexpensive alternative to indium tin oxide. Alternative transparent electrodes are available in a wide range of materials. These are films of carbon nanotubes [1], graphene [2] and conductive polymers.

The graphene monolayer is of particular interest. The graphene monolayer has high optical transparency and conductivity. However, due to the problems of scaling the production and quality of the obtained graphene layers, the mass use of graphene in optoelectronics is not yet possible. As you know, for the production of transparent electrodes with large diagonals (for example, in solar cells), large sheets of transparent conductive material without scratches and cracks are required. However, there is currently no suitable technology for producing graphene sheets over large areas. Another disadvantage of graphene production technology is that first graphene is synthesized on catalytic substrates. A copper plate is usually used as such a substrate. This suggests that after synthesis, graphene must be transferred to other transparent substrates. This two-stage synthesis greatly complicates the process. When transferred from catalytic surfaces to transparent substrates, thin
graphene layers are destroyed, deformed, and become unsuitable for use as transparent electrodes [3-8].

Transparent conductive polymers are also considered a good alternative in the field of transparent electrodes. These polymers is poly (3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT: PSS), polyaniline, polyacetylene, etc. However, these polymers are not independently used as transparent electrodes, since they have low electrical conductivity. Typically, transparent conductive polymers are used in combination with other conductive materials. For example, these is used with metal nanowires to increase mechanical strength and adhesion to the substrate.

Carbon nanotubes are also of interest in the field of optoelectronics. In addition to transparency in the optical range and electrical conductivity, they are flexible. The ability to synthesize directly on flexible substrates is the main advantage of carbon nanotubes. However, such synthesis methods are energy intensive, complex and not scalable. Therefore, it is very important to find a simpler method for obtaining transparent electrodes based on carbon nanotubes or to use other materials.

From a functional point of view, oriented metal nanowires are considered the best candidates for the development of transparent electrodes due to the combination of low surface resistance, high transparency [9], resistance to mechanical deformation and high operating temperatures. In addition, transparent electrodes based on metal nanowires are the most economically efficient.

At the moment, the main idea of creating flexible optically transparent coatings is the use of metal nanowires in conjunction with this or other transparent polymer. One of the most bright representatives of such a polymer is poly (3,4-ethylenedioxythiophene) (common abbreviated name - PEDOT) or its modification with higher electrical conductivity - poly (3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT: PSS) [10-13]. PEDOT: PSS is optically clear and has good conductivity.

The use of metals that are weakly susceptible to the effect of oxidation is promising. Of interest is platinum, more precisely, platinum nanobands. Anti-corrosion properties and excellent electrical conductivity make them promising alternatives for creating durable, chemically resistant optically transparent coatings.

![Figure 1](image_url)

**Figure 1.** Transmission spectra of oriented platinum networks on a glass substrate in the UV, visible, and near-IR regions at different amounts of deposited metal.
Previously, we developed a technique for obtaining an optically transparent coating based on oriented grid of platinum nanowires [14, 15]. Within this study's framework, we investigate the effect of the amount of platinum used on the transparency of the resulting coating on a glass substrate in the UV, visible and near-IR regions.

2. Results and discussion
In this work, samples of coating on glass with different amounts of platinum metal were synthesized. The change in the amount of platinum on the glass surface was carried out by adjusting hexachloroplatinic acid concentration (H₂PtCl₆·6H₂O). The concentration of hydrochloric platinum acid in the aqueous solution varied in the range 0.01 - 5 mM.

![Graph](https://via.placeholder.com/150)

**Figure 2.** Dependency ratio transparency at a wavelength of 550 nm from initial concentration values hexachloroplatinic acid.

![Graph](https://via.placeholder.com/150)

**Figure 3.** Absorption spectrum oriented nets of platinum on a glass substrate in UV, visible and near-infrared regions, corresponding to the value of the original concentration of hexachloroplatinic acid 0.1 · 10⁻³ mol/l.
All obtained samples were examined on a spectrophotometer in the wavelength range of 290-1100 nm. The averaged transmission spectra for some deposition densities of platinum nanowires are shown in figure 1. As expected, with an increase in the density of platinum deposition on the glass surface, a monotonic decrease in the transparency coefficient is observed over the entire optical range.

Length dependence of the transparency coefficient waves 550 nm from the value of the initial concentration hexachloroplatinic acid is shown in figure 2. Monotonic decrease of T550 has two linear sections on a logarithmic scale (black line in figure 2). It can be seen in the absorption spectrum that the absorption coefficient increases sharply in the near UV region (figure 3). This is explained by the properties of the glass substrate: it strongly absorbs UV radiation.

As a result of the studies carried out, the dependences of the coating's transparency on the amount of platinum used were obtained. In almost the entire region of optical radiation, the transparency is approximately 98%. The absorption spectrum shows that the absorption coefficient increases sharply in the near UV region. This phenomenon is due to the properties of the glass substrate: it strongly absorbs UV radiation.

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