Optical transparency and conductivity of oriented platinum nanonetworks on a glass surface

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Abstract. The work is aimed at creating an optically transparent conductive coating based on platinum nanowires which can become an alternative to the existing indium tin oxide. This coating can be used as transparent electrodes in solar panels, organic LEDs and many areas of modern electronics and optoelectronics. In work, the dependence of the sheet resistance of oriented platinum nanowires network on the amount of metal used is investigated. Oriented platinum nanowires are obtained by chemical deposition from an aqueous solution of hexachloroplatinic acid on a glass surface. The topography of the deposited metal layer on the glass is visualized by atomic force microscopy. It has been established that the platinum layer has good optical transparency. The synthesized coating would be of interest in terms of applicability as an optically transparent electrode.

1. Introduction

Liquid crystal screens, touch panels, organic LEDs, solar panels, and many other mass products of modern electronics and optoelectronics simply would not have appeared in our lives without thin-film transparent conductors which are made of indium and tin oxides (indium and tin oxide - ITO).

This material is still unrivalled in terms of the combination of high optical transparency (in a visible range) and electrical conductivity. However, its shortcomings (such as fragility, complexity of high-temperature technology for producing films and high cost) are the main reason for decades of research conducted in scientific laboratories of the world to find a flexible and inexpensive alternative. In recent years, these studies have become increasingly important in connection with the approaching depletion of the world's proven reserves of indium.

Besides, in all optoelectronics today, they are striving for flexibility, and ITO is quite fragile and may not withstand use on flexible substrates without cracking. Avoiding these limitations through the use of alternative materials, electrodes and device geometry is the most crucial research task in recent years. The difficulty lies in finding electrodes that are not only sufficiently reliable and inexpensive but also combine high optical transparency with high electrical conductivity.

In this regard, obtaining a material that would be close to ITO in terms of conductivity and transparency, but was significantly lower in price, is an essential task. A new material that could become a substitute for indium tin oxide can be developed based on metal [1-7]. In the present work, it is proposed to use oriented platinum nanowires deposited on the glass surface. An original technique is proposed for creating a transparent electrically conductive coating based on oriented networks of platinum nanowires.
2. Results and discussion
Briefly, the essence of the technique is to use the chemical deposition of platinum metal from an aqueous solution. A micellar template of a surface-active substance (surfactant) cetyltrimethylammonium bromide (CTAB) is used to create a form and orientation.

![AFM image of platinum strips on a glass surface](image1)

**Figure 1(a, b). (a)** AFM image of platinum strips on a glass surface; **(b)** section profile along the black line.

The template is created at the water-glass interface. At this stage of the work, a coating based on platinum nanogrids was obtained on the surface of a glass substrate using the method described above. The morphology of the resulting layer was studied by atomic force microscopy (AFM). Figure 1 shows a typical AFM image of a section of glass coated with platinum nanogrids. The image was taken on an atomic force microscope MultiMode V in intermittent contact mode.

![Schematic representation of the results of work](image2)

**Figure 2.** Schematic representation of the results of work.
Platinum nanowires at the height of 3-6 nm have a width of 50-60 nm, which corresponds to the shape of tape or strip. The ratio of strip length to width is approximately 500 : 1. The strip orientation is high, and the density on the glass surface is low [8]. This phenomenon contributes to obtaining high optical transparency of the layer with a small value of the surface resistance of the coating (Figure 2).

Elemental composition of the samples was investigated by means of X-ray fluorescence analysis using EDX attachment of transmission electron microscopy (TEM-EDX). Figure 3 shows spectrum corresponding to the pure sample (platinum lines are M\textsubscript{α1} = 2.050 keV, L\textsubscript{α1} = 9.442 keV). The spectrum contains lines of copper and carbon, which corresponds to a substrate on which nanowires of platinum are deposited.

**Figure 3.** TEM-EDX spectrum of platinum nanowires.

In addition to developing the concept of creating new types of transparent electrodes, the dependence of the electrical conductivity of the coating on the amount of platinum used is investigated. Different values of platinum concentrations on the surface of the glass substrate were used to synthesize coatings. The coatings were investigated by the van der Pauw method of four-probe measurements of surface resistance. The concentrations of the metal used in the initial solution are as follows: 0.01 mM, 0.02 mM, 0.05 mM, 0.1 mM, 0.2 mM, 0.5 mM and 1 mM. Percolation conductivity arises only at concentrations of platinum equal to 0.1 mM. Sheet conductivity at this concentration is 521 S / cm (Table 1).

**Table 1.** The dependence of the electrical conductivity of the coating on the amount of platinum.

| Concentration of the platinum, (mM) | Sheet conductivity, (S/cm) |
|-------------------------------------|---------------------------|
| 0.01                                | 0                         |
| 0.02                                | 0                         |
| 0.05                                | 0                         |
| 0.1                                 | 521                       |
| 0.02                                | 0                         |
| 0.05                                | 0                         |
| 1                                   | 0                         |

| Concentration of the platinum, (mM) | Sheet conductivity, (S/cm) |
|-------------------------------------|---------------------------|
| 0.01                                | 0                         |
| 0.02                                | 0                         |
| 0.05                                | 0                         |
| 0.1                                 | 521                       |
| 0.02                                | 0                         |
| 0.05                                | 0                         |
| 1                                   | 0                         |

Platinum nanowires at the height of 3-6 nm have a width of 50-60 nm, which corresponds to the shape of tape or strip.
TEM-EDX spectrum of platinum nanowires shows spectrum corresponding to the pure sample (platinum lines are M\(\alpha\)1 = 2.050 keV, L\(\alpha\)1 = 9.442 keV).

Sheet conductivity at concentration of platinum equal to 0.1 mM is 521 S / cm. For other concentrations, the average conductivity is 0 S / cm.

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