Development of methods for preparation transparent electrodes based on carbon nanotubes and graphene using Langmuir technique

What the iPhone, Kindle, LCDs and solar cells have in common. All these devices use a transparent electrode which is the material that simultaneously transmits visible light and conduct current. The amount of produced devices using transparent electrode is constantly growing, and the most frequently used material is indium tin oxide (ITO). Although production technology of the transparent electrodes on basis of ITO is well known but ITO has drawbacks restricting the use of modern devices. The biggest disadvantages of this material are its brittleness and the high price of indium, what makes impossible to build a cheap and flexible electronics. Alternative materials to replace ITO are conductive polymers or thin layers of carbon nanomaterials. Development of transparent and flexible electrodes based on carbon nanomaterials is essential for modern optoelectronic. In contrast to the indium price, the price of carbon nanomaterials constantly decreasing. Industrial grade CNT can be purchased at a price lower than 100 $/kg, industrial grade graphene at a price lower than 200 $/kg while the price of indium reaches 500 $/kg and the conductive polymer price is 1 000 $/kg (source: Argus Media Inc. United Nanotech Innovations Pvt. Ltd, Sigma-Aldrich Sp. z oo). Moreover, supply of indium in the world is limited. The use of carbon nanomaterials not only reduce the costs of production of flexible optoelectronic devices, but also reduce the demand for heavily exploited indium.

The aim of the project is to develop methods for preparation of the composite flexible transparent electrodes made of two kinds horizontally aligned carbon nanotubes (CNT) and graphene flakes prepared via Langmuir methods. The composite flexible transparent electrodes structure is shown in the Figure 1. Graphene and carbon nanotubes are materials with high electrical conductivity, but in thin films total resistance is increased significantly by the contact points. We expected that composite structure will reduce the overall resistance maintaining flexibility and a high transmittance in the UV-Vis. Although the composite flexible transparent electrodes may find interesting applications, first must be done a series of basic research that allows to describe the CNT/CNT and graphene/CNT interfaces and examine structural properties, physical endurance of the resulting material.

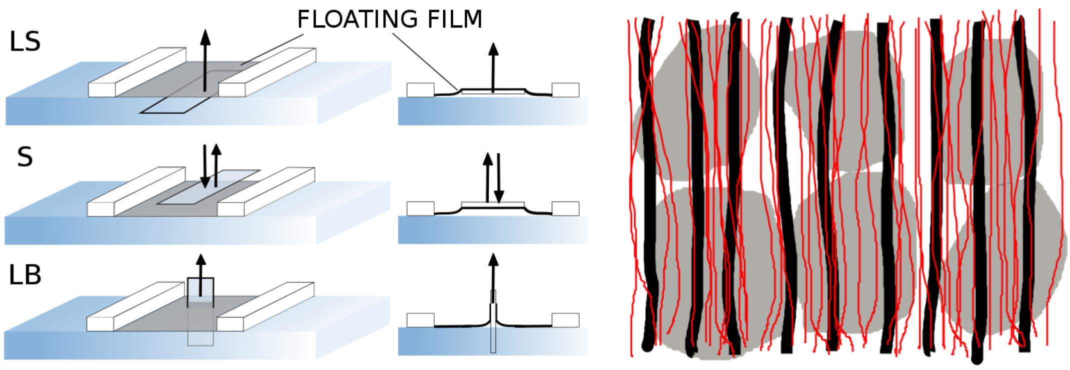

Figure 1. Schemes of Langmuir deposition methods (left), where: LB - Langmuir-Blodgett method, LS - Langmuir-Schaefer method, S - stamp Langmuir-Schaefer method and composite flexible transparent electrodes structure (right) composed of two kinds horizontally aligned carbon nanotubes (CNT) and graphene flakes

Langmuir technique involves the formation of a single layer of the material on the surface of water. This is accomplished by spreading a material solution in a volatile solvent onto air water interface. After evaporation of the solvent and providing suitable conditions of the experiment on the surface of the water left only very rarely packed material in the form of a so called two-dimensional gas (thickness dimension is negligible compared to the dimensions of length and width of the layer). Then, the material can be compressed mechanically by precisely controlled barriers in order to form a densely packed layer. If this process is executed under appropriate conditions, the material form a homogeneous ultra-thin film. Floating film can be transferred on substrate. Schemes of Langmuir deposition methods are shown in the Figure 1. Alignment of the carbon nanotubes can be achieved by repeated compression and expansion of the layer or by an electric field. Imposing prepared layers of graphene, aligned carbon nanotubes and aligned carbon nanotubes with smaller diameters on each other composite transparent electrode will be prepared.