MECHANICAL PROPERTIES OF OXIDE COATINGS HAVING SENSOR APPLICATION

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Abstract

An experimental investigation of the mechanical properties of planar structures of ZnO/Si for different indentor loads has been described. The influence of intensive solar-like light and temperature on hardness and plasticity parameters has been also investigated. It is obtained that the light exposure and temperature treatment cause not great changes of the microhardness and plasticity properties.

Keywords: nanoscale ZnO/Si planar structure, fabrication, microstructure, mechanical properties

1. Introduction

Planar structures have a wide application in modern engineering. In particular, planar structures like ZnO/Si are of interest as potential materials for optically-transparent electrodes in photonic devices such as solar batteries, photodetectors and luminescent diodes.

The successful use of planar structures is impossible without the study of their mechanical characteristics. Indentation hardness testing of solids provides a simple and quick method to obtain information about the mechanical properties of materials. These properties mainly include microhardness and microbrittleness. A particular advantage of the indentation hardness testing is that the investigation can be carried out on small specimens only a few micrometers of size. During the last two decades, significant advances have been made in applying surface engineering techniques to materials for improving their mechanical and chemical properties. These techniques include coating, ion implantation, multilayer superlattices and others. To test the mechanical properties of engineered surfaces and thin coatings deposited on substrates, nanoindentation hardness machines and techniques have been elaborated which allow the investigations to be carried out using low indentor loads over a range from μN to mN [1,2].

Y.G. Gogotsi and I.V. Uvarova (eds.),
Nanostructured Materials and Coatings for Biomedical and Sensor Applications, 305–310.

The proposed work involves the study of the mechanical characteristics of planar structures consisting of composites of the nanoscale films deposited on crystalline substrates (ZnO/Si) and the influence of light irradiation and temperature treatment on them. The results of mechanical behaviour investigations can be used for the optimisation of the manufacturing process of the nanocomposites in order to obtain the high-quality structures with the properties required for the practical applications.

2. Experimental details

The fabrication process of the ZnO/Si planar structures included three consecutive stages. At first, a conducting n^+-ZnO layer was formed on a p-Si substrate by organometallic deposition; zinc acetylacetonate $Zn(A_cA_c)$ was used as a source of Zn. The ZnO layer was deposited in a vertical reactor; the substrate temperature was maintained within 300-350°C. In the capacity of supporting gas, Ar saturated with Zn (A_cA_c) vapours and O_2 were utilised. During n^+-ZnO layer deposition, the temperature of the Zn (A_cA_c) source was 120°C; a flux of Ar mixed with O_2 in the proportion of $[Ar]/[Ar] + [0_2])=0.5$ was used. The obtained n^+-ZnO layer thickness was within the limits from 150 nm to 700 nm; the electron concentration in these layers was $(5\text{-}8)\times10^{19}cm^{-3}$, and electron mobility was ~ $50cm^2\ V^{-1}s^{-1}$. An additional n-ZnO layer of 100-300A° thickness was then deposited using electron-beam evaporation of n-ZnO crystals ($\rho=10^2\Omega cm$).

The microindentation hardness testing was made using a PMT-3 device and Vickers diamond square pyramid as indentor. The mechanical parameters were calculated using the usual formulae [3,4] with an indentor load P between 0,2 – 2N.

The brittleness of ZnO/Si samples was determined by measuring the summary amount (N) of acoustic emission (AE) signals excited in the tested material under a concentrated loading. The application of this method is based on the concept that the deformation and fracture processes are the sources of the acoustic signals bearing the profound information about the internal structure transformation. In the case of quasi-static indentation the acoustic emission signals were registered at indentor penetration into material (N_1) and as a summary account of AE signals accumulated under loading/unloading process (N_2). The value $\Delta N_2= N_2 - N_1$ indicates the AE signal sum appearing at the unloading stage.

Taking into account that the ZnO/Si planar structures, in the case of a practical application, can undergo an intensive light exposure, be influenced of high or low temperatures, it was of interest to carry out the respective experiments. To study the influence of an intensive light exposure the specimens were irradiated during 30 minutes using a quartz-mercury lamp PRK. Heat treatment of samples was made by two means: annealing over 6 hours at T=573 K and exposure during 1 hour in liquid nitrogen (T=77 K). The optical microscopes Neophot, Amplival, microinterferometer MII-4 and scanning electron microscope Tesla BS-350 were utilised for the surface microstructural investigations.