

Influence of ZnO surface polarity on the electrophoretic deposition of metal nanoparticles.

Roman Yatskiv, Jan Grym

Institute of Photonics and Electronics, Chaberska 57, Prague, Czech Republic
yatskiv@ufe.cz

Abstract

Zinc oxide (ZnO) is a wide band-gap (3.37 eV at room temperature) semiconductor with many advantageous properties such as large exciton binding energy of about 60 meV, high optical gain (about three times higher than in GaN), radiation hardness, or the possibility of wet-chemical processing. ZnO is a promising material for ultraviolet light emitting devices, laser diodes, solar cells, and gas sensors [1]. However the use of its potential requires the solution of several critical issues such as (a) preparation of p-type material, (b) understanding and control of electrical contact properties, (c) obtaining highly efficient ultraviolet emission from the near band edge. In the past few years, a number of studies have been conducted to improve the band-edge emission from ZnO films and nanostructures by metal capping; different metals (Ag, Au, Al and Pt in the form thin layer or small islands) have been used as capping layers [2,3]. A similar effect can be achieved by coverage of ZnO substrate by metal nanoparticles (NPs).

In this work we report the influence of ZnO spontaneous polarization [4] on the quality of the electrophoretically prepared metal nanolayer. Pt NPs were deposited on O-polar and Zn-polar n-type ZnO substrates growth by hydrothermal method (produced by MTI Company) by pulsed electrophoretic deposition (EPD) [5]. Pt NPs were prepared in isooctane by the reverse micelle technique reducing H_2PtCl_6 by hydrazine and were characterized by transmission electron microscopy (showing an average size of 10 nm) and by optical absorption spectra (two peaks at 260 nm and 236 nm due to surface plasmons of Pt nanoparticles, and a peak associated with AOT absorption were observed) [6]. As shown in Figure 1, significant face effect with higher coverage achieved on O- face compared to Zn- face was observed. This significant variation can be explained by the existence of nonzero net dipole moment perpendicular to Zn-polar and O-polar face. Free electrons move in an attempt to compensate the bound spontaneous polarization charge ($+Q_{SP}$, $-Q_{SP}$) and reduce the internal electric field. Electrons accumulate near the O-polar face and depletion region forms adjacent to Zn-polar face (Figure 2). As a result, positively charged Pt NPs are attracted by the negative charge to the O-face. This effect allows the self-deposition of nanoparticles on the O-face of ZnO without attached electric field (Figure 3).

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References

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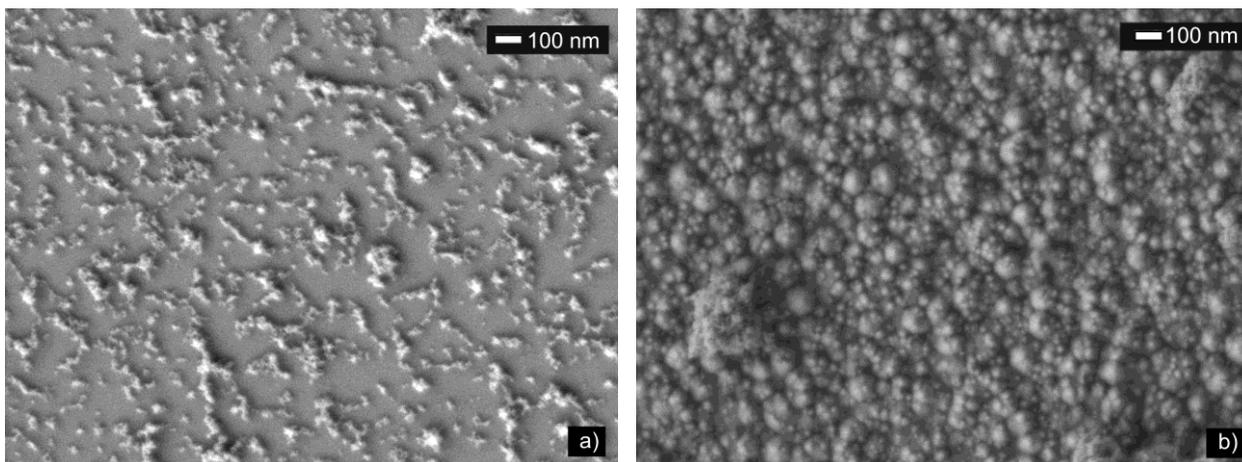


Figure 1 SEM images of Pt NPs deposited on the (a) Zn-face (b) O-face ZnO substrate by EPD (deposition time and applied bias were 1 h and 106 V, respectively).

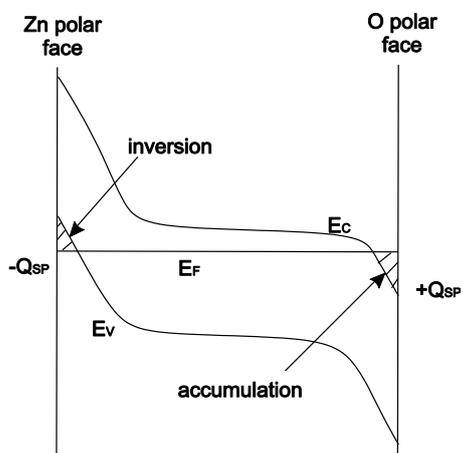


Figure 2 Schematics of the free carrier distribution in n-type ZnO in response to the presence of a spontaneous polarization field.

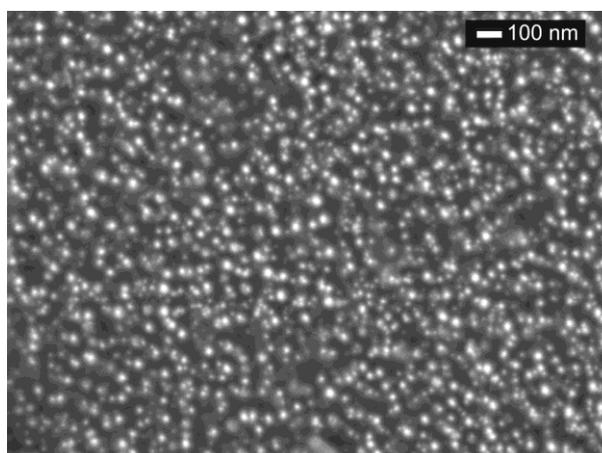


Figure 3 SEM image of Pt NPs self-deposition (without electric field) on O-face ZnO substrate (deposition time was 1 h).