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Letter

Effect of visible light on the water contact angles on illuminated oxide semiconductors other than TiO_2

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Abstract

Wide band gap semiconductor oxides such as TiO_2, Ta_2O_5, ZnO, indium–tin oxide, $InTaO_4$ or In_2O_3 are materials with water contact angles in dark between 60° and 130°. The present investigation shows that thin films of these oxides become hydrophilic when they are irradiated with ultraviolet light. This finding indicates that the transformation of the wetting properties of illuminated wide band gap oxides is a common phenomenon not restricted to TiO_2. An additional evidence found for ZnO and $InTaO_4$ is that the water contact angle decreases by 30°/40° when they are irradiated with visible light.

Keywords: Wetting; Oxide semiconductors; Visible light irradiation

1. Introduction

The control of the wetting properties of materials (i.e., the contact angle of liquids on their surfaces) is a subject of much scientific interest with many practical and industrial implications [1]. Within this context, the discovery by Wang et al. [2] that the surface of TiO_2 may be transformed upon UV light irradiation from partially hydrophobic (i.e., water contact angles around 80°) into fully hydrophilic (i.e., the water drops spread as a film on the surface), fostered the research on this material and this particular property [3–6]. At present, the practical use of TiO_2 as self-cleaning and an antifogging material is

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already a reality which has been incorporated in commercial glass. Other applications such as automobile side view mirror, window films, exterior tiles, highway road wall panels, etc., have also been proposed [7].

It is curious that despite the photoactive character of many other oxide semiconductors, the change in water contact angle upon light irradiation has only been extensively studied for TiO_2. Thus, although a similar behaviour has been described very recently for hepitaxial layers of ZnO [8] or for thin films of semiconductor oxides such as ZnO, SnO_2, WO_3 and V_2O_5 [9], checking the possible UV-induced wetting of oxide semiconductors others than TiO_2 is still missing. Another still open issue for the practical implementation of these photoactive surfaces is to make them sensitive to photons in the visible region of the spectrum. In this letter, we report about the change in water contact angle on semiconductor oxides such as ZnO, Ta_2O_5, In_2O_3, $InTaO_4$ or indium–tin oxides (ITO) and the unexpected response of some of them to irradiation with visible light. TiO_2 has been used as a reference material. These oxides are known because they present some kind of photoactivity and have band gaps within the UV region of the spectrum [10–13]. Except for ZnO, no results about hydrophilic adjustment of contact angles upon light irradiation have been reported for the other investigated oxides. Meanwhile, for $InTaO_4$ it has been reported recently that this photoactive material doped with nickel is able to split the water into H_2 and O_2 when irradiated with visible light [14].

2. Experimental

ZnO, Ta_2O_5, In_2O_3 and $InTaO_4$ thin films, together with a commercial ITO covered glass (Präzisions Glas & Optik GmbH) have been selected for this study.

Ta_2O_5 and In_2O_3 thin films have been prepared by electron evaporation under 10^{-4} Torr oxygen from the respective bulk oxides. $InTaO_4$, thin films are prepared by alternative and successive evaporation of thin layers of the two constituent oxides followed by annealing at 800 °C. ZnO and TiO_2 thin films have been prepared by plasma-enhanced chemical vapour deposition according to previously described procedures [15,16]. Illumination of the samples was carried out with a Xe lamp with a photon intensity at the position of the samples of $2\,W\,cm^{-2}$ for the complete spectrum of the lamp (i.e., UV + visible + infrared photons, although for simplicity we will refer this situation in the text and figures as UV) and $1.6\,W\,cm^{-2}$ for visible illumination. In this latter case, UV and infrared filters (i.e., a water bath) were kept between the lamp and the samples to remove the UV and IR photons and to prevent any possible heating by the infrared radiation.

3. Results and discussion

For the synthesized oxide thin films and for ITO commercial plates, water contact angles were measured as a function of the irradiation time, first by employing the whole spectrum of the Xe lamp and then by using visible light only. Fig. 1 shows that the surface of all selected materials becomes hydrophilic upon UV irradiation. In addition, it is also found that visible light irradiation contributes to restore their original water contact angles. In all cases the restoration time was very long, the process lasting for hours when not days, depending on the oxide. Even longer restoration times were required when the films were stored in the dark.