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Self-organization of nanoparticles in a TiO_2 thin film on a glass substrate

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Abstract

Nanocrystalline titanium dioxide colloids have been synthesized using a sol–gel technique followed by growth under hydrothermal conditions in an alkaline environment at temperatures between 190 and 270 °C. Thin films have been made from aqueous suspension of these colloids. Grazing-incidence wide-angle X-ray diffraction (GIWAXD) analysis showed the films to be primarily the anatase crystal phase. This is in agreement with previous scanning electron microscopy (SEM) results, which had revealed a predominantly rod-like particle morphology after growth at lower temperatures. The formation of principally truncated tetragonal or tetrahedral bipyramidal nanocrystallites followed growth at higher temperatures. The rod-like particles self-organize into regular cubic arrays with the long axis of the rods aligned perpendicular to the film surface. This self-organization is dependent upon the base used in colloidal synthesis.

Keywords: Titanium dioxide; Sol–gel; GIWAXD

1. Introduction

Applications of titanium dioxide colloids and thin films are numerous, including photovoltaic, electrochromic, photochromic, electroluminiscence, catalytic devices and sensors [1]. We have explored sol–gel syntheses of nanocrystalline titanium dioxide [2] together with many research groups [3–6]. Both acidic [7] and alkaline environments [8,9] have been used to prepare sol–gel-derived anatase nanocrystals for use as electrode in dye-sensitized solar cell. Formation of hexagonally packed, colloidally derived, ordered thin films has been done by using a base-catalyzed sol–gel synthetic scheme [10,11].

The aim of this work is to use the grazing incidence wide-angle X-ray diffraction (GIWAXD) method in order to compare with SEM results obtained by Burnside et al. [6] on ordered structures formed from titanium dioxide nanoparticles synthesized using a sol–gel technique.

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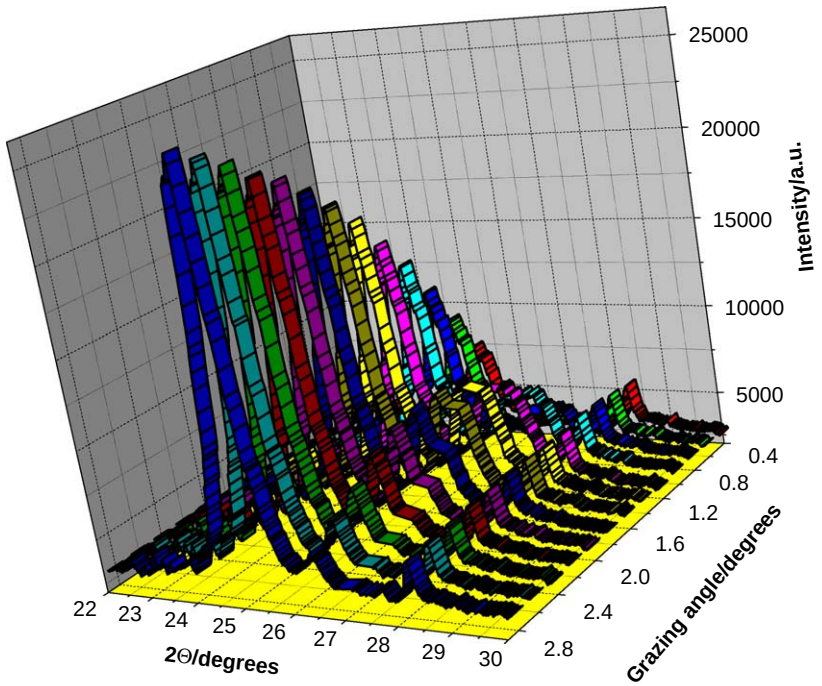

Fig. 1. GIWAXD 3D-pattern of alkaline-ordered TiO_2 film autoclaved at 210 °C; *x*-axes: 2Θ degees, *y*-axes: grazing angles changing by 0.2°, and *z*-axis: intensity of diffraction. At ~25° change of intensity of the line at 24.95° is apparent showing that the surface parallel to the substrate has (1 0 0) orientation.

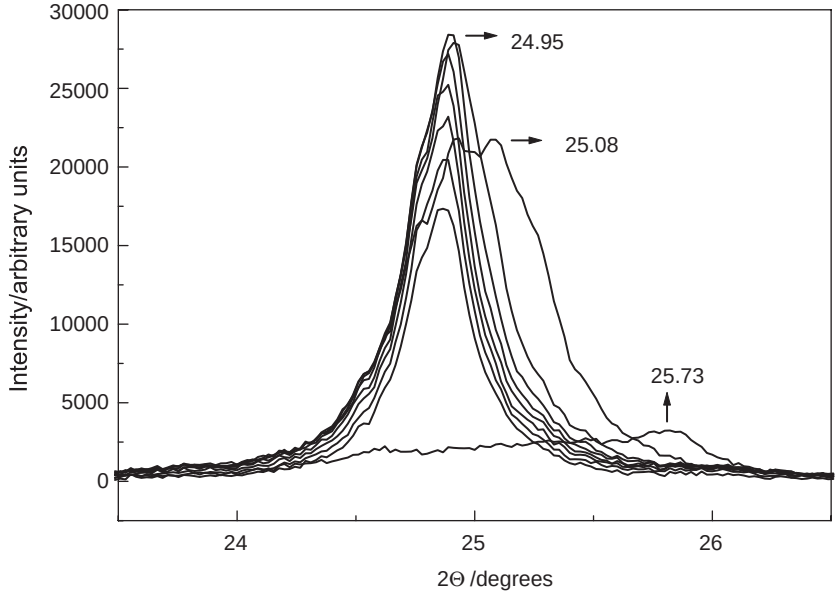

Fig. 2. GIWAXD of alkaline-ordered TiO_2 film on SnO_2-coated glass in 2D-representation with grazing angles changing by 2°.