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Influence of the substrate on the morphological evolution of gold thin films during solid-state dewetting

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The evolution of electron-beam evaporated Au thin films deposited on crystalline TiO_2 (c-TiO_2) and amorphous TiO_2 (a-TiO_2) as well as amorphous SiO_2 substrates are investigated. The kinetic of dewetting is clearly dependent on the type of substrate and is faster on TiO_2 substrates than on SiO_2 substrates. This difference can result from the difference in adhesion energy. Furthermore, the kinetic of dewetting is faster on a-TiO_2 than on c-TiO_2, possibly due to the crystallization of TiO_2 during annealing induced dewetting process. The morphologies of dewetted Au films deposited on crystalline TiO_2 are characterized by branched holes. The XRD patterns of the Au films deposited on TiO_2 substrates constituted peaks from both metallic Au and anatase TiO_2. The activation energy of Au films deposited on crystalline TiO_2 substrates was higher than that that of the films deposited on amorphous TiO_2 substrates.

1. Introduction

Solid-state dewetting of metallic thin films has been the subject of great interest recently, due to its potential in producing nanoparticles for catalysis, magnetic storage and plasmonic applications [1]. The dewetting of metal films occurs by atomic diffusion and is driven by the reduction of the surface energy of the films and the interface energy between the film and the substrate [2]. In polycrystalline thin films, grain boundaries and grain boundary triple junctions are often considered as nucleation sites for substrate exposing holes [3]. Grooves form at grain boundary triple junctions, and when they become deep through the thickness, substrate-exposed holes form. Growth of holes is then followed by the formation of particles or islands due to the Rayleigh instability [4].

Factors influencing the dewetting process have been well documented and include among others, the annealing temperature [5], annealing time [6], film thickness [6], annealing atmosphere [7] and substrate type [8]. Since nanoparticle formation from thin films is a highly surface-and-interface-dependent phenomenon, then the substrate properties, such as physical topography and interfacial energy have significant influence on the shape and size of the dewetted particles [8]. This calls for more studies on the influence of substrate surface morphology on the dewetting of thin films. However, there are very few reports on the influence of substrate type on the dewetting properties of metal thin films.

Lee and his co-workers [8] investigated the dewetting behaviours of e-beam evaporated Au thin films on various substrates: monolayer graphene (MLG) and bilayer graphene (BLG) on quartz, quartz and SiO_2. The films were annealed at 900 °C for 30, 60 and 120 min in Ar ambient. It was reported in their work that the Au mean particle diameters increased from SiO_2 to quartz, then to MLG and BLG surfaces for all annealing conditions.

Recently, Seguini et al. [5] investigated the morphological evolutions of Au dewetted particles on SiO_2 and HfO_2 substrates. It was found that under the same deposition conditions, the deposited Au thickness on SiO_2 was twice as that deposited on HfO_2 due to the peculiar interactions of the impinging Au with the host. In addition, the signature of the preferential orientation increased with the increase in the thickness and was higher in the films grown on HfO_2 than on SiO_2 substrates.

In the current work, we report on the influence of the substrate nature on the dewetting behaviour of Au nanoparticles.

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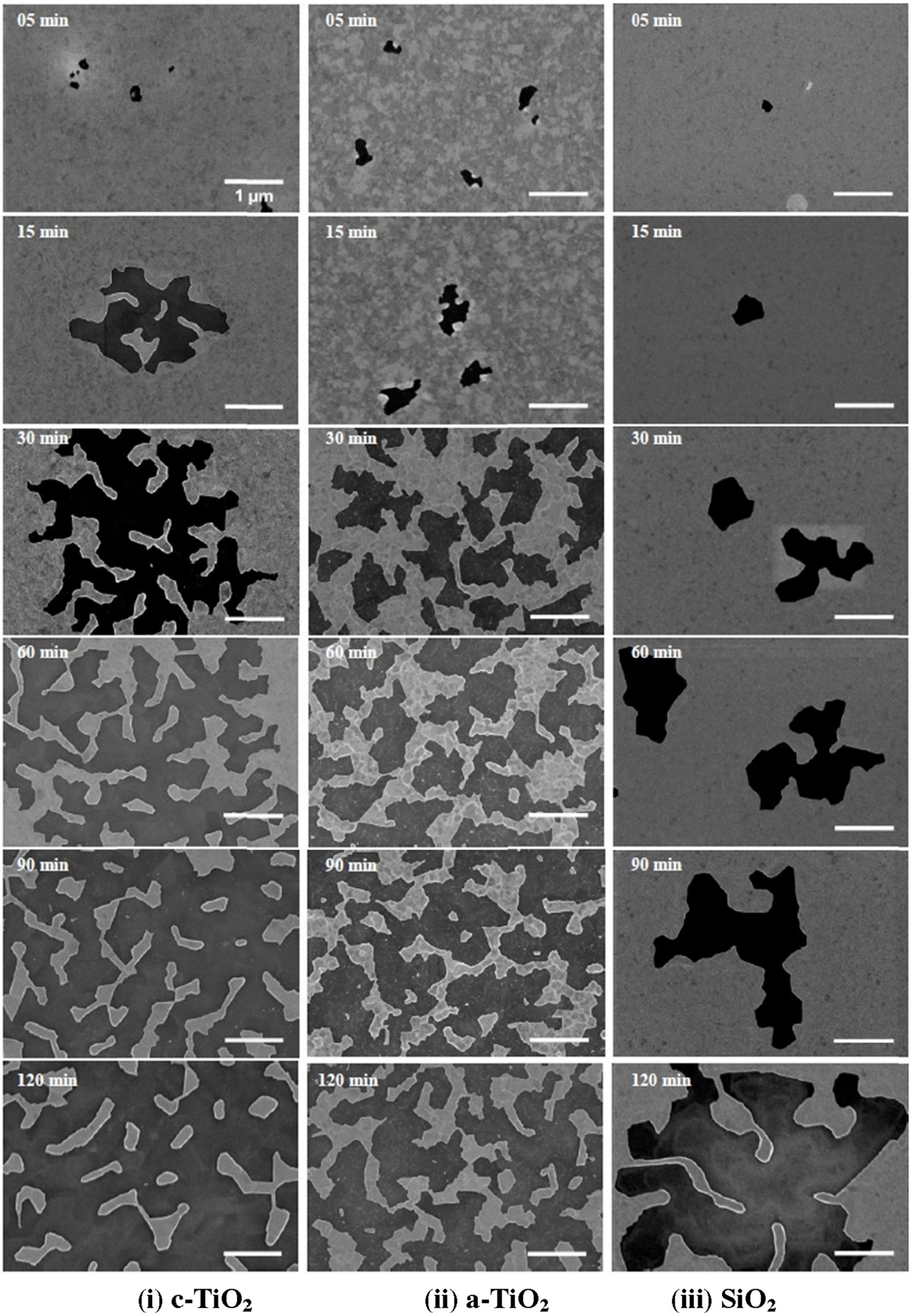

Fig. 1. SEM images for (i) Au/crystalline TiO_2, (ii) Au/amorphous TiO_2 and (iii) Au/SiO_2 dewetted at 500 °C and at different durations. The scale bar applies to all images.