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Microstructural Investigations of Platinum Shape Equilibration in Alumina

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Metal-ceramic (MC) materials are important both in fundamental science and in many technological applications [1], many of which feature applications metal-implanted ceramics. The properties of such metal-implanted structures are determined by the location and the shape of the metal inclusions. While the equilibrium shape of the metal inclusions is a function of MC interfacial energies, metastable metal shapes are also affected by the equilibration kinetics. In order to predict or stabilize metastable shapes of metal inclusions in ceramics, full information regarding relative MC interface energies, including the energies of interfaces that absent in the equilibrium shape of a ceramic-embedded metal, should be available, and the kinetics of microstructural evolution should be investigated.

In the current study a model system of Pt-implanted polycrystalline alumina (PCA) is used for investigating the equilibration kinetics of metal inclusions in a ceramic matrix. The implantation was conducted in liquid nitrogen (lN_2), resulting in amorphization of the upper alumina (Al_2O_3) layer [2,3]. The system was annealed at 1565°C for 5, 25, and 100 hours promoting PCA grain-growth. Upon annealing in air, the implanted Pt^+ ions coalesced into metal inclusions, and were consequently swept by growing α-Al_2O_3. This sequence of events enabled the investigation of Pt shape-equilibration kinetics. The Pt particles occluded in the α-Al_2O_3 grains found in different stages of re-equilibration with the new Al_2O_3 orientations were investigated by transmission electron microscopy at high spatial resolution.

These investigations reveal that the mobility of Pt particles differs as a function of the moving Al_2O_3 grain-boundary (GB) plane. Al_2O_3 orientation at the GB affects the Pt-Al_2O_3 interface energy at times resulting in atomically flat Pt-Al_2O_3 interfaces (Figure 1) that inhibit Pt movement on specific Al_2O_3 GBs. Those Pt particles separate from the low-energy GBs before reaching theoretical maximum size and/or velocity. As a consequence, the size, distribution, and orientation of metal precipitates after ion-implantation and annealing at 1565°C are not uniform, and depend on the orientation of a specific ceramic matrix grain. Large amounts of differently oriented Al_2O_3 grains that grow during annealing enable the investigation of metastable equilibrium states of Pt particles, which are forced to re-orient in accordance with newly imposed, host Al_2O_3 grains (Figure 2). Those metastable states provide valuable information regarding relative energies of Pt-Al_2O_3 interfaces not usually present under global equilibrium conditions. Study of MC interfaces not present in the Wulff shape enables the determination of the necessary conditions (in terms of the ceramic grain orientations) for stabilization of metastable MC ORs.

Previous attempts to reach full equilibration of Pt in sapphire failed due to the pinning of the {111} Pt planes to the (0006) sapphire surfaces, and due to the lack of ledge-producing defects on this interface [3]. The PCA system includes a wide selection of Al_2O_3 orientations, in some of which the grain-growth direction is not perpendicular or parallel to the (0006) alumina plane, enabling full equilibration of the Pt particles in some Al_2O_3 grains within relatively low annealing times (up to 100 hours) [4].

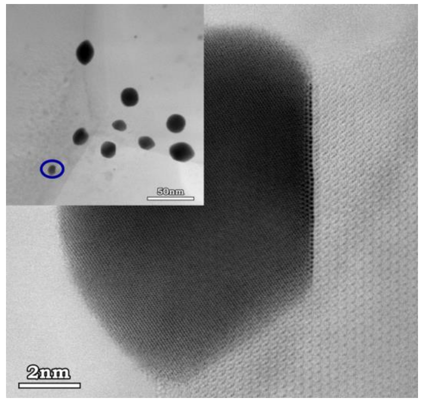

Figure 1. Bright-field scanning transmission electron microscope (BF-STEM) micrograph of a Pt particle on Al_2O_3 surface after 5 h anneal. The flat Pt-Al_2O_3 interface can be detected. The inset is a triple junction region in which this Pt particle (marked by an oval) is located.

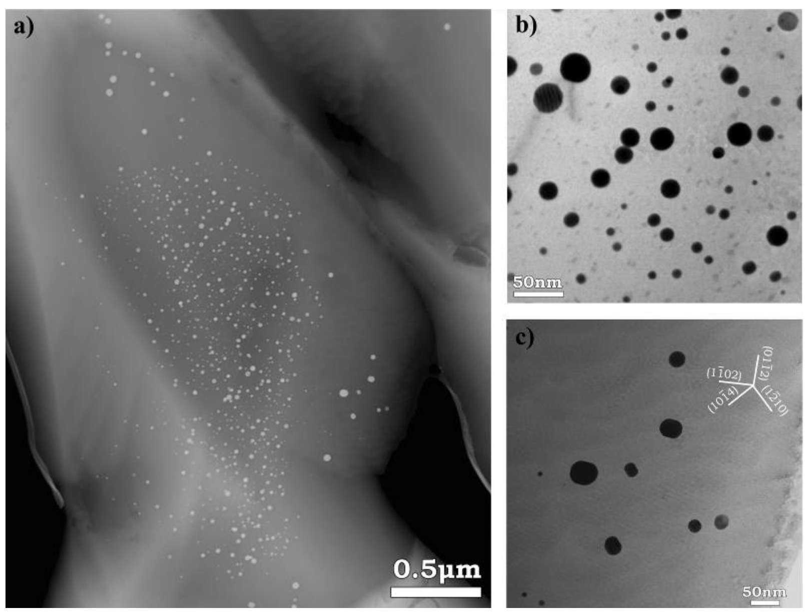

Figure 2. (a) High angle annular dark field (HAAFD) STEM micrograph of an Al_2O_3 grain after 25 h anneal. (b) Bright field (BF) TEM micrograph of the central region of (a) with equilibrated Pt particles. (c) BF TEM micrograph of the lower region of (a) with non-equilibrated Pt particles.

References:

[1] CB Carter, MG Norton in “Ceramic Materials: Science and Engineering”. 2-nd ed., (Springer Science, New York) p. 5.

[2] MK Santala *et al*, Scripta Materialia **62(4),** (2010), p. 187-190.

[3] MK Santala *et al*, Acta Materialia **59(12),** (2011), p. 4761-4774.

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