Void Formation at the Interface Between Particles and Matrix in Deformed Al-Al_2O_3 Foils

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Al-foils containing a dispersion of 2.5 wt % Al_2O_3 particles were deformed inside the electron microscope. It was observed that in the necked regions formed voids are nucleated at the particle/matrix interface. These small voids grew with continued straining by elongating and widening. Occasionally elongated voids were pinched off and a row of rather circular loops was left in the matrix. Fracture of particles did not occur.

A considerable amount of attention has recently been devoted to the ductility behaviour of Al–Al_2O_3 alloys which consist of an Al-matrix with dispersed Al_2O_3 particles [1–6]. However, direct information on the formation of voids at the particle/matrix interface in the Al–Al_2O_3 alloys during deformation, is not available. In this note an electron microscope study is described, which consisted of the tensile deformation and simultaneous observation of Al–Al_2O_3 foils inside the electron microscope. The results of our observations show that during straining of Al–Al_2O_3 foils at $\sim$ 30° C (i) voids are nucleated at the particle/matrix interface; (ii) these small voids may act as a starting point for the formation of cracks perforating the foil.

The material studied was an Al–2.5 wt % Al_2O_3 alloy fabricated by powder metallurgical techniques from Al-powder of 99.99% purity. Foils of 100 μm thickness were prepared from an extruded rod of this alloy by cold-rolling and a subsequent annealing for 1 h at 630° C in vacuum. The microstructure observed in the foils after this treatment has already been shown in [7] and [8]. The relevant details are as follows: The grain size was about 200 μm. The Al_2O_3 particles, in the form of triangular or hexagonal plates, were rather homogeneously dispersed within the grains and were oriented with their basal face parallel to the foil plane. Their mean width was about 500 to 800 Å and their thickness $\sim$ 200 Å. The particles were incoherent with the matrix and were surrounded by a weak strain field which was due to differential thermal contraction effects during cooling from the annealing temperature. The density of dislocations was low and no voids were detectable at the particle/matrix interface.

Foils having the above described characteristics were used for the tensile experiments. Foil strips of about 3 mm length and 1 mm width and being electron transparent on one side were mounted on the Philips micro-tensile straining device designed for the electron microscope Philips EM300. This device, fitted to a holder and inserted into the goniometer stage of the microscope allows straining of specimens at a slow rate to large amounts, and tilting for $\pm$ 35°.

The strips were strained during observation until a crack opened at the transparent side and propagated across the strip into the thick parts not transparent to electrons. It was observed that voids were formed at the particles situated in the region ahead of the progressing tip of the crack.

The voids always appeared brighter than the background, the contrast being mainly due to absorption [9]. Pairs of micrographs taken at different angles for stereo-viewing showed that the voids were attached to the interface between the particles and the matrix. During straining the crack sometimes stopped to propagate in the thicker part of the strips, and necked regions, transparent to electrons, were formed in the neighbourhood of the crack tip. In such regions voids were observable at *all* particles as shown in fig. 1a. The voids were usually formed on

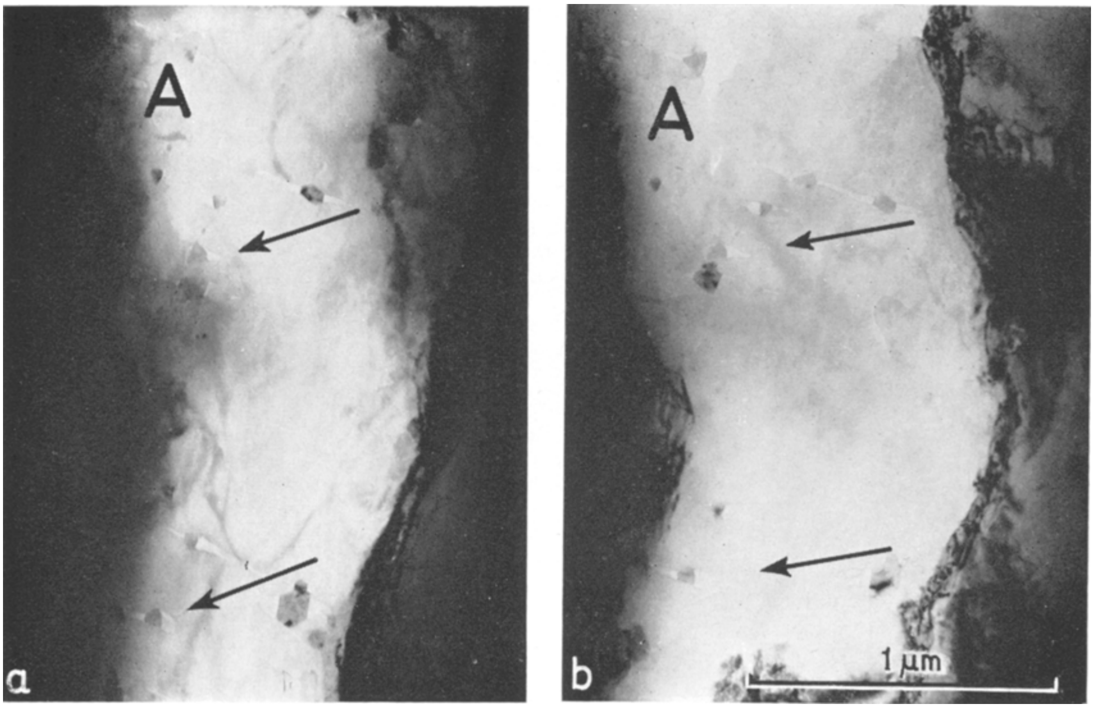

Figure 1 Annealed Al–2.5 wt% Al_2O_3 foil deformed in tension inside the electron microscope. (a) Formation of necked region in thick part of the foil. Note voids within the foil attached to particles. (b) The same region after further straining. The voids at particles indicated by arrows have elongated and widened. A crack perforating the foil has formed by interconnection of the voids attached to the particle marked A.

opposite sides of the particles, presumably in the direction of the maximum applied stress. On further straining the voids grew by elongating and widening as shown for the voids indicated by arrows in figs. 1a and b. Occasionally the elongated voids were pinched off and a row of rather circular ones was left in the Al-matrix.

Furthermore it was observed that the voids formed at the particle/matrix interface within the necked regions acted as a starting point for the formation of cracks perforating the foil. This is shown in figs. 1a and b for the voids at the particle marked by the letter A.

Inspection of the particles located in the thicker foil close to the necked regions revealed that the particles were surrounded by a high density of dislocations (fig. 2). It is therefore suggested that the voids observed at the particles in the necked regions form as a consequence of high stress built up during deformation at the particle/matrix interface leading to fracture of this interface.

Fracture of the particles themselves as proposed by Ansell and Lenel [10] was not observed.

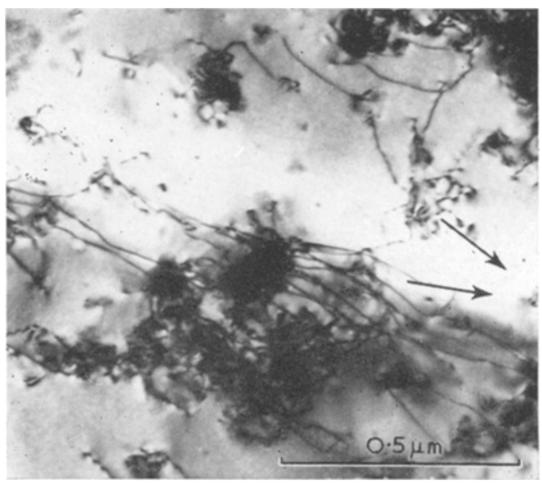

Figure 2 Area of Al–2.5 wt% Al_2O_3 foil deformed in tension. The particles located in the thicker foil close to the necked region are surrounded by a high density of dislocations. A void has formed at a particle situated in the necked region (arrows).

A detailed account of this work will be given later.

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