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COMMENTS ON "FLOW STRESS-GRAIN SIZE RELATIONSHIP IN ALUMINUM"

MARC A. MEYERS
Centro de Pesquisa de Materiais
Instituto Militar de Engenharia
Pça.Gen.Tibúrcio - Urca - ZC-82
Rio de Janeiro, RJ, Brasil

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In a recent article, Shiroor et al[1] presented an analysis of the tensile curves of commercial purity aluminum with various grain sizes and obtained the internal stress σ_{ie} and Hall-Petch Slope k defined in the Hall-Petch expression [2,3]. However, their experimental techniques were such as to invalidate the results, as shown by the following discussion.

Strips with 12.5mm width were cut from sheets of 1.3mm thickness. Test specimens with 50mm gage length were machined out of these strips. The gage width is not specified in the paper, but should be no larger than 10mm. Heat treatments were done on the strips, producing average grain diameters - as measured by the linear intercept method - varying between 1.78 and 4.78mm. This is not acceptable because of the following reasons:

a) The number of grains in the cross section of the test specimens can be calculated and varies approximately from 7 to 2, for the smallest and largest - sized grains, respectively. These grains cannot, due to the limiting thickness, be equiaxed, and the measurements loose therefore their reliability. Or, it is known that the term "polycrystal" is reserved for cases where there are more than 20 grains/cross section[4]. Fleisher and Hosford[5] showed that the stress-strain curves are strongly dependent upon the number of grains per cross section, up to a value of 12.7. The flow stress increases with the number of grains/cross section. Therefore the stress-strain curves obtained by Shiroor et al[1] are not representative of polycrystalline aluminum, as claimed; in addition, the flow stress dependency obtained by them might very well be due to the variation of grains/cross section.

b) In the Hall-Petch relationship the grain boundaries are of utmost importance; they are directly involved, whether the pileup of dislocations[2] or grain-boundary dislocation sources[6] are used as the underlying mechanisms. Kocks[7] states that, if one wants the fraction of surface grains to be smaller than 10 percent, the specimen diameter has to be at least 30 to 40 times the grain diameter. It is obvious that the experiments by Shiroor et al[1] did not meet this condition and that, consequently, most grain boundaries were not subjected to the constraints encountered in a polycrystalline metal.

The value of k obtained by Shiroor et al[1] (k = 2.2) is different, by an order of magnitude, from that obtained by Carreker and Hibbard[8,9] (k = 0.22) for 99.97 pct. aluminum. Composition, although affecting k, should not have such a drastic effect; for instance, for aluminum - 3.5 pct. magnesium k is equal to 0.85[9]. Rather than that, the large difference is probably due to the number of slip systems involved; the smaller the number of slip systems, the larger k. In multicrystals (1 - 20 grains/cross section) a maximum of two or three slip systems supply the vast majority of slip[5]. However, five independent slip systems are required in a truly polycrystalline material due to the compatibility relations.

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