The Influence of the Average Grain Size on the Internal Size Effect in Polycrystalline Films of Lead

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The presence of a large number of grain-boundaries in thin polycrystalline films, with which excess energy is connected, leads to the internal size effect appearance. It can be explained by the fact that grain-boundaries, separating a grain from neighboring ones, disappear while melting. Energy gain in this process is determined by the grain size and its orientation with respect to the surrounding grains. As a result, each of the crystallites in the film starts to melt at its own temperature. The internal size effect was experimentally observed previously in polycrystalline films of metals. It has been found, that while melting of such films on the substrates with a temperature gradient, the crystal-melt boundary has a finite width, in which a partial melting of the film is observed. Due to the large value of the grain-boundary energy contribution, even for polycrystals, consisting of micron-size grains, the melting range can reach 3–4 K.

It is naturally to suppose, that the temperature width of the partial melting will increase together with the rise of the grain-boundary energy contribution into the total energy of the polycrystalline film. This contribution is determined by the mean grain size, which in its turn depends on the conditions of films production.

In this paper, we present the results of the internal size effect investigation in Pb films with different mean grain size. The samples were formed on the prolonged glass or Al_2O_3 substrates with pre-deposited amorphous carbon layer. To produce samples with different grain size the substrate temperature was varied in the range 150–400 K during the condensation of Pb. It enabled us to obtain Pb film samples with a grain size of 2–12 microns. It can be seen on Fig. that the width of the melting area increases with the mean grain size reduction. Such evolution is well described by a hyperbolic dependence, which follows from the triple junction model. Using obtained data, we determined the mean grain-boundary energy value, which was estimated to be 230 mJ/m^2. This value is constant at all sizes studied.