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Relaxation resistance of copper films strengthened with molybdenum nanoparticles

A.I.Il'insky, S.I.Lyabuk, A.I.Zubkov

National Technical University "Kharkiv Polytechnical Institute",
21 Frunze St., 61002 Kharkiv, Ukraine

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Cu–Mo (1 % vol.) films deposited in vacuum have been examined using transmission electron microscopy, active tension, and stress relaxation in the as-prepared and annealed (900°C) state. The high-strength film structure presents a submicrocrystalline Cu matrix with nanosize particles of Mo. Annealing during different periods (up to 10 h) results in the particle average size growing from 10 to 35 nm manifesting itself as a sharp drop of strength and non-monotonous variation of relaxation resistance. The last effect is explained by competitive effect of grain-boundary source of dislocations and interphase one.

Пленки композита Cu–Mo (1 об.%), полученные вакуумным осаждением, исследованы методами просвечивающей электронной микроскопии, активного растяжения и релаксации напряжений в исходном и отраженном (900°C) состояниях. Структура высокопрочных пленок представляет собой субмикрокристаллическую матрицу Cu с нанодисперсными частицами Mo. Отжиг различной длительности (до 10 час.) приводит к увеличению среднего размера частиц от 10 до 35 нм, что проявляется в резком снижении прочности и немонотонном изменении релаксационной стойкости. Последний эффект объясняется конкурирующим влиянием зернограничного и межфазного источников дислокаций.

Novel materials in the form of films and coatings obtained using the PVD technique present very good functional properties and are of considerable interest in instrument building, electronics, and precision machine building [1]. It is just submicrocrystalline composites with nanosize particles of high-melting strengthening phase that are of especially good prospects due to combination of unique mechanical properties (strength, plasticity) and physical ones (electric and heat conductance). The practical application of such non-equilibrium systems is hindered by their dimensional instability due to relaxation processes under temperature action, residual and operating stresses [2].

The purpose of this work was to study the effect of dispersed Mo particles on the relaxation resistance of PVD-manufactured Cu–Mo films. The samples of 25±5 μm thickness contained about 1 % (vol.) of molybdenum. The tension and stress relaxation assays were done using a rigid type universal machine TIRAtest-2300. The structure was studied using an EM-100l electron microscope [3, 4]. The stress relaxation curves were recorded after the active tension was over at the stress level corresponding to the yield limit σ_0. The permanent set did not exceed 0.1 %.

The as-deposited composites show a biphase structure consisting of a submicrocrystalline matrix with grain size about 1 μm and nanodispersed Mo particles of about 10 nm size (Fig. 1a). Such a structure defines extremely high strength characteristics. So, the yield limit σ_0 amounts about 0.6 GPa. To study the Mo particle dispersity, annealing in vacuum at 900°C for 2, 5, and 10 h was used. This heat treatment results in an increase of the average particle size by a factor of 3.5 while