CRYSTALS GROWTH IN AMORPHOUS FILMS OF Ta_2O_5

A. Bagmut[1], I. Bagmut[1], G. Nikolaychuk[1], N. Resnik[1], A. Taran[2]
[1]National Technical University «Kharkiv Polytechnic Institute», Kharkiv
[2]National Science Center «Kharkiv Institute of Physics and Technology», Kharkiv

Amorphous films are formed on substrates at room temperature in the process of pulsed laser sputtering of rotary Ta target in oxygen atmosphere. Electron beam irradiation causes their crystallization with the formation of Ta_2O_5 crystals with hexagonal lattice. Electron microscopic investigation, including "in situ" and video recording methods, revealed the following crystallization modes in different regions of the same amorphous film of Ta_2O_5.

1. Layer polymorphous crystallization (LPC). In the studied area of the amorphous film, a single crystal nucleates and grows. In this case time dependence of the crystal diameter $D \sim t$, time dependence of the fraction of the crystalline phase $x \sim t^2$ and the relative length $\delta_0 \approx 3659$. In the case of (001) Ta_2O_5 the relative length is the number of cell parameters a_0, stacked at the distance, equal to the characteristic unit of length D_0. A similar situation took place during LPC of amorphous films of Cr_2O_3, where $\delta_0 \approx 3107$ and of V_2O_3, where $\delta_0 \approx 4553$ [1 - 4].

2. Interjacent character of crystallization is characterized by the nucleation and growth of several (3-4) disoriented crystals. Each crystal grows at the constant rate until it touches with the neighbouring crystal. The dependence x(t) can be successfully approximated by the polynomial of the third power. The relative length $\delta_0 \approx 1783$. The resulting number is close enough to $\delta_0 \approx 1030$ for IPC of Yb_2O_2S [3].

3. Island polymorphous crystallization (IPC) mode. At the influence of the electron beam irradiation in amorphous film, a great number of disoriented crystals nucleate and grow. The dependence on time of the crystallization centres density is described by the curve with saturation, which is achieved at $N_s \approx 1.67 \cdot 10^9$ cm^{-2}. Time dependence of the average crystal diameter $\langle D \rangle \sim t$. The relative length $\delta_0 \approx 416$. The dependence of the fraction of the crystalline phase x on time t has the exponential character, described by the JMAK formula with the reaction order k = 1.7 and the effective rate constant n = 0.4 $s^{-1.7}$. A similar formula described the IPC of amorphous ZrO_2 film, where $\delta_0 \approx 118$ [2]. According to [5] when k = 1.5-1.8, the crystallization processes correspond to the grain growth with the nucleation and with the decreasing of the nucleation rate. This is the situation, which is realized in our case of crystallization of amorphous film of Ta_2O_5. The crystallization process ends with the formation of the polycrystalline film.

Reference:

[1] Bagmut A., Func. Mater., 26, 6 (2019).
[2] Bagmut A., Phys. Solid State, 59, 1225 (2017).
[3] Bagmut A., Bagmut I.A., J. Non-Cryst. Solids, 547, 120286 (2020).
[4] Bagmut A., Func. Mater., 29, 52 (2022).
[5] Ohshima N., J. Appl. Phys. 79, 8357 (1996).