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On the Dependence of the Deposition Rate on the Structure of Magnetron-sputtered Alumina Thin Films

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Normally, synthesis of magnetron-sputtered thin films with properties suited for specific applications is carried out by variation of the deposition parameters. In this optimization procedure, the deposition rate is not taken into account. In the present study, reactively magnetron-sputtered alumina films were deposited at a fixed cathode power and substrate bias, while the cathode voltage was varied in order to control the deposition rate. As observed with X-ray diffraction, an increase in deposition rate leads to changes in the observed nanocrystalline and amorphous phases. As a rule-of-thumb, an amorphous structure appears when the time required for a deposited atom to find an equilibrium position is larger than the time it takes to deposit a monolayer. Two series of depositions with substrate temperatures of 150 ^{o}C and 530 ^{o}C were carried out. The 150 ^{o}C-films were all X-ray amorphous with a constant hardness (measured by nanoindentation) and density (measured by X-ray reflection). In the 530 ^{o}C-films, at low deposition rates, nanocrystals embedded in an amorphous matrix were observed. With increasing deposition rate the hardness decreased, corresponding to an increase of the amorphous phase. Eventually, only fully X-ray amorphous films were observed – with hardness values and densities higher than the corresponding values belonging to the amorphous 150 ^{o}C-films. These differences in hardness and density suggest that the amorphous 530 ^{o}C-films are closer to (if not being in) the metastable equilibrium than the 150 ^{o}C-films. With a further increase of the deposition rate, the hardness and the density of the 530 ^{o}C-films decreased even further, indicating an additional increase in the Gibbs free energy.

Keywords
Hardness
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