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Influence of ion-plasma sputtering conditions and mechanical stresses on the Bi and Ni films structure

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Non-equilibrium structure obtained by ion-plasma sputtering with an effective cooling rate of 10^{12}-10^{14} K/s have unique physical properties which explains the interest in their research.

X-ray analysis showed that with increasing the deposited atom energy from 20 to 200 eV there was a mixture of nanocrystalline rhombohedral Bi phase (a = 0.47459 nm, α = 57,237 °), metastable bcc-Bi (a = 0.3795 nm), which is formed only at high pressure (~ 7.74 GPa), and α-modified Bi_2O_3 phase with monoclinic lattice, which is responsible for the hysteresis properties in the original Bi films. Ni films phase analysis showed that the reduction of deposited atom energy from 100 to 20 eV has led to the nanocrystalline fcc β-Ni, α-NiO, and metastable of hcp α-Ni phase formation. Moreover, almost double increase of deposition rate leads to an increase of the size of coherent-scattering regions on ~20%. It is shown that activation energy (E_A) calculated by the method of Kissinger in the case of disintegration of HCP Ni exceeds E_A of beginning of recrystallization almost in three times and reaches ~21000 K. In addition, it is shown that increase of deposition rate brings the rise of activation energy of beginning recrystallization (from $5{,}310^3$ to 1210^3 K) and indicates the formation of more stable structure in the films. In both cases, the films heating to 750 K leads to the metastable bcc-Bi and hcp-Ni phases disintegration on rhombohedral Bi and fcc-Ni respectively.

For the calculation of the metal films elastic stress, which arise due to the difference of thermal expansion coefficients of the film/substrate used the model in the approximation of a two-layer structure for the semiconductor films.

Using the obtained data it was found that the formation of non-equilibrium Bi phase, which is formed, as noted, only at high pressure, can be explained by the high cooling rate and high mechanical stress levels between the film and the substrate (σ ~ 0.3 – 0.4 MPa).

Thus, an increased deposited atoms energy level (~ 200 eV) during the Bi films deposition and elastic mechanical stress lead to the formation of a metastable Bi phase at atmospheric pressure.