THE INITIAL STAGE OF GROWTH OF GOLD AND COBALT THIN FILMS OBTAINED BY ION BEAM SPUTTER TECHNIQUE

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As is known, the process of film nucleation on a substrate surface starts on a nanodimensional level and is not necessarily continuous. For this reason, the properties of films with thicknesses in the nanometer range are determined to a considerable extent by peculiarities of the initial deposition stage. The knowledge of the initial deposition stage is especially important for obtaining films with the properties required for particular practical applications.

The gold and cobalt films were prepared using the ion beam sputter deposition technique. Targets were sputtered by a beam of argon ions with an energy of 0,8 keV (for gold) and 1,2 keV (for cobalt). The targets were a plate of gold and cobalt with a purity of no less than 99,99 %. The residual vacuum in the working chamber was below 10^{-3} Pa, and working pressure during deposition did not exceed 10^{-2} Pa. The flux of gold atoms sputtered from the target was deposited onto the surface glass substrates smooth on a subnanometer level and onto Si(001) substrates with nanodimensional inhomogeneities in the form of germanium atomic islands; atoms of cobalt was deposited onto the surface of substrates of thermally oxidized Si(100). Cobalt films were covered by gold films in a uniform vacuum cycle with thickness up to 1,5 nm. Average speeds of sedimentation: gold - 0,9 Å/s, cobalt - 0,5 Å/s.

The surfaces of the initial substrates and deposited films were studied using the Femtoscan-001 atomic force microscope (AFM). A sample surface area of up to 5×5 μm was scanned in a contact mode with a silicon cantilever of the CSC 12 type (www.spmtips.com). The surface resistance ρ_s of prepared films were determined by the four-point-probe technique. The optical transmission spectra of the some samples were measured on the Hitachi-340 spectrophotometer.

Figure 1 shows the typical AFM images of a silicon substrate with germanium nanoislands before (a) and after (b-d) gold deposition for a certain period of time: 10 (b), 15 (c) and 20 s (d). An analysis of the AFM images shows that the surface of such plates contains nanoislands of two types: large (dome-shaped) and small (pyramidal), spaced by island-free surface areas smooth on a subnanometer level. Large dome-shaped island have a height of about 12 nm and an average lateral size about 62 nm (full width at half-height).

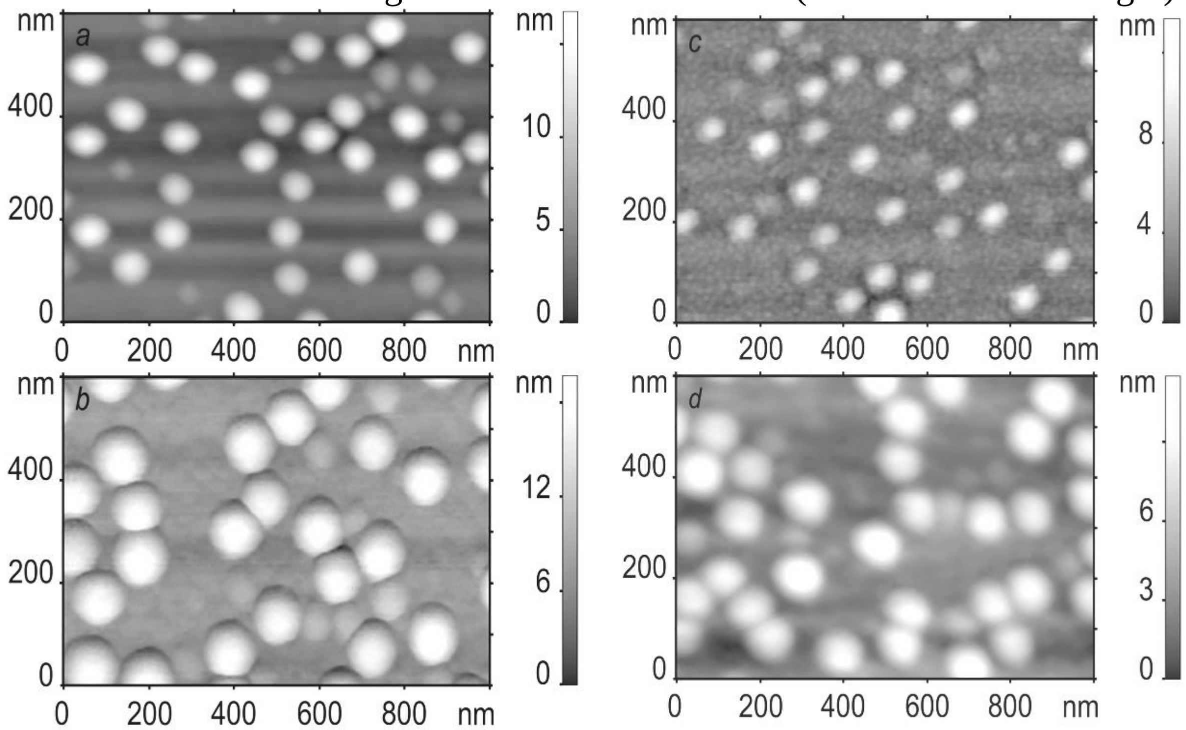


Fig. 1. Typical AFM images of a silicon substrate with germanium nanoisland before (a) and after (b-d) gold deposition for 10 (b), 15 (c) and 20 s (d).

The lateral size and height distributions of small pyramidal islands reveal two groups: first, with an average lateral size of 35 nm and a height of about 2 nm and second, with these dimensions of 45 and 4,5 nm respectively.

After ion beam sputter deposition of gold for 10 s, the height of the dome-shaped islands on silicon decreases to 10 nm while their average lateral size increases to 88 nm (Fig. l b). Analogous changes are observed for the pyramidal islands. The island-free substrate surface becomes more rough than the initial one, but the size of inhomogeneities does not exceed 1,5 nm. The surface of a glass substrate after 10 s deposition acquires blue color, surface resistivity of 1,8-2 kΩ/□ and a transmission on a level of 85% (Fig.2*, curve 1*).

When the time of continuous gold deposition is increased to 15 s, the silicon substrate appears as uniformly covered with small roughnesses with a height up to 3 nm and a lateral size within 10-25 nm over the entire area, except for the apices of dome-shaped islands, the heights and lateral dimensions of which decrease to 7 and 48 nm respectively

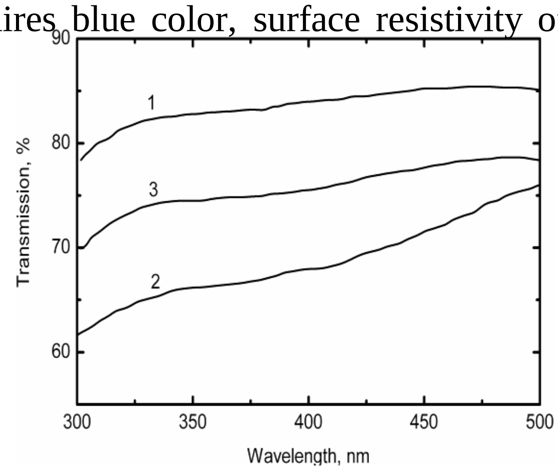


Fig. 2. Optical transmassion of gold films deposited for 10 (1), 15 (2) and 20 s (3) onto glass substrates

(Fig. 1c). The inhomogeneities are electrically insulated from one another: the surface resistance of such film on a glass substrate exceeds 10 kΩ/□. Gold films on a glass substrate upon a 15 s deposition exhibit gray color and a transparency below 75 % (Fig.2, *curve 2*).

After continuous deposition of gold for 20 s, the areas between islands on silicon substrates again appears smooth. The dome-shaped islands are still decreased in height (relative to the initial value) on the average to 7,4 nm, their average lateral size increases to 90 nm (Fig. 1d). The gold film upon a 20 s deposition on a glass substrate have a surface resistance of 350-400 Ω/□, posses a deep blue color and a transmission on a level of 80 % (Fig. 2, *curve 3*). Further increase in the time of continuous disposition leads to a decrease in the height of dome-shaped islands on silicon substrates, spreading of their lateral dimensions, and merging of these islands together. The corresponding coatings on glass substrates acquire a yellow tint and the surface resistance decreases below 100 Ω/□.

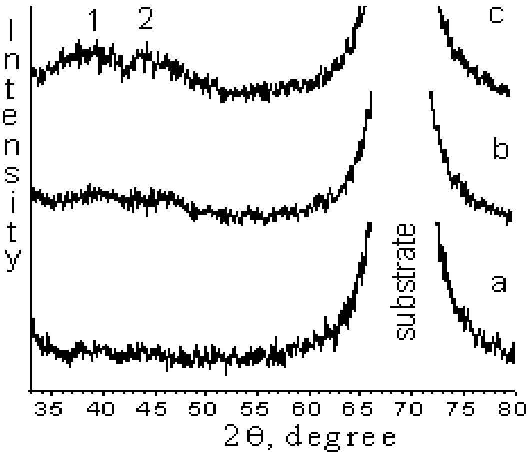
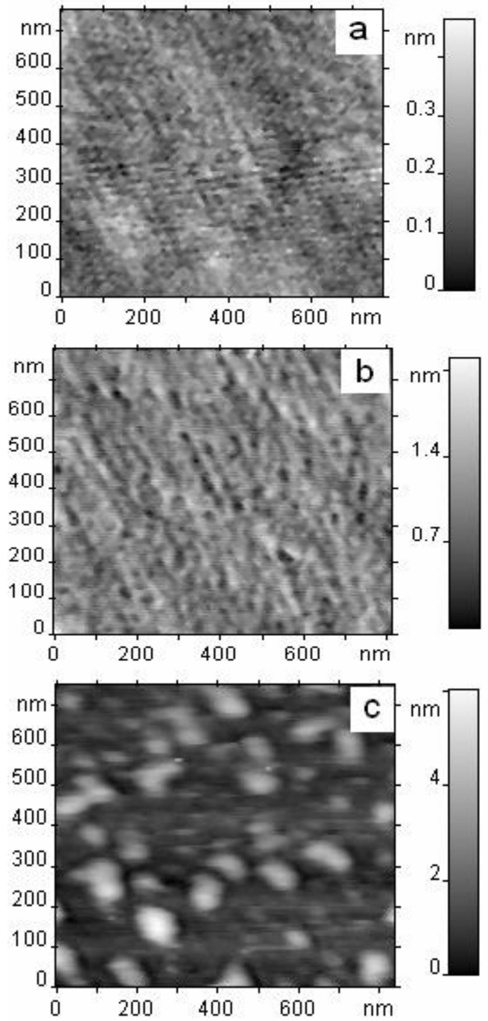


Fig. 3. The conventional roentgenograms cobalt films deposition for 80 (a), 120 (b) and 240 s (c).

The structure of the received cobalt films were defined by the X-ray diffraction with using of radiation - CuK_{α} (Fig. 3). Unfortunately, X-ray diffraction analysis didn't give the complete picture for definition of structure cobalt films. However in process of growth of cobalt films were observed increase intensity of two widened peaks (noted *1* and *2*). The peak *1* corresponds steady α-chemical modification with hexagonal close packed (hcp) grid, while peak *2* - unstable (β-chemical modification with face centred cubic (fcc) grid. Last circumstance speaks us on presence α- and β-phases in received cobalt films.



The surface of silicon substrate and deposited cobalt films show on figure 4. The findings show that cobalt deposition initially leads to the formation of a stable layer with a thickness of several atomic monolayers.

The cobalt films with thickness above 2...3 nm are continuous and homogeneous. Terminated in an intermediate stage, the sputter deposition of cobalt may result in the formation of an inhomogeneous layer of the island type. It also specify surface resistance - time of sedimentation relationship (Fig. 5). The inhomogeneities are electrically insulated from one another: the surface resistance of such film on a silicon substrate ~ 380 Ω/□.

Temperature dependences of specific magnetization of cobalt films σ = f(T) were measured in a nonuniform magnetic field 0,86 Tl (Fig. 6). Specific magnetization cobalt films noticeably increases in process of growth of cobalt films. At an initial stage of interruption the ion beam sputter deposition process σ differs in 6...8 times from the value of massive analogue. The stage of granulation was characterized by step function. The cobalt films have specific magnetization close to values of massive analogue when they are deposited more than 120 s.

These results show that by terminating the ion beam sputter deposition of gold or cobalt initially leads to the formation of a continuous film with a thickness up to 3-4 atomic monolayers. This film remains stable if the deposition process is terminated. Thicker coatings may separate, upon termination of the deposition process, into isolated islands with a height up to 3 nm (for gold) or up to 6 nm (for cobalt). No such island formation is observed and the gold and cobalt coating appears as a continuous film if the continuous deposition time increases and the deposit thickness is comparable with or greater than the height of these islands.

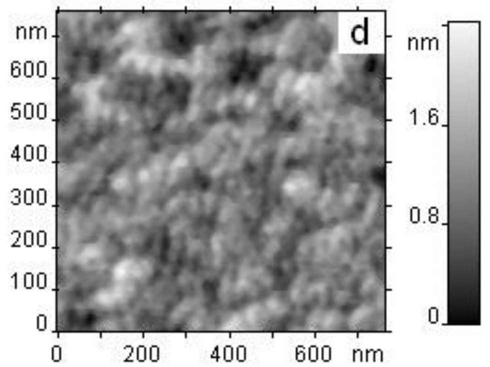


Fig. 4. AFM images of a silicon substrate before (a) and after (b-d) gold deposition for 15 (b), 20 (c) 100 s (d).

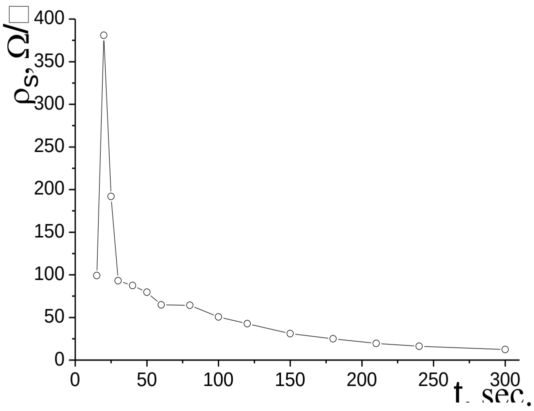


Fig. 5 Time of simicondaction of surface resistance cobalf films.

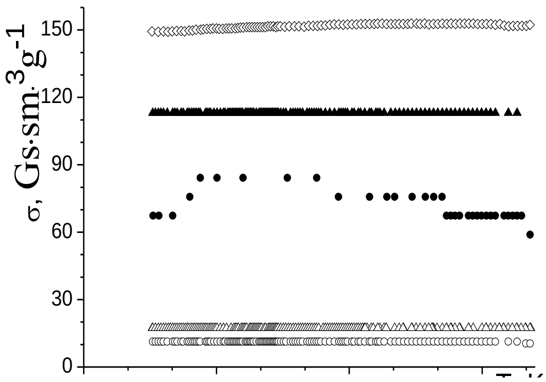


Fig. 6 Temperature dependences of specific magnetization cobalt deposition for ○-15, Δ-30, ●-60, ▲-120 s and ◊-plate of cobalt.