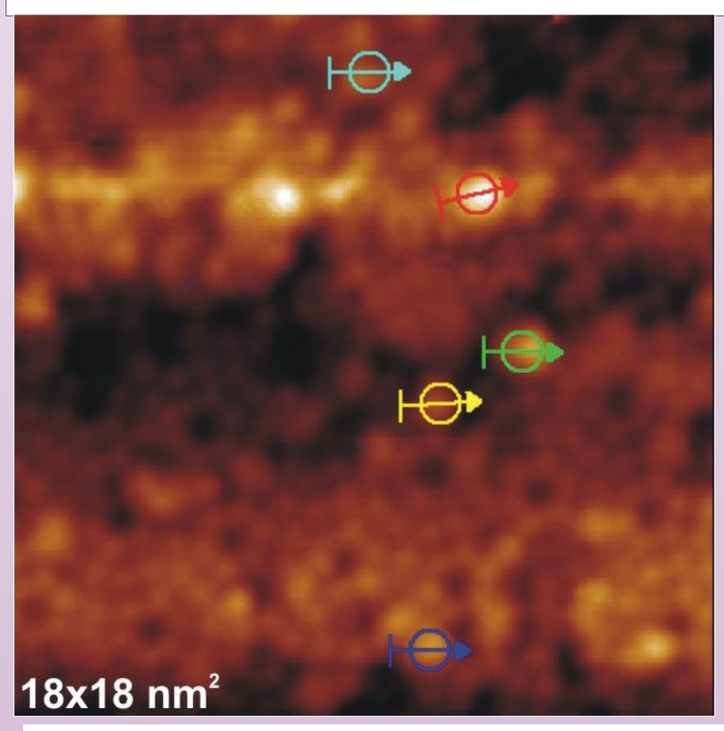
Smolyak S.S., Karbivskyy V.L.,
Karbivska L.I., Shvachko N.K.

Ni nanostructures on semiconductor surfaces

G. V. Kurdyumov Institute for Metal Physics of the N.A.S. of Ukraine

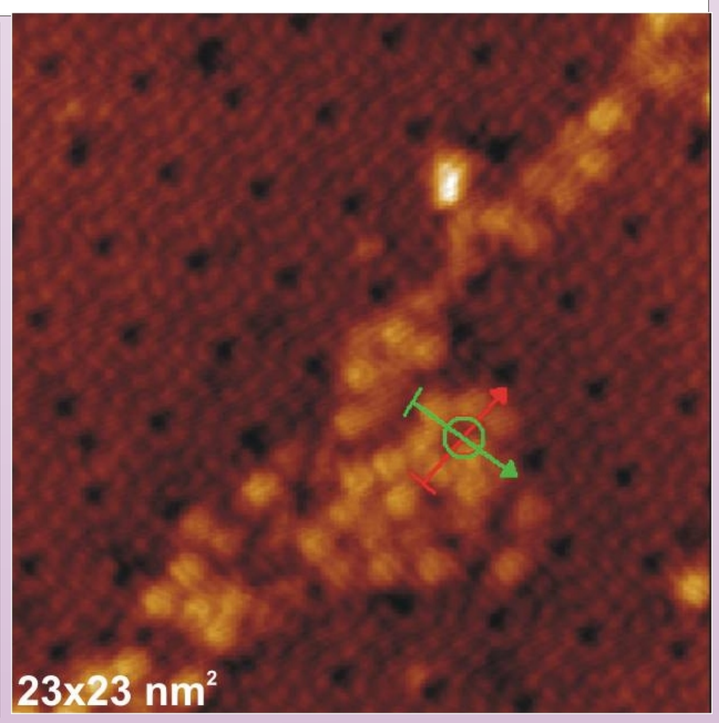
The formation mechanism of nickel nanorelief on the silicon surface (plane-111) during thermal evaporation in vacuum was investigated (all images on JSPM-4500 tunneling microscope were acquired in constant current mode). After the first deposition cycle (1 sec.), nickel forms islands with a height of about 0.11 nm (fig. 1). After increasing the application time to three seconds, a percolation effect is observed, in this case, nickel nanoparticles completely cover the silicon substrate, which corresponds to 4 - 5 metal monolayers.

It was found that nanoformations have a nearly spherical shape and form clusters consisting of approximately 5 - 10 nickel nanoparticles. This shape is typical for liquid metal droplets, which flatten on impact with the substrate. With an increase in the deposition time to 5 sec., an almost twofold increase in the height of nanoparticles is observed, while the longitudinal and transverse dimensions remain almost unchanged. A significant interaction of Ni nanostructures with the substrate was found.



After significant heating of the surface, partial desorption of Ni is observed (fig. 2). The nanostructures obtained after thermal loading form an intermediate $NiSi_2$ phase.

In general, the formation of transition metal silicides on single-crystal surface is an important problem for microelectronics. Among the many interesting technological properties, one can note their importance in connection with the formation of a silicon-silicide phase boundary in a Schottky contact [1].



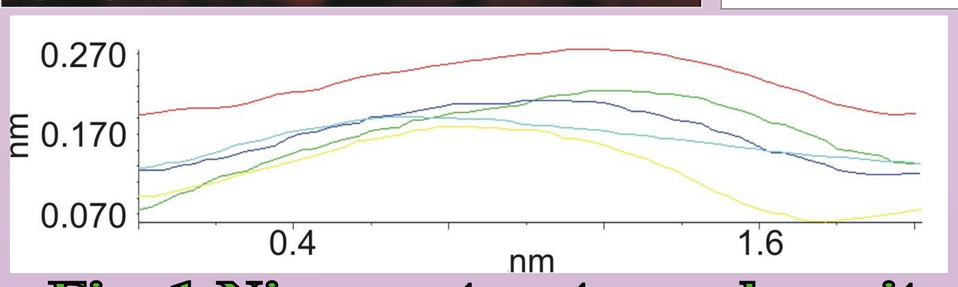


Fig. 1.Ni nanostructures deposited for 1 sec. On the Si (111) surface

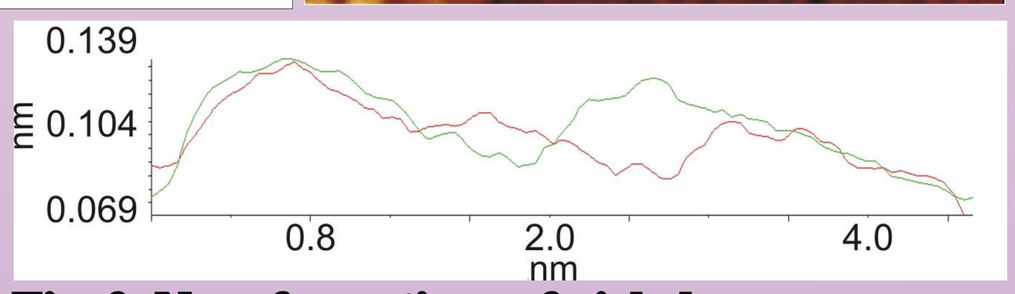


Fig. 2. Nanoformations of nickel on Si (111) at T=1150 °C.

One of the important characteristics in the analysis of surface-applied nanostructures is sub-roughness, which refers to the coating nano-geometry and determines its important performance properties, in particular wear resistance, strength, chemical resistance and other properties. Sub-roughness is determined using precision techniques and research tools such as atomic resolution scanning probe microscopy. The nature of sub-roughness is determined by the internal structure of the solid, its defects and the processes of interaction of the surface with the environment. As a result of an increase in the deposition time, the parameters of the initial sub-roughness can change as a result of relaxation processes in the structure, which is accompanied by the processes of growth and transformation of clusters. In this case, the elements are segregated to the surface, changing the electronic structure and properties of the surface.

CONCLUSIONS

The parameters of sub-roughness (R_a, R_q, R_{zjis}, R_z, S_{ratio}) for coated surfaces and their dependence on the technological parameters of application have been established. It is shown that there is an increase in the size of clusters with the general preservation of the tendency for an increase in the maximum difference between the peaks and valleys at ten points.

Nickel on the surface of silicon forms stable chemical complexes $NiSi_2$ of spherical shape, which are characterized by a monomodal distribution in size with an average diameter of 1.0 nm.

The linear ordering of spherical clusters is determined by the presence of twinning boundaries.

REFERENCE

1. W.R. Lambrecht, N.E. Christensen, and P. Blochl. Electronic structure and properties of $NiSi_2$ and $CoSi_2$ in the fluorite and adamantane structures // Phys. Rev. B.- 1987.-36, No. 5.-P. 2493-2503.