Surface modification by metal ion implantation forming metallic nanoparticles in insulating matrix.

Ripples, Nano-Fabrication

Surface modification by metal ion implantation forming metallic nanoparticles in insulating matrix

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There is special interest in the incorporation of metallic nanoparticles in a surrounding dielectric matrix for obtaining composites with desirable characteristics such as for surface plasmon resonance, which can be used in photonics and sensing, and controlled surface electrical conductivity. We investigated nanocomposites produced through metallic ion implantation in insulating substrate, where the implanted metal self-assembles into nanoparticles. During the implantation, the excess of metal atom concentration above the solubility limit leads to nucleation and growth of metal nanoparticles, driven by the temperature and temperature gradients within the implanted sample including the beam-induced thermal characteristics. The nanoparticles nucleate near the maximum of the implantation depth profile (projected range), that can be estimated by computer simulation using the TRIDYN. This is a Monte Carlo simulation program based on the TRIM (Transport and Range of Ions in Matter) code that takes into account compositional changes in the substrate due to two factors: previously implanted dopant atoms, and sputtering of the substrate surface. Our study suggests that the nanoparticles form a bidimentional array buried few nanometers below the substrate surface. More specifically we have studied Au/PMMA (polymethylmethacrylate), Pt/PMMA, Ti/alumina and Au/alumina systems. Transmission electron microscopy of the implanted samples showed the metallic nanoparticles formed in the insulating matrix. The nanocomposites were characterized by measuring the resistivity of the composite layer as function of the dose implanted. These experimental results were compared with a model based on percolation theory, in which electron transport through the composite is explained by conduction through a random resistor network formed by the metallic nanoparticles. Excellent agreement was found between the experimental results and the predictions of the theory. It was possible to conclude, in all cases, that the conductivity process is due only to percolation (when the conducting elements are in geometric contact) and that the contribution from tunneling conduction is negligible.