Electroless Deposition of Thin Films and Metallization of Nanoparticles

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There was developed the technology of electroless metallization enabling us to replace adequately Au and Ag with Ni-P or Ni-B alloys in industry and to simplify significantly the metallization process. Other proposed nanotechnologies for the first time allow one to produce photomasks and microdevices with nano-sized adjacent elements.

For development of the optimum technology, we improved the entire cycle of the metallization process: the preliminary treatment of various substrates (sensitization and activation), the composition of solutions and the parameters of electroless deposition, the parameters of heat treatment after deposition, the conditions of photolithography, the selective etching processes, etc.

Reactions of decomposition of hypophosphite and electroless reduction of nickel ions are represented by equations:

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 O   O-            O    O-           O   O-
   \\ /              \\ /              \\ /
    P +OH-H+cat→ P +H-ad+H+cat→P+H + e + H+
   /  \              /  \             /  \
 H    H            H  O-H           H   O-H        (1)
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$H_2PO_2^- + e \rightarrow P + 2\ OH^-$ (2)

$Ni\ (II) + 2e \rightarrow Ni$ (3)

$H + e + H^+ \rightarrow H_2$ (4)

$Ni^{2+} + 2H_2PO_2^- + 2H_2O = Ni + 2H_2PO_3^- + H_2 + 2H^+$ (5)

There were developed methods of fabricating the ultra-thin void-free and pore-free electroless coatings on micro-, meso- and nano-sized particles (carbides, borides, nitrides, oxides, diamond, graphite, zeolites, etc.). These methods allow us to obtain nanostructured composite materials and coatings with the specified properties, metal-coated fullerences; metallized carbon nanotubes; conductive nano-sized additives to plastics and rubber; nanoparticle-reinforced tires; sensors; detectors of chemical and biological agents; unique catalysts; adsorbents; hydrogen storage materials**,** etc.

The method allows us to vary the electrical, optical, magnetic, mechanical properties and melting points of the coatings in the wide range. The great importance of deposition of void-free and pore-free films on powder-like particles by the proposed method is emphasized also by the fact that the theoretical strength of metals exceeds the strength obtained in practice 100 or even 1000 times. The incorporation of metallized powder-like particles into metals, alloys, ceramics or plastics can significantly increase their strength, microhardness, tribological properties, wear resistance, temperature and radiation stability, and provide dry lubrication. This point is important for powder metallurgy; for increasing the toughness of metals (having high or low electrical resistance and melting points), ceramics and other dielectrics; ecology (in the case of obtaining high-quality adsorbents); civil nuclear techniques (at obtaining getters for ultra-high vacuum); electric-vacuum devices; composites fabrication; power electronics; microelectronics; photonics; machine building, etc.

The developed competitive methods which allow us to substitute palladium chloride with inexpensive non-precious substances for activation both of non-metallic powder-like particles and bulk dielectrics prior to electroless metallization.

A gram of the powder-like particles having the 1 µm diameter contains 10^{12} particles and their total surface area is $150 m^2$. The metallized micro-, meso- and nano-sized particles having the specified catalytic activity and very large specific surface area can be also successfully used for capturing toxic gases and cleaning the environment.

The proposed method of metallization of powder-like particles can be applied for safe transportation and destruction of gunpowder without explosion. The proposed technology can aid in protection against terrorism. Usage of high- strength metals with incorporated metallized particles (composite materials) is promising for production of impenetrable jackets and helmets, reliable boxes for storage of explosives and gunpowder, etc.

The abovementioned specified properties of metallized micro-, meso- and nano-sized particles provide great possibilities of their application in a biomedical field, in medical practice, etc.

The developed method of metallization of diamond particles and bulk graphite (particularly, for production of molds for hot press of metallized diamond) insures high adhesion of coatings to diamond particles and bulk graphite. The proposed method enhances strength and toughness of cutting and drilling instruments. The composites on the basis of metallized diamond exhibit superior abrasion resistance and hardness, and increase lifetime of cutting instruments and drills.

Metallization of diamond particles enhances toughness, thermal stability of diamond and diamod-keeping in matrices of cutting instruments. This is a great problem in prolongation of the lifetime and improvement of the output of diamond-containing cutting and drilling instruments.

The proposed methods of metallization of various materials are widely used at the enterprises of the Commonwealth of Independent States (CIS) for production of quartz resonators and filters (several tens of million items were produced), monolithic piezoquartz filters, photomasks, piezoceramic devices for hydroacoustics and delay lines of colour TV sets (several hundreds of million were produced), casings of integrated circuits and semiconducting devices, ceramic microplates, precise microwire and film resistors and other devices.