Physical Vapor Deposition Techniques in Electrical Contacts in Automotive

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Abstract

Today, there are about 1500 electrical terminals in each automobile. As the electrical content in the automobile increases at a rate of 10 to 15% a year, the demand for reliable, economical, and environmentally benign electrical connectors is expected to grow. To ensure reliable electrical contacts, various coatings are applied to the connectors.

Presently, most connectors used in automobiles are electroplated with tin. as the under-hood space becomes more compact and an increasing number of sensors are mounted close to the engine, the coatings are required to function at 150 C to 200 C in the under hood environment. Electroplated tin coatings fail at these temperatures because of inter diffusion which causes bonding between mating contact surfaces, alloy formation at the Sn-substrate interface, and oxidation of mating surfaces. On the other hand, a gold layer of 1 to 3 um thickness, which has been used successfully in military vehicles for high temperature applications, is considered too expensive for civilian vehicles. Further more, the friction coefficient of tin coatings is high, which can cause difficulties during the assembly of multi-pin connectors. In contrast to the large amount of work for electrical contacts in electronics and computers, research and development efforts for automotive electrical contacts have been few. The growing demands and the harsh environment encountered by electrical connectors in automobiles call for new coating compositions, structures, and, perhaps, new processing techniques.

Although electroplating is used for mass production of tin coated connectors, vapor deposition has been suggested as an alternative method for coating electrical contacts. The advantages of vapor deposition over electroplating are numerous. From a research point of view, vapor deposition can be used to create coating structures and composition which are often either difficult or impossible to make by electroplating, including multilayers, composites, and amorphous alloys of metals and ceramics.

In the microelectronics industry, vapor deposition techniques are standard industrial processes. In non-electronic applications, vapor deposition techniques have been integrated into continuous process lines for coating metal strips, window glass, plastic foils, and automobile parts.

Using vapor deposition as a tool, novel coating structures have been developed for low friction coefficient, fretting wear resistant, and high temperature stable electrical contacts. Thin films of Ag and Ag-Ni nanocrystalline composites between 100- and 500 nm thick were deposited by electron beam evaporation onto sputter cleaned 301 stainless steel substrates. The structure and composition of the films were studied in details using x-ray diffraction (XRD), scattering electron microscopy (SEM), electron probe microanalysis (EPMA), and Auger depth profiling.

The contact properties, such as contact resistance, friction coefficient, fretting wears resistance, and thermal stability of these coating s have been measured. The friction coefficient of the Ag-coated contacts decreased with decreasing film thickness. A low friction coefficient of 0.2 was achieved for the 100-nm thick Ag on 301 steel. This Ag coated contact lasted about 200,000 cycles during fretting wear test. Both then Ag and $Ag_{81}Ni_{19}$ composite

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coatings about 500 nm thick passed the 1000,000-cycle fretting wear test. These coatings also showed good high temperature stability during heat aging at 150 C in air, especially the $Ag_{81}Ni_{19}$ composite coating. This study shows that vapor deposition is a very powerful technique, which can be used to discover new coating compositions and structures for electrical contact applications. The advantages of vapor deposition over tradition plating processes are also discussed.

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