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Effect of pulsed laser parameters on the corrosion limitation for electric connector coatings

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Abstract

Materials used in electrical contact applications are usually constituted of multilayered compounds (e.g.: copper alloy electroplated with a nickel layer and finally by a gold layer). After the electro-deposition, micro-channels and pores within the gold layer allow undesirable corrosion of the underlying protection. In order to modify the gold-coating microstructure, a laser surface treatment was applied. The laser treatment suppressing porosity and smoothing the surface sealed the original open structure as a low roughness allows a good electrical contact. Corrosion tests were carried out in humid synthetic air containing three polluting gases. SEM characterization of cross-sections was performed to estimate the gold melting depth and to observe the modifications of gold structure obtained after laser treatment. The effects of the laser treatment were studied according to different surface parameters (roughness of the substrate and thickness of the gold layer) and different laser parameters (laser wavelength, laser fluence, pulse duration and number of pulses). A thermokinetic model was used to understand the heating and melting mechanism of the multilayered coating to optimize the process in terms of laser wavelength, energy and time of interaction.

Keywords: Excimer laser; Pulsed laser treatment; Atmospheric corrosion; Gold coatings; Heat propagation; Melting process

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1. Introduction

Materials used in electrical contact applications are usually constituted of a copper alloy (brass or bronze) interesting for its excellent electrical conductivity and an inexpensive materials cost. However, a major difficulty in the use of copper contacts is its high reactivity to atmospheric environment. The classical solution is to use a protective coating of noble metals like gold or palladium. In our study, the copper surface is firstly nickel-plated and then protected by a thin gold coating (0.4–1 μm thick). The nickel layer is used as a diffusion barrier between the copper and the gold, and the gold layer is used as a corrosion barrier. The nickel and gold coatings are deposited by an electrochemical process. Electrodeposition of these metals usually leads to columnar structures, which favor the concurrent formation of micro-channels. In addition, the thickness of the gold alloy coatings must be limited to less then 1 μm for economical considerations. In this case, one cannot completely eliminate the influx of corrosion to the substrate [1]. In order to enhance the protective role of the gold coatings, an additional surface treatment must be applied. Two positive effects are desired: reduction of porosity inside the gold thin layer, and smoothing of the surface to achieve a highly reflective surface, an efficient electrical contact, and hence a good product for industry. In this paper a laser heat treatment is tested for this surface modification.

The surface treatment for electrical contacts depends on various restraints closely linked to the manufacturing process. It must be fast and usable in air atmosphere. In considering the multilayer compound at the micron level, one should treat only the gold layer without damaging the nickel sub-layer. Moreover, the surface of the material must be heated to the gold melting temperature (without reaching the boiling one) and the temperature should be lower than the nickel melting. Thus, the process requires a low and controlled penetration depth of the heat wave. Pulsed laser re-melting technology, using a pulsed nanosecond lasers, appears to be a soft and fast alternative method. Furthermore, a desired laser treatment could be achieved in a few pulses, that remains interesting and competitive for industrial applications.

To check the efficiency of our laser treatment, samples were submitted to corrosion tests, microscopy characterization (scanning electron microscopy (SEM), optical microscopy) and chemical analyses (energy dispersive X-ray (EDX), Rutherford backscattering spectroscopy (RBS)) for both treated and untreated samples. In turn, laser parameters were adjusted incrementally until achieving the best improvement in corrosion resistance.

To understand the physics of heat melting, the dynamics of laser interaction were modeled via heat conduction equation with phase change. The simulation deals with thermal data including conductivity and thermal diffusivity. Because the situation is different between bulk and thin film materials, the modeled thermal data were altered with respect to data from the literature to discuss the simulation results. By comparison with cross-sections observed by SEM, realistic values are proposed for thermal data and melting kinetics. These results are shown for gold films with thicknesses from 200 to 800 nm deposited on nickel substrates.