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Electrical properties of contacts covered with multicomponent coatings by the dynamic ion mixing

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Abstract

The paper presents the results of operational characteristics measurements on electrical contacts covered with two-component coatings of Ni + Au, Au + W, Pt + Au and Ni + Ag on copper surfaces. A method of one-beam dynamic ion mixing has been used to deposit those layers. An essential depth redistributing the deposited atoms is revealed by AES spectroscopy. Energy of an electrical arc that formed when the contacts get opened has been determined. It has been found that the coatings reduce mean energy of the arc between contacts from 1.74 J for pure copper down to 1.12 J for a coating of Au + W.

Keywords: Ion beam; Assisted deposition; Metals; Electrical contacts

1. Introduction

Copper and its alloys are the most commonly used material to fabricate contacts in the switchgear for medium power devices. To improve operating conditions of the contacts and increase functional reliability of switches the copper surface is covered with gold, silver or other materials. Among the known methods, ion bean-assisted deposition (IBAD) is a promising technology for layered structure preparation.

For example, titanium and tungsten nitride or carbide films prepared by IBAD on the surface of steal parts greatly improve their wear resistance and corrosion resistance and, hence, extend their service lifetime [1,2]. Recent publications (see, e.g. [3]) have indicated that the structural, tribological, adhesive, and mechanical properties of IBAD films depend to a great extent on ion irradiation conditions (ion energy, ion current density,

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fluence, and target temperature). In particular, the mechanical properties, adhesion to the substrate, and structural perfection of the coatings are appreciably improved if the ion beam density is sufficiently high.

It has been shown that nitrogen ion implantation [4] or IBAD of metal layers [5] results in microhardness increase of copper surfaces as well as it can contribute to the decrease of the electric arc energy and operation temperature of switches [4].

Recently [5,6], we have suggested a novel one-beam IBAD system for the modification of the surfaces of materials. The main feature of this technology is that the in situ implantation of ions and the deposition of layers are performed by the same ion beam. The basic unit of the setup is the target in the form of a truncated cone that is made of a desired material or of any material coated by layer of desired material. This approach allows us to essentially simplify the technology and make the associated equipment less expensive, while retaining the advantage of the IBAD process.

Moreover, the above-mentioned method makes it possible to produce protective coatings of alloys (e.g. nickel–gold, gold–tungsten, platinum–gold, silver–nickel and the like) and to introduce coating atoms deep into the base material to improve the coating—base material interface characteristics.

Therefore, in this paper we concentrate mainly on the deposition of two-component material layers, depth distributions of deposited/implanted atoms as well as results of electric testing the surface layer of copper doped by means of the dynamic ion mixing.

2. Experimental

Taking into consideration the above-mentioned advantage properties of the copper layers with coatings, a study of temperature and arc properties of the switches with contact surfaces modified by dynamic ion mixing has been undertaken.

Key-type switches ($U_n = 230\,V$, $I_n = 10\,A$ of alternating current) were selected for the investigation. In order to determine the effect of various coatings the switches listed below were tested: switches with copper contacts, switches with copper contacts coated with silver by electroplating and switches with two-component coatings deposited by dynamic ion mixing. The latter samples have been modified by depositing the following metals: nickel and gold, gold and tungsten, platinum and gold as well as silver and nickel.

The conical system enabled us to carry out in situ ion implantation and metal layer deposition by the same ion beam was described in Ref. [5]. A diaphragm (with the diameter coincident with that of the sample) in the upper part of the conical system (see Fig. 1 of Ref. [5]) serves to provide one of the possible operating regimes: ion-assisted deposition (without the diaphragm) or deposition of layers (with the diaphragm) with a weak assistance by the scattered on a cone surface ions. Thus, during the ion irradiation of the truncated cone we are dealing with ion implantation, sputtering, and deposition of cone atoms proceedings simultaneously. In our experiments, copper contacts have been screened with the diaphragm to cut off a beam part that directly hits their surfaces causing a partial sputtering of the depositing layer and thus that disadvantageous phenomenon has been reduced.

Ar^+ ions with an energy of 75 keV have been used to sputter the cones. In all the cases the applied ion fluence was $3 \times 10^{17}\,cm^{-2}$. Such cones consist of six equal segments out of which three are made of one material and the three remaining ones of the other. It should be noted that an atomic composition of deposited layers can be controlled by a number and square of the segments mentioned above.

We have used Auger electron spectroscopy (PHI 660 Perkin-Elmer) for obtaining the component distributions over the whole modified structure depth.

The testing duration for each switch was equal to 15,000 switching cycles or up to a failure of the switch. Individual parameters of a switch i.e. temperature and voltage drop were recorded on a computerized stand [7] for 15,000 switching cycles (5000 cycles of cyclic operation + 1500 cycles of continues operation + 5000 cycles of cyclical operation + 1500 cycles of continues operation + 2000 cycles of cooling down).