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INFLUENCE OF IMPURITIES ON CONTACT RESISTANCE OF ELECTRICAL CONTACTS

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Influence of surface cleaning methods on contact materials as well as on the contact resistance of stationary and sliding electrical contacts was investigated. Two cleaning methods were studied: cleaning with fluorochlorohydrogencarbon (FCHC) and low temperature cleaning in reductive plasma. Contact materials for professional electronics were investigated. Dependence of the contact resistance on contact force was measured. All measurements were performed with a computer controlled system, constructed and developed in our laboratory.

1. *Introduction*

Influence of different cleaning methods on the electrical contact resistance of switch and sliding contacts was studied [1–5]. Two materials, of four different forms of the electrical contact were used. AgMg alloy Argelec 180 material was used as a strip on the electrical contact of switch type, while a wire of NiCuZn alloy Niclal 180E was a sliding contact. The first half of the samples was cleaned in FCHC in an ultrasound bath and the second half was cleaned in the hydrogen discharge plasma.

The plasma discharge cleaning has become a widely used method for removing surface impurities. Active particles created in plasma which interacted with surface impurities, could be succesfully removed not only adsorbed, but also chemisorbed. By creating plasma from a mixture of various gases it was possible to remove different kinds of impurities.

For reduction of surface oxide layers, hydrogen or a mixture of a noble gas and hydrogen were used. In the past decade, this method has been widely investigated by many authors. Plasma was created by different means including high frequency discharges, magnetron discharges and high pressure DC discharges. Most authors were interested in cleaning of silver and nickel alloys [6–8]. They showed that impurities can be successfully removed at elevated temperature without changing the surface morphology. Impurities in silver and nickel alloy can be successfully cleaned by the hydrogen plasma treatment [9].

2. *Experimental*

Plasma cleaning was carried out in a vacuum system, consisting of a discharge vessel, a liquid nitrogen cooled trap and a two stage mechanical rotary pump. The base pressure in the system was 10^{-3} mbar. The discharge vessel was a glass cylindrical tube 80 cm long and 4 cm in diameter. Plasma in the discharge vessel was created by an inductively coupled RF generator at the freqency of 27.12 MHz with the maximum output power of 700 W. Plasma parameters were measured with a double Langmuir probe and a catalytic probe. The electron temperature in plasma was 6 ± 1 eV, while the plasma density was a function of the position. Discharge cleaning experiments were carried out at the pressure of 0.5 mbar, when the plasma density was highest. Samples were mounted in the middle of the discharge vessel and treated with hydrogen plasma. Due to the recombination of atomic hydrogen on the sample surface, the absorption of UV light from plasma, and the bombardment of the surface with charged particles, the temperature on the surface reached 150 °C.

The samples for investigation of the contact resistance were Argelec (AgMg) alloys formed into contact strips and Niclal (CuNiZn) wire. Three different contact strips were used in our investigation. The strips were rectangular, of cross–section 4 mm $\times$ 0.2 mm, 1.5 mm $\times$ 0.15 mm and 3.7 mm $\times$ 0.4 mm.

The contact elements were first cleaned in the ultrasound bath in a water detergent mixture in order to remove weakly bonded impurities from the samples. One half of the samples was then treated by hydrogen plasma for 30 minutes. The second half of the samples was treated in the FCHC ultrasound bath.

For the measurements of dependence of the contact resistance on the contact force, a custom made system was developed. The system consists of a PC, KEITHLEY multimeter 195A, analytical balance and vertical linear motion actuator, with a 0.4 micron resolution. The system enables the measurement of the contact resistance for varying contact force with increments of 0.05 cN.

3. *Results and discussion*

The dependence of electrical contact resistance on the contact force for different preparation methods is shown in Figs. 1–4. In each figure, two curves are shown:

one marked with p represents the samples cleaned in plasma and one marked with f represents the samples cleaned in FCHC.

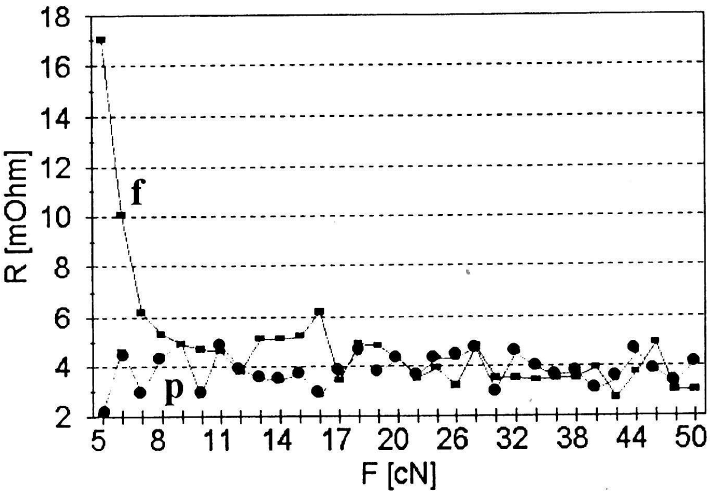

Fig. 1. Dependence of the electrical contact resistance on the contact force for Argelec strip of cross–section 4 mm × 0.2 mm*: f – data after cleaning in the FCHC bath, and p – data after cleaning by plasma discharge.*

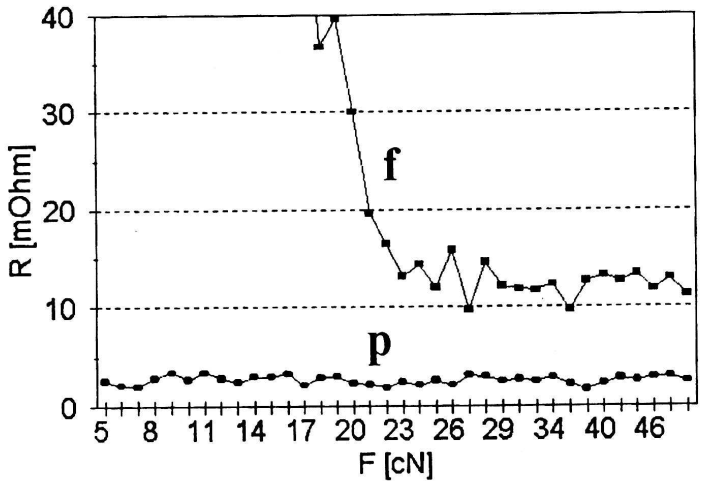

Fig. 2. Dependence of the electrical contact resistance on the contact force for Argelec strip of cross–section 1.5 mm × 0.15 mm*: f – data cleaning in the FCHC bath, and p – data cleaning by plasma discharge.*

Figure 1 shows two curves, boths for Argelec strip of 4 mm × 0.2 mm cross–section. Only a small difference in contact resistance, caused by a large con-

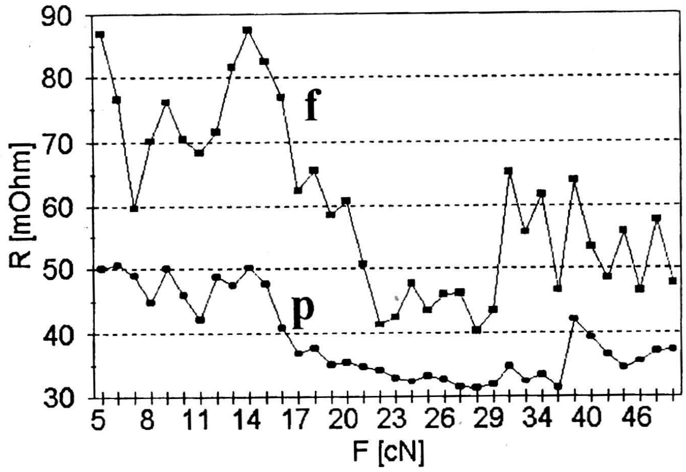

Fig. 3. Dependence of the electrical contact resistance on the contact force for Niclal of 0.2 mm *wire type contact: f – data after cleaning in the FCHC bath, and p – data after cleaning by plasma discharge.*

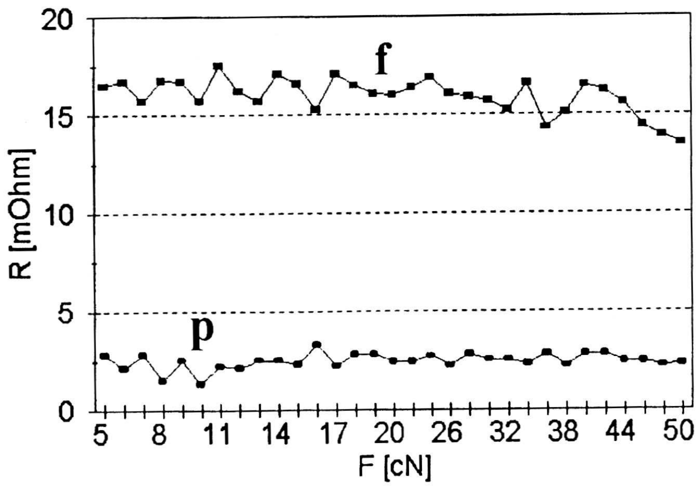

Fig. 4. Dependence of the electrical contact resistance on the contact force for Argelec strip 3.7 mm × 0.4 mm *with semicircle cross–section: f – data after cleaning in the FCHC bath, and p – data after cleaning by plasma discharge.*

tact area and comparable to surface cleanniss can be noticed. In Fig. 2 slighty corroded Argelec strip of 1.5 mm × 0.15 mm cross–section was used. The plasma cleaning showed lower contact resistance, because with this method the thin oxide film was removed from the contact surface. The FCHC cleaning method did not remove the thin oxide film from the surface. Therefore, it is less suitable for cleaning of slighty corroded contact strips. In Fig. 3 results for a wire type contact made from a low cost Niclal of 0.2 mm in diameter was used. There was a considerable contact resistance variation in the sample cleaned in FCHC, caused by insufficiently cleaned oxide film on the contact surface of a variable contact area. Figure 4 shows Argelec strip 3.7 mm $\times$ 0.4 mm with semicircle cross–section. These samples were measured 48 hours after cleaning and showed that "plasma cleaned" contacts maintain their low contact resistance for a longer time.

The results clearly demonstrate that the plasma cleaning is suitable or is even better than the FCHC cleaning.

4. *Conclusion*

The results of our investigation showed that cleaning in low temperature plasma can offer interesting alternative to the standard FCHC cleaning techniques because it is less demaging to the environment. The Montreal Agreement requires a reduction of FCHC consumption in the cleaning and freezing applications and total prohibition in ten years.

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UTJECAJ NEČISTOĆA NA OTPOR ELEKTRIČNIH KONTAKATA

Ispitivane su metode čišćenja površina kontaktnih materijala i kontaktni otpor mirnih i kliznih električnih priključaka za profesionalnu elektroniku. Proučavano je čišćenje fluoroklorougljikovodikom i niskotemperaturno čišćenje u reducirajućoj plazmi. Mjerena je ovisnost kontaktnog otpora o pritisku. Sva su mjerenja načinjena pomoću sustava vođenog računalom, razvijenog u našem laboratoriju.