Nanoscale Particles Modified Gold Plating

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Nanoscale Particles Modified Gold Plating

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Fretting is considered to be one of the major problems that affect the lifetime of electrical connectors. Different phenomena are related to fretting, such as fretting wear, fretting fatigue, fretting corrosion, insulating layer and oxides [1-3]. Among these phenomena corrosion, insulating layer and oxides are basically the direct cause of a major increase in contact resistance. Therefore using metals, which have little or no film-forming tendency, generally known as precious metals, as plating materials should be an effective measure to avoid failures caused by fretting. When using precious metals, one of the limitations to their lifetime is the tribological behaviour of the plating material, particularly the wear resistance. This has been observed by some authors [1, 2]. Gold is one of the most commonly used precious plating materials for high performance connectors. Pure gold is very soft. In order to improve the wear resistance of gold plates, hard gold is usually used. The high degree of hardness is achieved by alloying elements such as cobalt, iron or nickel. However, the effect of alloying elements is limited by the galvanic process and other surface properties, which are also required for electric contacts.

In this paper a new way of the modification of gold plates is investigated. Instead of alloying elements nanoscale particles, mostly metal oxides, are used for the modification of plates. Some of the nanoscale particles show considerable impact on the performance of plates for electric contacts. This paper shows the first results and new challenges when using nanoscale particles for electroplating.

For the wear and fretting corrosion tests an apparatus is used which enables a small and precise displacement of fretting motion at the contact interface (Fig. 1).

A piezoelectrical actuator moving forwards and backwards generates the relative motion between the contacts. The amplitude is adjustable between 1 to 200 µm and the duration of a cycle is adjustable between 0.1 to 10 s. The contact force is provided with a dead load. Different normal forces were applied for the investigation. A closed loop heating system enables tests at high temperature. The contacts are wired for a four-wire resistance measurement. A computer controls the data acquisition system. The lifetime is defined by the number of cycles up to the beginning of the drastic increase of contact resistance. A mobile messaging system sends the operator a short message as soon as a certain limit has been reached. This feature is very useful for different kinds of investigation, for example for the analysis of the state of the contact surface at the moment of an electrical failure [4].

A transmission electron microscope (TEM) combined with an image processing program was used for characterization of nanoscale particles powder. An Ultrafine Particle Analyzer (UPA), which incorporated the Controlled Reference Method (CRM) in a dynamic light scattering instrument, was used to determine the particle size distribution in electrolytes. The wear of the contact area was measured after the wear test with a micro surface explorer, which measured the surface topography with a precision of up to 10 nm. A scanning electron microscope (SEM) with a Focused Ion Beam System (FIB) and an energy-dispersive X-ray spectroscopy (EDX), an X-Ray fluorescence spectrometer and an optical microscope were also used for the material and surface analysis of the gold plating.

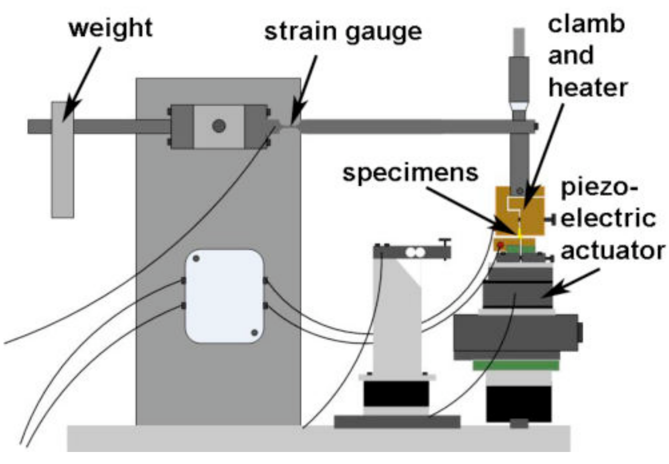

Figure 1: Apparatus for Wear and Fretting Corrosion Tests

The contact springs were stamped. The size and set-up are shown in Fig. 2. The base metal used was phosphor bronze (CuSn).

The coating systems tested in this study were platings with different nanoscale particles modified gold as upper layer with a lower layer (barrier layer) of nickel, which prevents the diffusion between gold and base material. The nanoscale particles used for the investigation were mostly metal oxides. The thickness of gold was between 0.6 and 1 µm. The samples were all electroplated. The mating parts for each test were always coated with the same material.

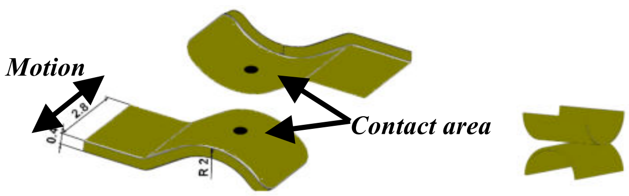

Figure 2: Contact spring

The basic target of our investigation is to increase the lifetime of gold plated electrical contacts. Several criteria can be used to determine the lifetime. The number of cycles to the rapid increase of contact resistance was used as lifetime, since it has the strongest impact on the behaviour of connectors and it is closely related to the wear performance of gold plating, Fig. 3.

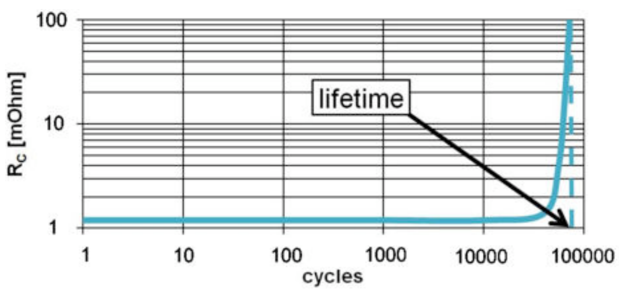

Fig. 3: Increases in contact resistance due to fretting corrosion

Nanoscale particles of different particle size distributions were used for the investigation. Due to agglomeration, the particle size distribution in the electrolytes changed. Much bigger particles were observed in electrolytes (Fig. 4).

The particle size distribution in powder and in electrolytes with a TEM and an Ultrafine Particle Analyzer (UPA) was determined without any difficulty. Finding rapid and affordable methods for the determination of the particle size distribution and the amount of nanoscale particles in the gold plating turned out to be a big challenge. The X-Ray fluorescence spectrometer is only suitable for a rapid and rough control and classification of the thickness and some of the elements in the gold plating. A FIB and SEM combined with EDX are promising ways to do these kinds of analyses. The FIB is especially useful for the analysis of agglomeration of nanoscale particles in the plating (Fig. 5). In the first step the concentration of nanoscale particles in electrolytes was used as a process parameter in the electroplating. The investigation of the correlation between the concentration of nanoscale particles in electrolytes and the amount of nanoscale particles in the gold plating is ongoing.

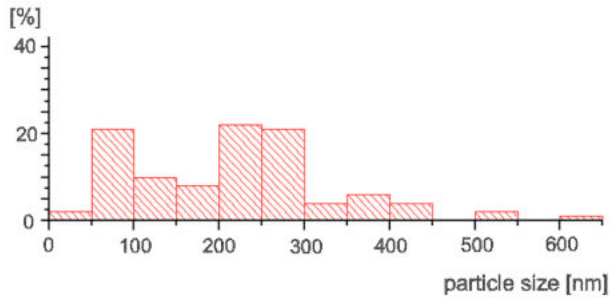

Fig. 4a: Particle size distribution of powder

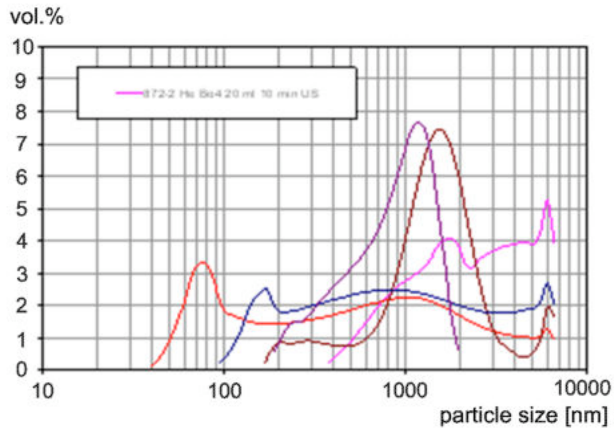

Fig. 4b: Particle size distribution in electrolyte

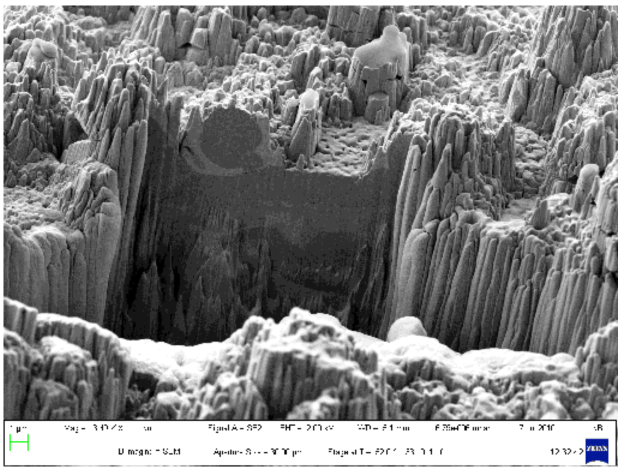

Fig. 5: Agglomeration of nanoscale particles in the plating

The effect of different nanoscale particles on the lifetime of the electrical contacts in the wear and fretting corrosion tests is shown in Fig. 6. The line indicates the typical value for platings with gold alloys, which are most widely used for high performance electric contacts and the doted line shows the typical value for platings with pure gold. The large range of lifetime is not due to a single runaway value. It is verified by numerous measurements. The large range of lifetime shows on the one hand the extensive potential of nanoscale particles modified gold plating, on the other hand the big number of parameters in the process chain from generation of nanoscale particles to the nanoscale particles modified gold platings, which yet have to be investigated and characterized. Among the relevant parameters are particle size distribution in powder, in electrolytes and in plating which is quite different, the amount and distribution of nanoscale particles in the plating which is of special importance.

The specimens with the best results were further investigated with a SEM combined with FIB and EDX analysis and revealed approximately 1.2 % of nanoscale particles in gold plating. The nanoscale particles in the plating were evenly distributed.

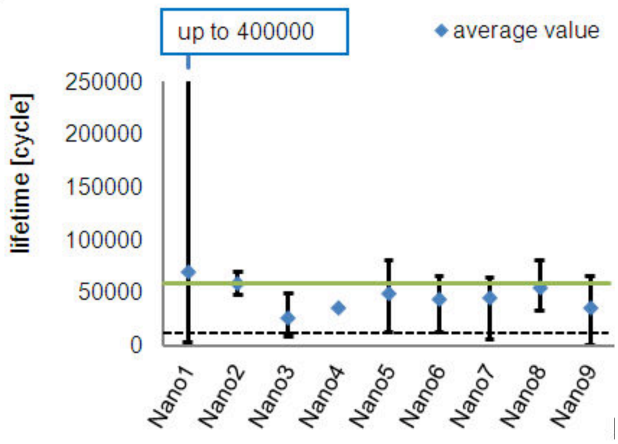

Fig. 6: Effect of different nanoscale particles

A close dependence between wear of gold and wear pattern can be observed at nanoscaled particles modified gold plating, Fig. 7a and 7b.

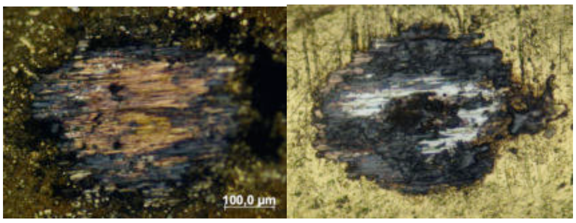

Fig. 7a (left): Microscopy of contact area (average depth of wear crater: 4 µm, contacts survive a 50,000-cycle test, nanoscale particles modified plating of 0.8 µm)
Fig. 7b (right): Microscopy of contact area (average depth of wear crater: 6 µm, contacts fail at 50,000-cycle, nanoscale particles modified plating of 0.8 µm)

Fig. 7 shows the wear area of two specimens after 50,000-cycle tests. The specimen with a low electrical resistance has a much lower wear thus a lot of gold can still be observed after a 50,000-cycle test, Fig. 7a, speaks for a favorable wear pattern. The specimen with a high contact resistance after a 50,000-cycle test has a much higher degree of wear and the contact area is completely covered with nickel of the lower layer and oxide indicated by the dark black color, Fig. 7b.

A favorable wear pattern can be also observed with an energy dispersive X-ray spectroscopy (EDX). In case of a favorable wear pattern, the mapping of gold distribution shows a large amount of gold in the contact area after a long term test, Fig. 8.

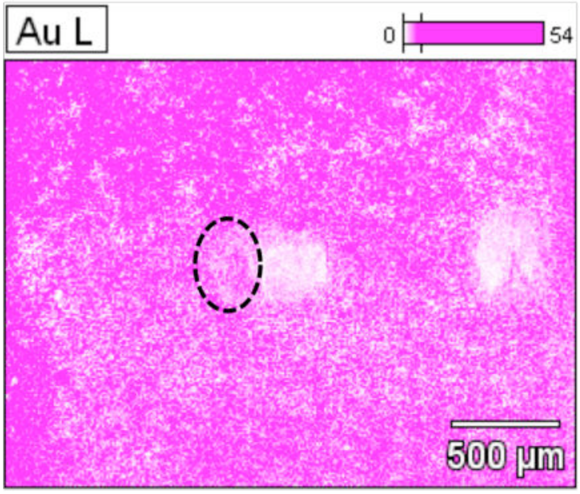

Fig. 8: Mapping of gold in the contact area (cycle of doted line, contact survives a more than 50,000-cycle test)

Our investigation shows that the modification of the gold plating by means of nanoscale particles have a high potential to increase the wear resistance and therefore leading to a large increase in the lifetime of electric contact. A lot of experiments are still to be done in order to find the optimal nanoscale particles for gold plating, to master the electroplating process and the production of nanoscale particles. The key issues of nanoscale particles are particle size distribution and particle distribution in gold plating.

Acknowledgment

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