Tribological Study of nanostructured Aluminium and Al-Based Materials

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Friction is one of the oldest problems in physics and certainly one of the most important from a practical point of view. The ability to produce durable low-friction surfaces and lubricant fluids has become an important factor in the miniaturisation of moving components in many technological devices. These include magnetic storage and recording systems (computer disk heads), miniature motors, and many aerospace components. From the other side, for the development of the small and light drive assemblies aluminium with the superior surface properties becomes a promising candidate.

Surface properties can be improved by structural or/and elemental surface modification. One way is based on the strengthening effect of the grain refinement [1]. It is known, for example, that nanocrystalline Ni electrodeposits exhibited drastically reduced wear rates and lower coefficients of friction as compared to conventional polycrystalline Ni [2]. Another possible way to strengthen the material is based on the formation of multilayers, artificial, man-made periodic arrangements of thin layers of two different materials.

To obtain differently structured materials films in forms of single Al or Al-alloy layers and Al/Me multilayers were deposited on top of Si substrate by electron beam evaporation or magnetron sputtering at different temperatures. It is generally known that both the grain morphology and the developing film structure are sensitive to the environmental impurities been present during the film preparation characterising the applied technology as well as to the applied additives.

In order to get inside of tribological film properties in the nanoscale “NanoTriboscope” (Hysitron) combined with AFM has been applied as a main characterisation tool. ”NanoTriboscope” offer unsurpassed quantitative measurements and/or control of force and displacement. These capabilities is used for investigation of physical material properties and open the door to measurements and testing techniques that provide insight into the fundamental mechanics.

Because of small size of nanocrystalline samples, studies of strength has been confined to hardness measurements. Moreover, well controlled wear tests has been provided where the wear rates and any structural changes has been accurately detected. The scratch test has been used to assess the properties of coated systems since it readily allows the differing dominance of various deformation mechanisms – and the friction response – to be measured as a function of contact severity.

According to Bowden and Tabor [13] the measured friction force may be divided into two components due to adhesion and ploughing. With respect to the tip geometry, the second component of the friction, ploughing, dominates during the scratch test wile tip-surface adhesion forces at ambient conditions has to be measured separately by applying surface force apparatus.

The sistematical study of different samples give the possibility to put a line between film structure, composition, topography on one side and tribological behaviour on the other. As an example Fig.1 shows the scratch made on the Al film with the grain size of 600 nm and RMS-roughness 50 nm (a) and $Al_{94}Cu_4Zn_2$ film with the grain size 30 nm and RMS-roughness 0.5 nm. It has been found that fine structured films exhibit low and homogeneous abrasion.

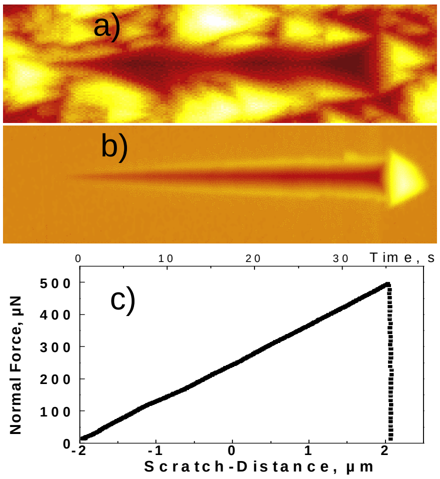

Figure 1. 4 µm long scratch on (a) Al-film sputtered at 300°C and (b) $Al_{94}Cu_4Zn_2$-film sputtered at room temperature. (c) Corresponding measurement parameters: normal force versus scratch distance.

References

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