Application of surface-capped metallic nanoparticles as lubricant additives

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The use of ultrafine particles to improve the performance characteristics of lubricant oils in the form of colloidals suspension is known since 1950s [1]. The effectiveness of the solid lubricant as additives is known to be very much dependant on the particle size. During the last decade, a number of attempts were made to synthesize smaller inorganic nanoparticles, ranging from 5 to 200 nm, with special control of microstructure and composition as a component for liquid lubricants [2]. As example, the tribological properties of surface-capped molybdenum sulphide nanoparticles dispersed or dissolved in hydrocarbon lubricants have exhibited better antifriction and antiwear properties in respect to bulk material. Other important benefit of the addition of nanoparticles to the lubricant is the increment of load-bearing capacity. Under sever contact conditions both fluids and greases are squeezed out from the contact area and consequently do not provide adequate lubrication conditions. One of the main difficulties of using nanoparticles as additives is their dispersion in the lubricant oils. With the surface modification of nanoparticles trough long chain high molecular weight hydrocarbons, more and more inorganic compounds stably dispersed in lubricant oils become feasible [3]. In this work, we report the employment of surface-modified metallic nanoparticles (palladium and gold) with sizes below 5 nm as additive for lubricant oils.

The metallic nanoparticles were synthesised via chemical reduction in the presence of organic surfactants (thiol or alkylammonium chains). Pin-on-disk experiments were carried out using steel counterfaces (AISI M2 disks and 6-mm AISI 52100 balls) and a dispersion of the metallic nanoparticles in paraffin as lubricant. The test parameters were set at 7N of applied load, 10 cm/s of linear speed, and 5 km of sliding distance. Under these conditions the maximum contact Hertzian pressure is estimated to be 1.26 GPa. Simultaneously to the friction coefficient, the electrical resistance of the contact is measured.

Representative images obtained by transmission electron microscopy of the palladium and gold nanoparticles are shown in Fig. 1. The particle sizes and morphology appear rather homogeneous with a mean particle size of 2.2 nm in both cases. The surfactant covering layer was composed of tetraalkylammonium and alkanethiolate chains for Pd and Au cores respectively. Both types of nanoparticles were dispersed in paraffin (5 wt. %) as base oil and tested as lubricant between steel counterfaces. From the beginning of the test, the friction coefficients are situated below 0.1, typically 0.07-0.08, with very small fluctuations (cfs. Figure 2a and 2b). Besides a significant decrease of the contact electrical resistance is observed when using palladium nanoparticles as compared to the resistance measured for the paraffin alone (44.3 kΩ). The observation of the ball scar reveals the presence of a transfer film formed by accumulation of particles during the test. In figure 3 it is shown the ball surface for a test with palladium nanoparticles compared with that obtained with paraffin oil alone (Fig. 3a). The nature of this deposited material is mainly palladium as determined by EDX analysis (Fig. 3c). The built-up of this layer onto the ball surface decreases the shear strength across the interface (f<0.1), accommodates the load, and protects the surfaces against wear (K rate: 10^{-9}-10^{-10} mm^3/N). In addition for the Pd, the resistance of the contact remains low (<1 kΩ) due to the metallic nature of the nanoparticle core what allows its use for the lubrication of electrical contacts [4].

References:

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[3] Chinas-Castillo, F., Spikes, H.A., Tribol. Trans., **43** (2000) 387.
[4] Sanchez-López, J.C. et al. 2005, Spanish Patent Application Nr. 200501040.

Figures:

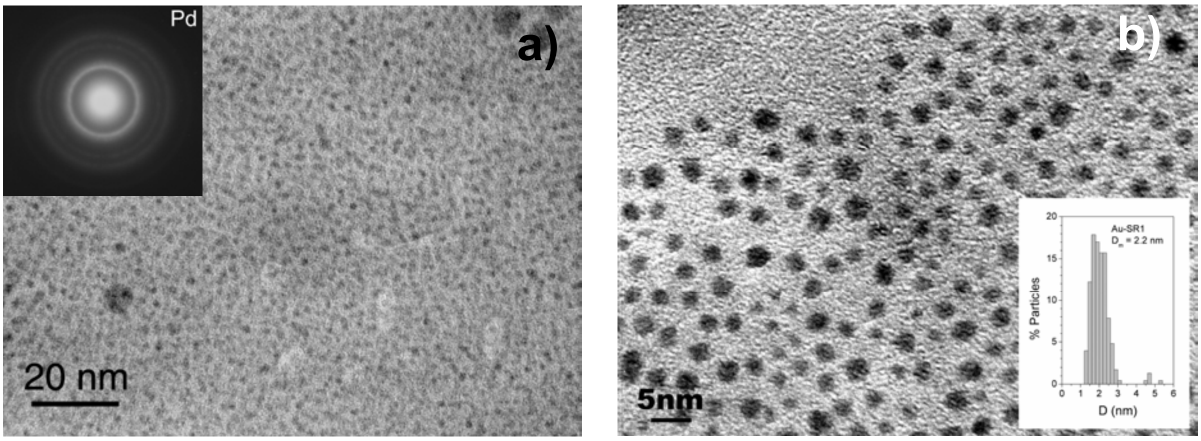

Figure 1. TEM micrographs obtained for the surface-modified metallic nanoparticles: a) alkylammonium-Pd; b) Alkanethiolate-Au.

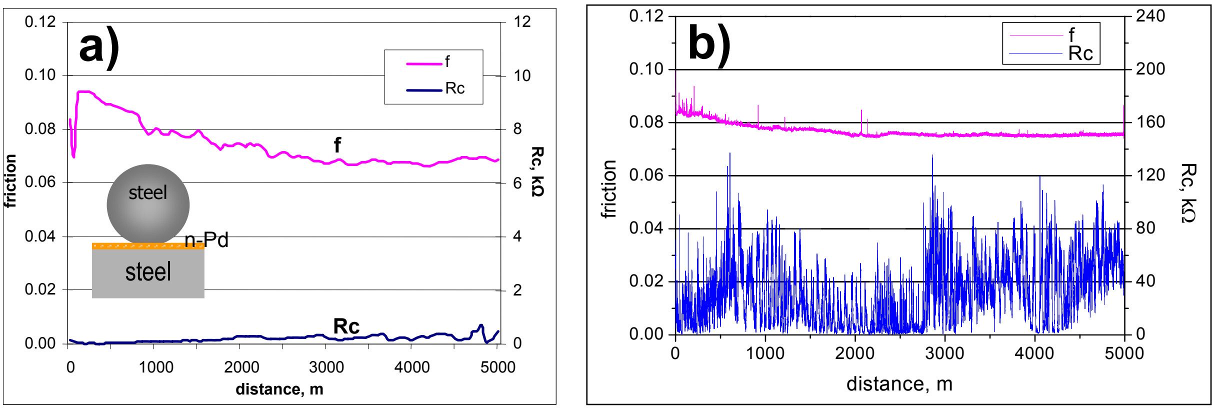

Figure 2. Evolution of the friction coefficient and electrical resistance of the contact for a preparation of nano-Pd (a) and nano-Au (b) in paraffin (5 wt. %).

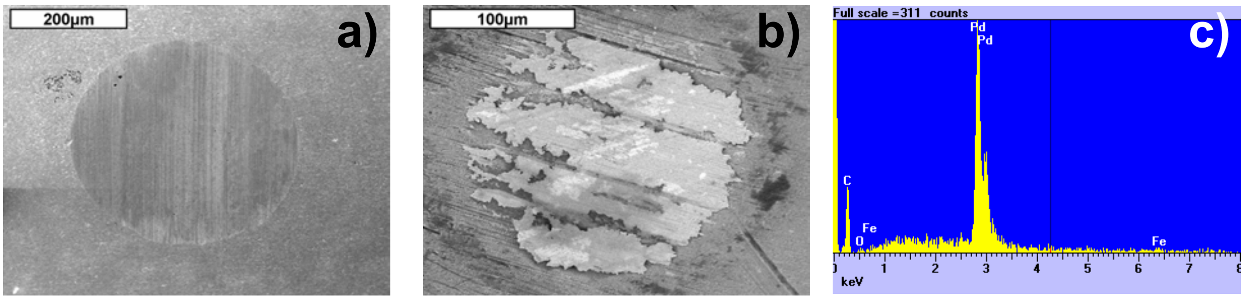

Figure 3. SEM observation of the ball scar after friction test in paraffin oil (a) and 5 wt. % Palladium nanoparticles dispersion (b). The EDX spectrum (c) obtained from the deposited material in (b) is mainly composed of Palladium. No signs of oxidation are put in evidence.