Palladium and gold nanoparticles for anti-wear applications

M.D. Abad, L. Kolodziejczyk, E. Guerrero, A. Fernández, J.C. Sánchez-López
Instituto de Ciencia de Materiales de Sevilla, (Centro Mixto CSIC-Universidad de Sevilla),
Avda. Américo Vespucio 49,41092-Sevilla, Spain
mdavid@icmse.csic.es

The tribological performance of lubricants is favourably altered by adding small amounts of nanoparticles which provides reduced wear and low friction [1]. Other important benefit of the addition of nanoparticles to the lubricant is the increment of load-bearing capacity. Under severe contact conditions both fluids and greases are squeezed out from the contact area and consequently do not provide adequate lubrication conditions. However, one of the main difficulties of using nanoparticles as additives is their dispersion or dissolution in lubricant oils. These base oils are typically of hydrocarbon nature, what provides insulating properties to the dispersion and thus limiting their applicability for microelectronics. 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 [2]. 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 character of the nanoparticle core might decrease the electrical resistance of the dispersion affecting the electrical conductivity properties of the contact region.

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 and TBA as lubricant base oils. The test parameters were set at 7N and 15N 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 and 1.62 GPa, respectively. Simultaneously to the friction coefficient, the electrical resistance of the contact is measured.

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 [3] and Au [4] cores respectively. Dispersion of both types of nanoparticles (5 wt. %) were prepared using paraffin and tetrabutylamonium acetate (TBA) as base oils. Table 1 shows the tribological behaviour for the different lubricant compositions in terms of ball wear rate (K_b in mm^3/Nm) and friction coefficient at 7 N of applied load. A significant decrease of wear rate is observed for gold dispersed in paraffin and palladium nanoparticles independently of the base oils. The K_b values are ten times lower as compared to the lubricant bases alone without nanoparticles. In figure 1 it is depicted the evolution of the friction and electrical resistance of the contact for the optimized combinations (i.e. Au nanoparticles in paraffin and Pd-NP in TBA). The friction coefficient does not vary significantly depending on the lubricant composition and its value is mainly controlled by the nature of the base lubricant remaining low (<0.07) and steady. The excellent tribological properties can be explained by the formation of a transfer film onto the ball surface that decreases the shear strength across the interface, accommodates the load, and protects the surface to slide directly on the counterface (Fig.1c and 1d.). The nature of this deposited material is mainly palladium and gold respectively as determined by EDX analysis. Besides a significant decrease of the contact electrical resistance is observed when using palladium nanoparticles but not with gold nanoparticles. This is probably due to a higher connection and coalescence among the Pd nanoparticles as the tetrabutylamonium chains can be easier displaced from the shell than thiols. In figure 2 it is shown the influence of the load with tests at 7N and 15N respectively. The anti-wear properties of the nanoparticles are more relevant as the severity of test conditions increase. In both cases the wear rate is maintained or even is improved with the load. In summary, the use of surface-capped metallic nanoparticles is demonstrated to increase the load bearing capacity of base lubricants. 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.

References:

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Table 1 : Tribological results for Pd and Au nanoparticles (NP) dispersed in paraffin and TBA lubricants. The values obtained for the base lubricants alone are included for comparison. (K_b: K ball in mm^3/Nm)

Load=7N	**Pd-NP**		**Au-NP**		**Base without NP**	
	K_b	*f*	K_b	*f*	K_b	*f*
Paraffin	< 3E-10	0,077 ± 0,004	3,08E-10	0,090 ± 0,001	5,30E-09	0,070 ± 0,008
TBA	< 1E-10	0,074 ± 0,006	7,80E-09	0,038 ± 0,018	5,47E-09	0,041± 0,025

Figure 1 Friction coefficient (f) and contact electrical resistance (Rc) behaviour for two different lubricant compositions. (a) nano-Pd (5 % w/w) in TBA. (b) nano-Pd (5 % w/w) in paraffin. In the bottom part, SEM observations of the ball scars after finishing the tests with Pd-TBA (c) and Au-paraffin (d).

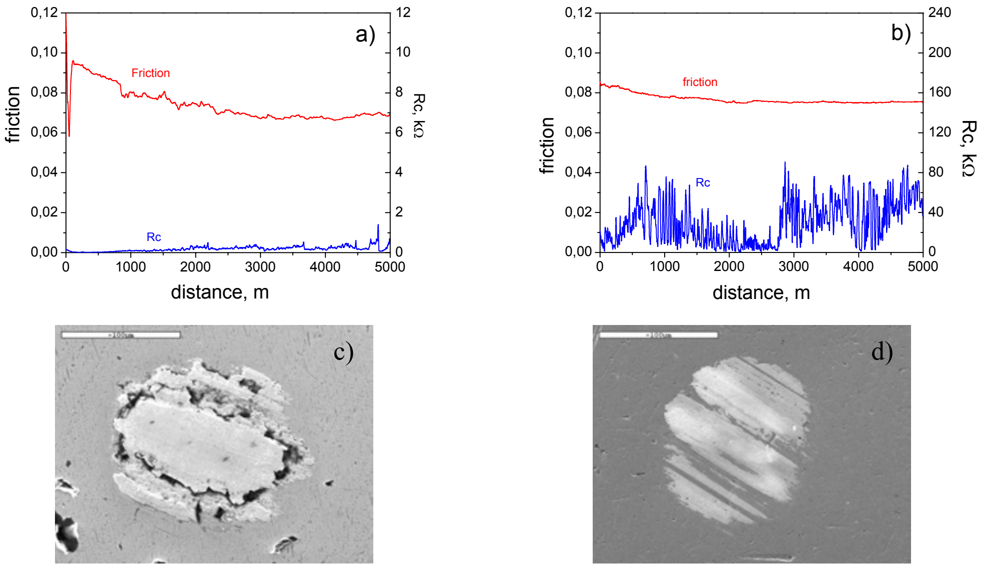

Figure 2. Influence of the applied load on the tribological properties (friction, ball and disk wear rates) of Pd and Au nanoparticles.