Improved Tribological Properties of Brass through Multi Charge Ion-implantation

K. Vaideeswaran, O. Sereda, C. Yamahata •, S. Biselli, C. Spoerl •, M. Dadras

The improvement of the tribological properties of a wide range of materials through ion implantation has been previously demonstrate [1,2]. In comparison to single charge ion implantation, Multi-Charged Ion Implantation (MCII) provides for a more uniform penetration of ions over a wide range of depths through the simultaneous implantation of ions with different energy levels associated with different charged ions (e.g., N+, N2+, N3+ and N4+ in the case of nitrogen) [3]. In this study, the MCII technique has been optimized for application to brass (free machining and lead-free). As a result, more than two-fold reduction of the coefficient of friction (COF) and a 100× reduction in the wear has been achieved. Process optimization realized by fine microstructural investigation. Such improvements are of great interest for industries using brass components in precision-mechanisms, such as watchmaking.

The project aims at optimizing the MCII technique in order to modify the surface microstructure through the implantation of nitrogen ions into free machining brass (CuZn39Pb3), resulting in a reduced coefficient of friction (COF) and lower wear. Metallographic observation of the alloy showed the presence of three phases: α FCC brass, β BCC brass, and Pb particles.

The process parameters of the MCII technique (implantation bias, implantation dose) were optimized in order to obtain a reduced COF that remains stable over long sliding distances. As a result of the optimized parameters for implantation of free-machining brass, the COF was not only reduced from ~0.7 to <0.3, but was also shown to be stable for over 400 m of sliding (see Figure 1). The resulting wear track profiles from these experiments were analyzed to obtain the resulting wear rate. The free machining brass surface implanted with nitrogen MCII results in a 100× lower wear in comparison to unimplanted reference surface. Application of the optimized parameters to implant lead-free brass (CuZn37, see Figure 2) surfaces resulted in a 2.5× reduction of the COF, demonstrating the applicability of the process to lead-free brass.

The low wear observed in the implanted brass sample surface is related to the surface hardening during implantation. Grazing-Incidence X-Ray Diffraction (GI-XRD) studies after implantation showed no peaks corresponding to any crystalline nitrides. These results corroborate well with other studies [4] and imply that the surface hardening is not achieved from a second phase formation. Transmission Electron Microscopy (TEM) observations of the implanted sample show a microstructure modification over a depth of about 70 nm from the surface (see Figure 3 left). Two modified layers are clearly observed: a "porous" layer (named "b") and a layer with very fine crystallite size (named "c"), the latter being distinguished in dark field TEM micrograph (see Figure 3 right). Through elemental analysis, presence of N was clearly detected in the inner layer (named "b").

These observations suggest the occurrence of recrystallization of the brass grains at the surface as a result of the kinetic energy transferred from the implanted ions. The presence of nanocrystalline grains in layer "c" as well as the "pores" observed in layer "b" impede dislocation movement, resulting in a higher wear resistance of the layer.

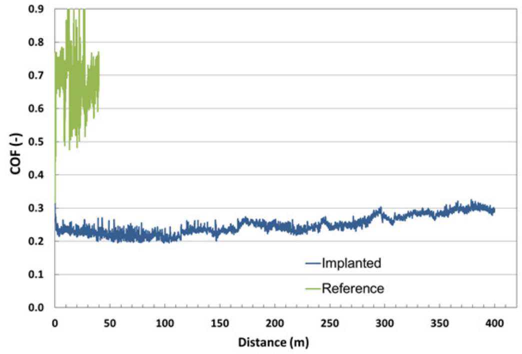

Figure 1: For an applied force of 5 mN, the COF was reduced from >0.7 for the reference (unimplanted) to <0.3 for the implanted Cu39ZnPb3 sample.

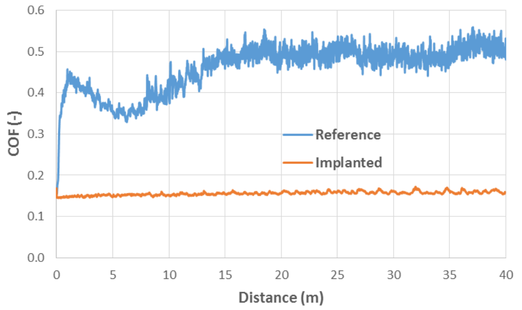

Figure 2: Application of optimized MCII to lead-free brass also results in the lowering of the COF by a factor of 2.5.

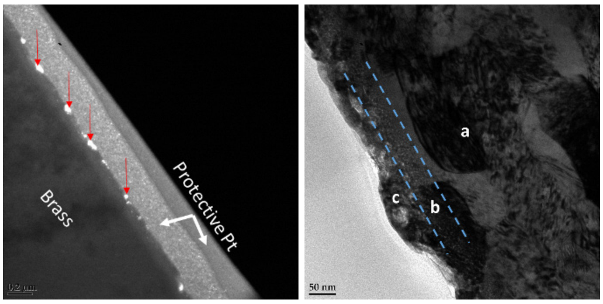

Figure 3: (left) Bright field TEM micrograph showing the microstructural modification of the implanted surface (right) Dark field TEM micrograph showing nanocrystalline brass in layer 'c'.

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• IDONUS Sarl, Rouges-Terres 61, 2068 Hauterive, Switzerland

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