Tribochemical Events on and under the Surface Effectively Reduce Wear of Self-mating Metal Pairings.

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All-metal hip joints are nowadays fabricated from cobaltbase alloys by either casting or forging. Depending on the manufacturing process, the mean grain size of the bulk material varies significantly and is generally in the range of 30 – 100 µm for wrought alloys and > 1 mm for cast alloys. The authors show that the articulating surfaces were nanocrystalline; with a grain size prevalence of 30 nm. It is supposed that mainly mechanically driven mechanisms achieve this significant grain refinement by a factor of up to 40.000.

In this study, in vivo (McKee-Farrar explants) and in vitro (DoP) samples were investigated by means of TEM preparation technique, which enables the cross-sectional imaging of the worn surface. The results indicate that the dynamic recrystallization in cobaltbase alloys is achieved via two different – but simultaneous - pathways.

Due to the low SFE of CoCrMo type alloys, dislocations do not climb or cross slip but move on discrete fcc sliding planes. Furthermore, wear induced plastic deformation leads to the generation of martensite needles and twins which also form along the planes of highest electron density. Thereby a network of nanoscopic rhombic cells forms in a depth of approximately 5 µm below the top surface. Further shear stresses shift the cells relative to each other with the result of newly formed high angle grain boundaries. Although this mechanism explains a crystal refinement towards the surface, it is hypothesized that a second mechanisms acts parallel on the surface which helps to generate the observed nanocrystals: direct metal-on-metal contact leads to intense mechanical mixing and alloying of the top surface, thereby creating a thin nanocrystalline layer with viscous properties. With both mechanisms acting in parallel, cobaltbase alloys form an elastic surface and a strengthened sub-surface in-situ. This combination of properties can explain low in vivo wear rates, fine debris and tribological side effects such as self-polishing.

Keywords: mechanical mixing, dynamic recrystallization, nanocrystalline surface, metal-on-metal hip joint