MICROTRIBOLOGY CENTER μTC

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Marker Techniques for Visualization of Subsurface Shear

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Subsurface plastic deformation in tribology

is often connected to the setup of a severe plastically deformed layer (a) under the surface which is supported by a plastically sheared zone (b, fig. 1). For a better understanding of friction and wear, subsurface shear analysis can be useful.

Disks with different subsurface microstructures show varying friction and wear behavior. As shown by wear measurements with radioactive tracers, wear rates and sensitivity vary by a factor of 10 to 25 (fig. 2).

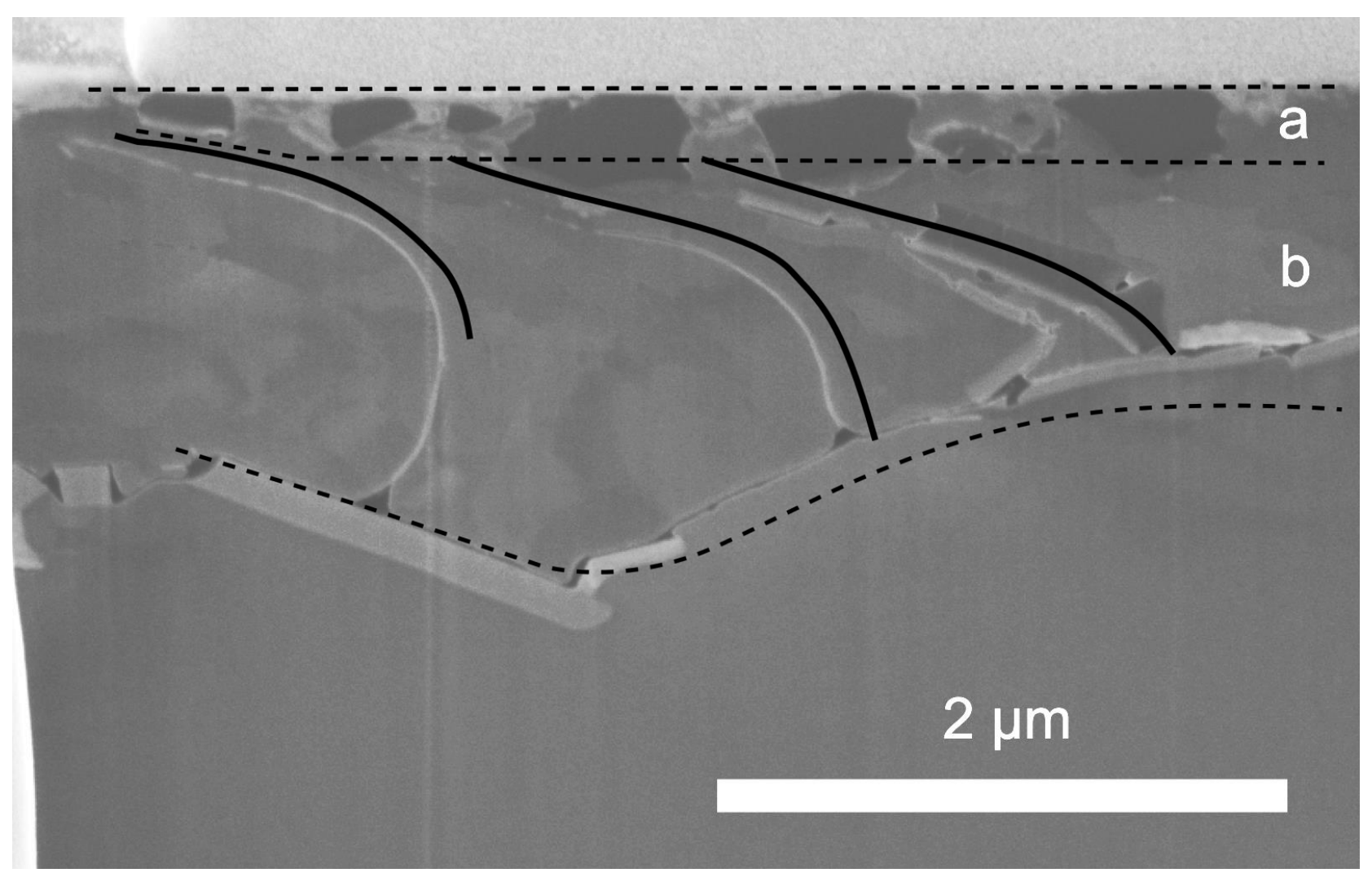


Fig. 1: FIB-cross section of a worn subsurface. Shear zones are clearly recognizable.

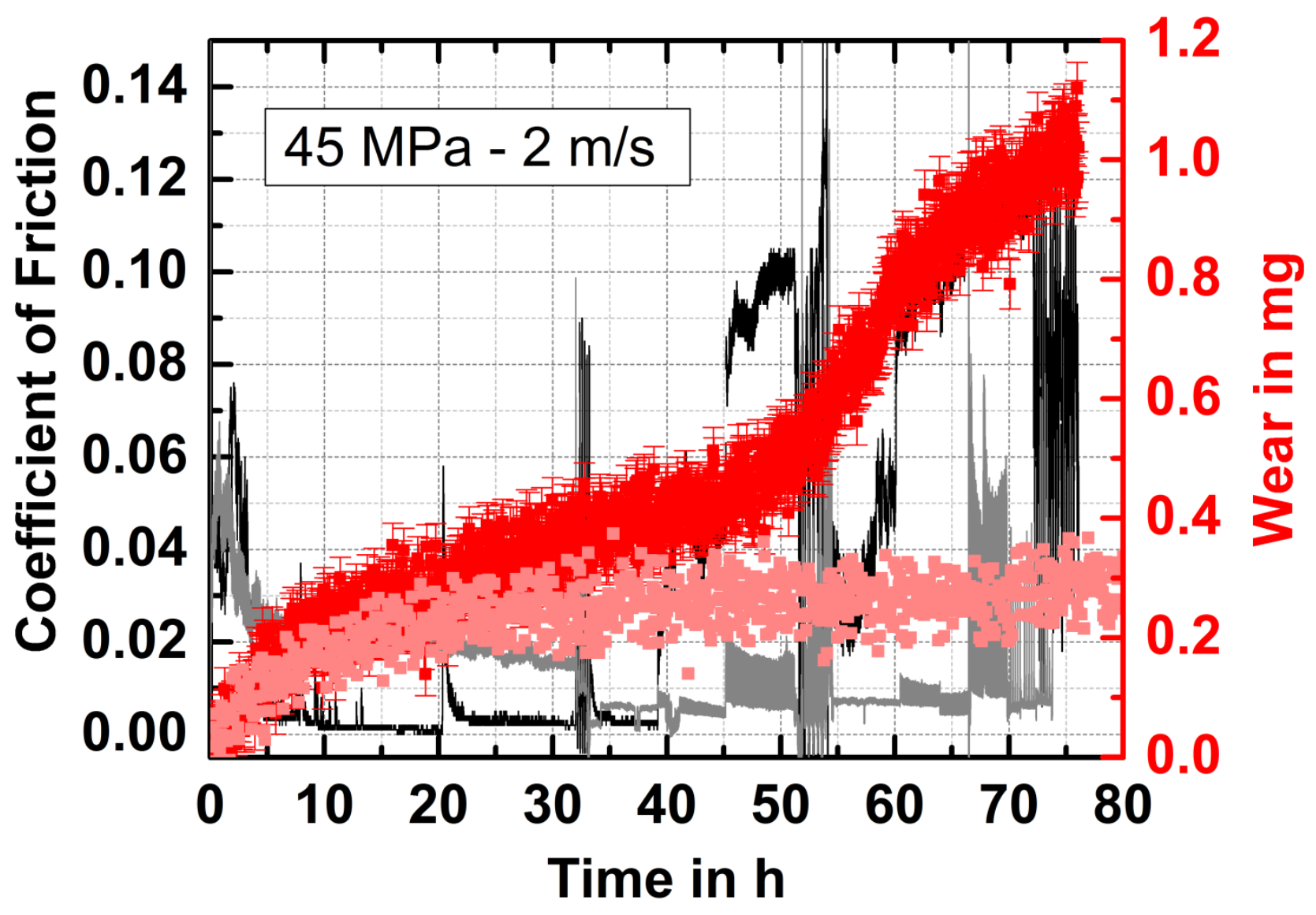
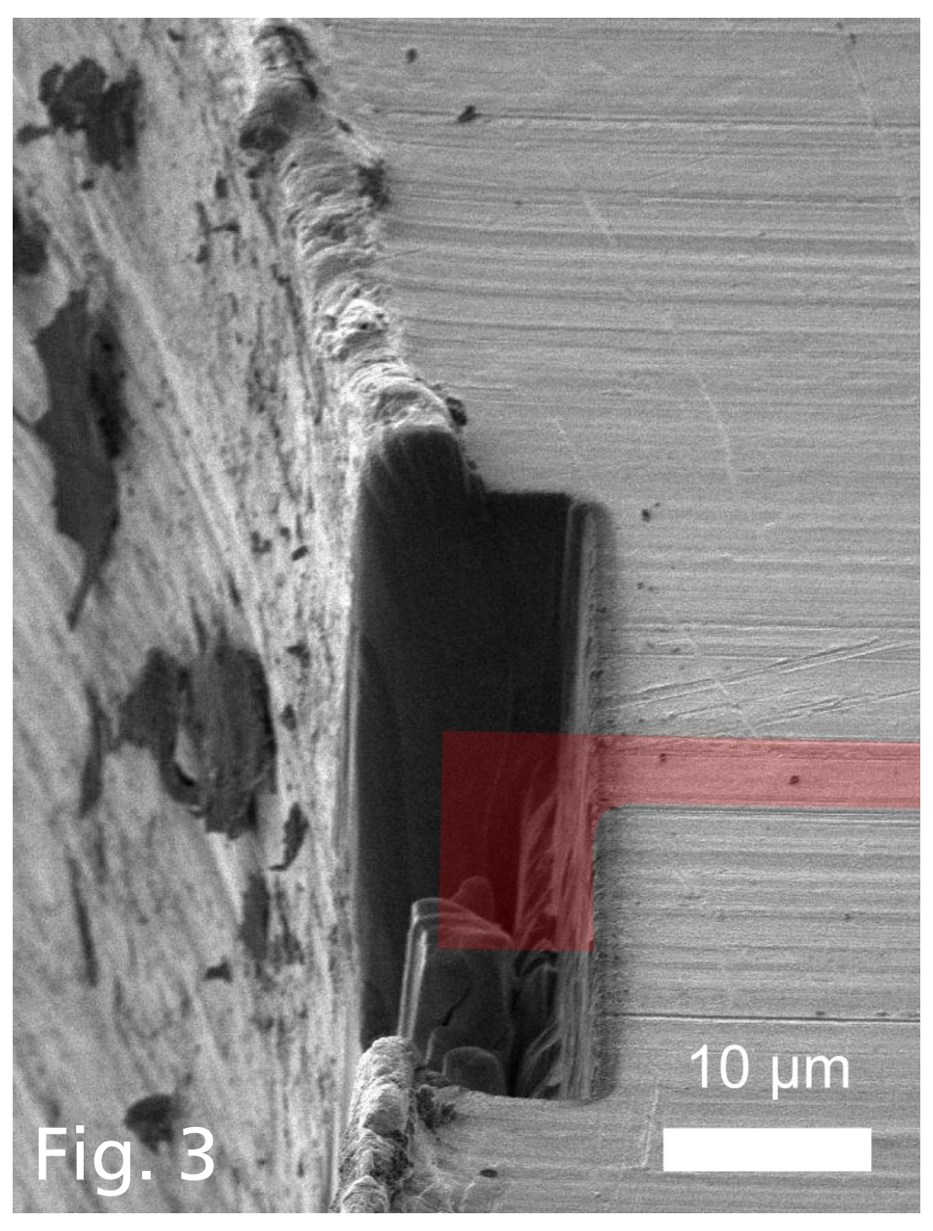


Fig. 2: Differences in friction and wear behavior of tribosystems with as-cast and heat treated disks, respectively [1].

Application of markers in fine grained materials

In the fine-grained subsurface microstructure of the unworn disks (fig. 2), the evaluation of shear from microstructural features is not possible. Markers visualize the subsurface shear (fig. 3-5):

- Gallium is implanted in the subsurface with a focused ion beam (FIB).
- Platinum markers (see also Persson [2]) and trenches are set up with the FIB.
- Rims of microbores are prepared with FIB to create defined edges.



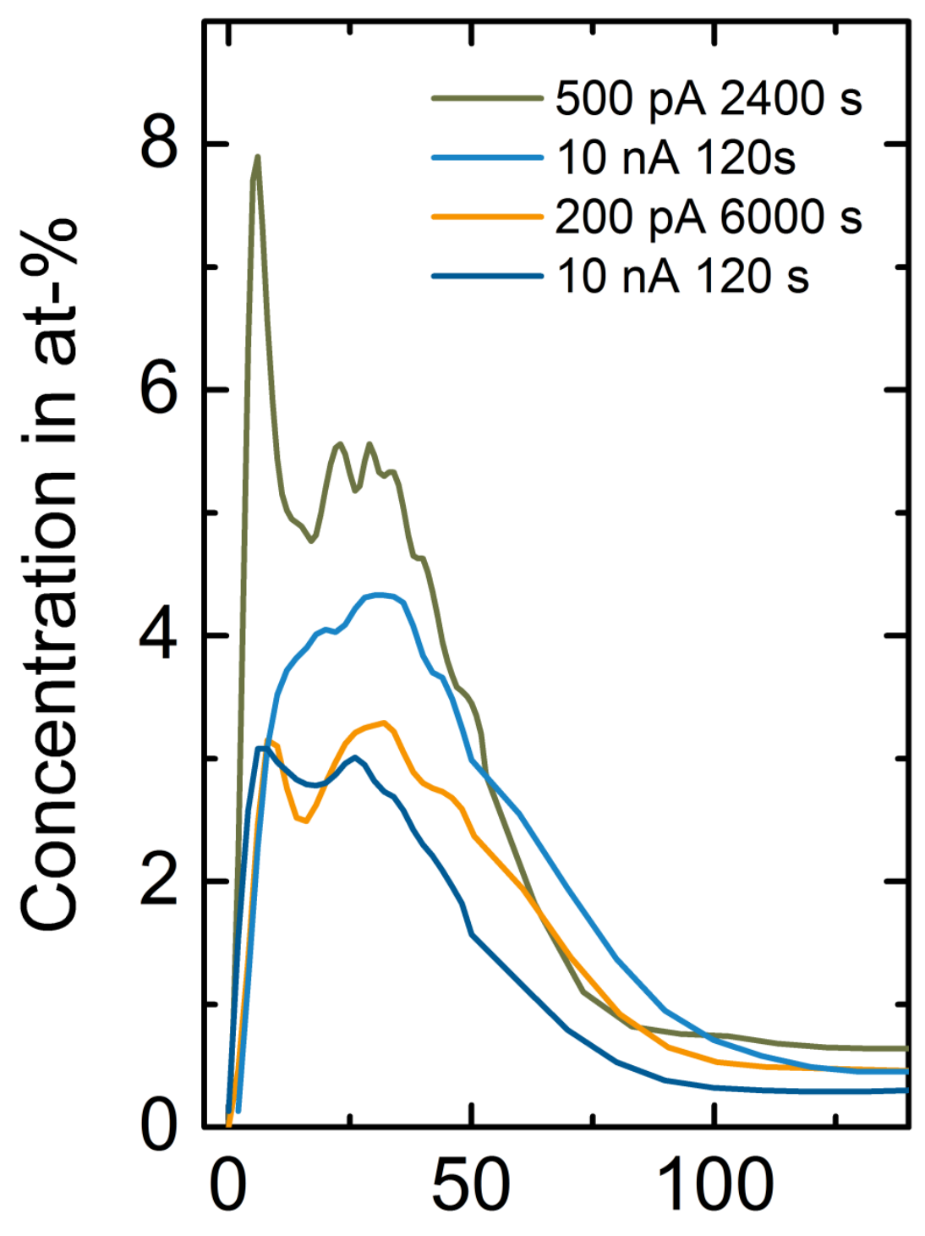


Fig. 4

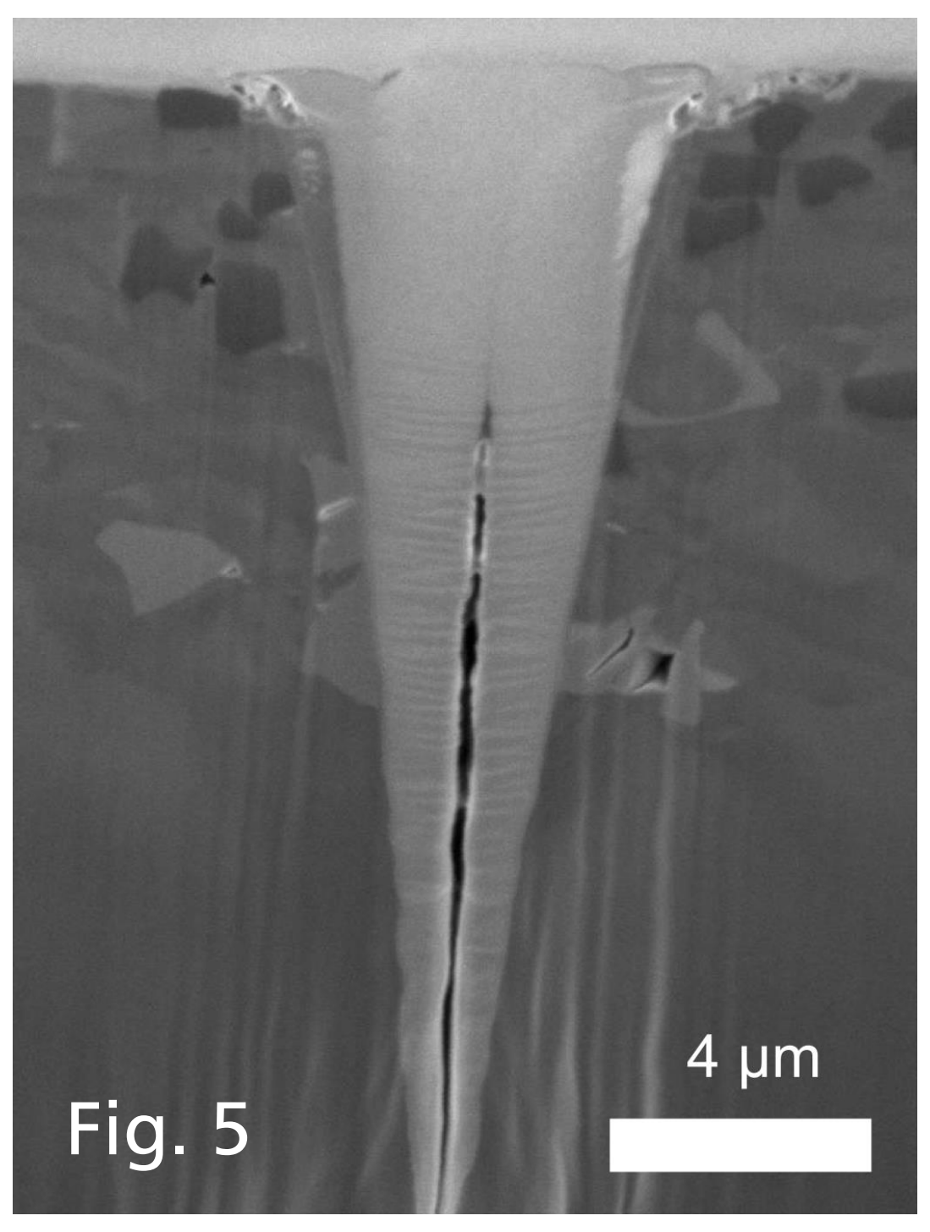
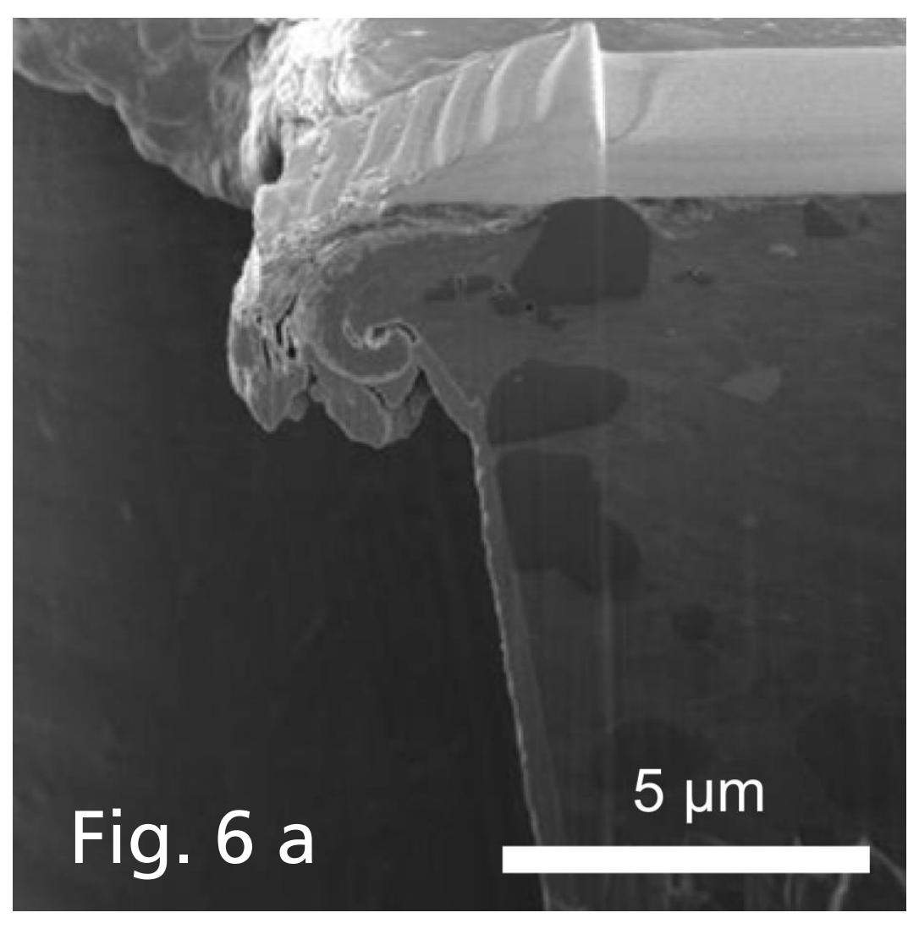


Fig. 3: Prepared edge of a microbore. The red plane is the image plane in fig. 6.
Fig. 4: Gallium depth profiles measured with X-ray photoelectron spectroscopy.
Fig. 5: non-sheared platinum marker.

Relative results of displacements from microbores



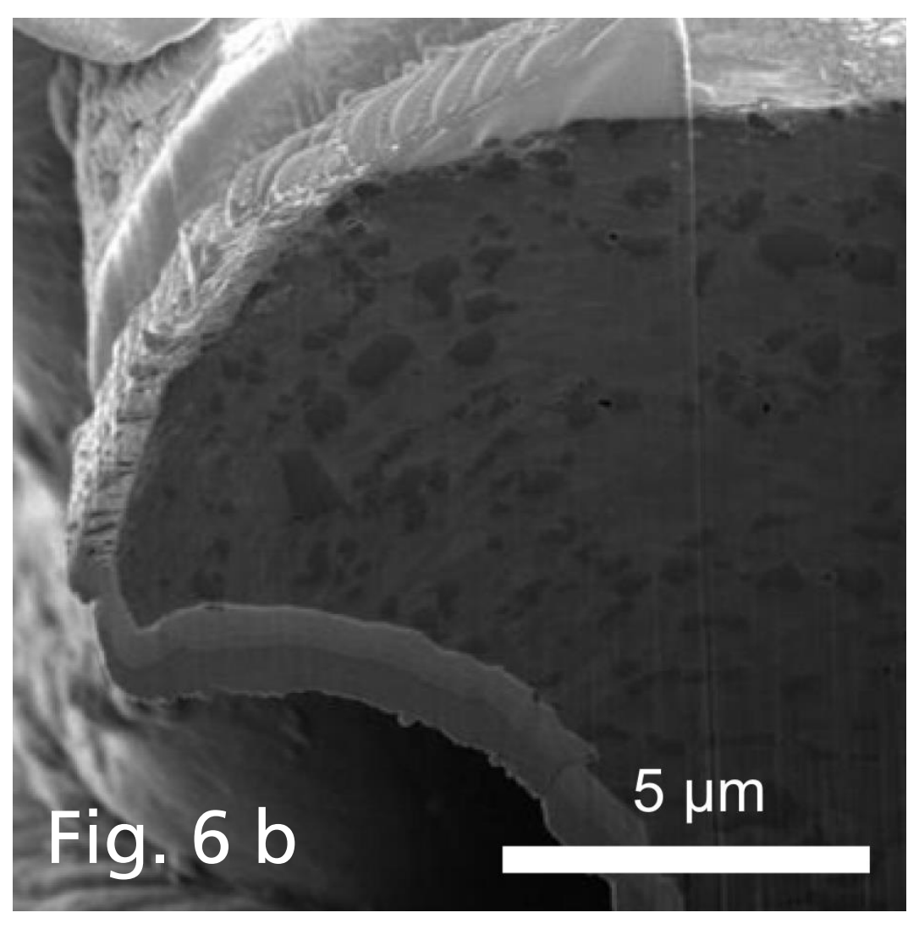


Fig. 6: Material displacement into microbore. Difference in tribological behavior is shown in fig.2. Sliding direction of the pin was from right to left.
a: heat treated system
b: as cast system

FIB cross sections in the prepared edge of the microbore after tribological testing shows the material displacement into the disk due to the friction force. Pronounced shear gradients are visible in the heat treated disk. Compared to the platinum markers, the displacement measured from edges in the microbores are larger. The received shears are therefore suitable only for comparative discussion.

Gallium marker analysis with Auger electron spectroscopy

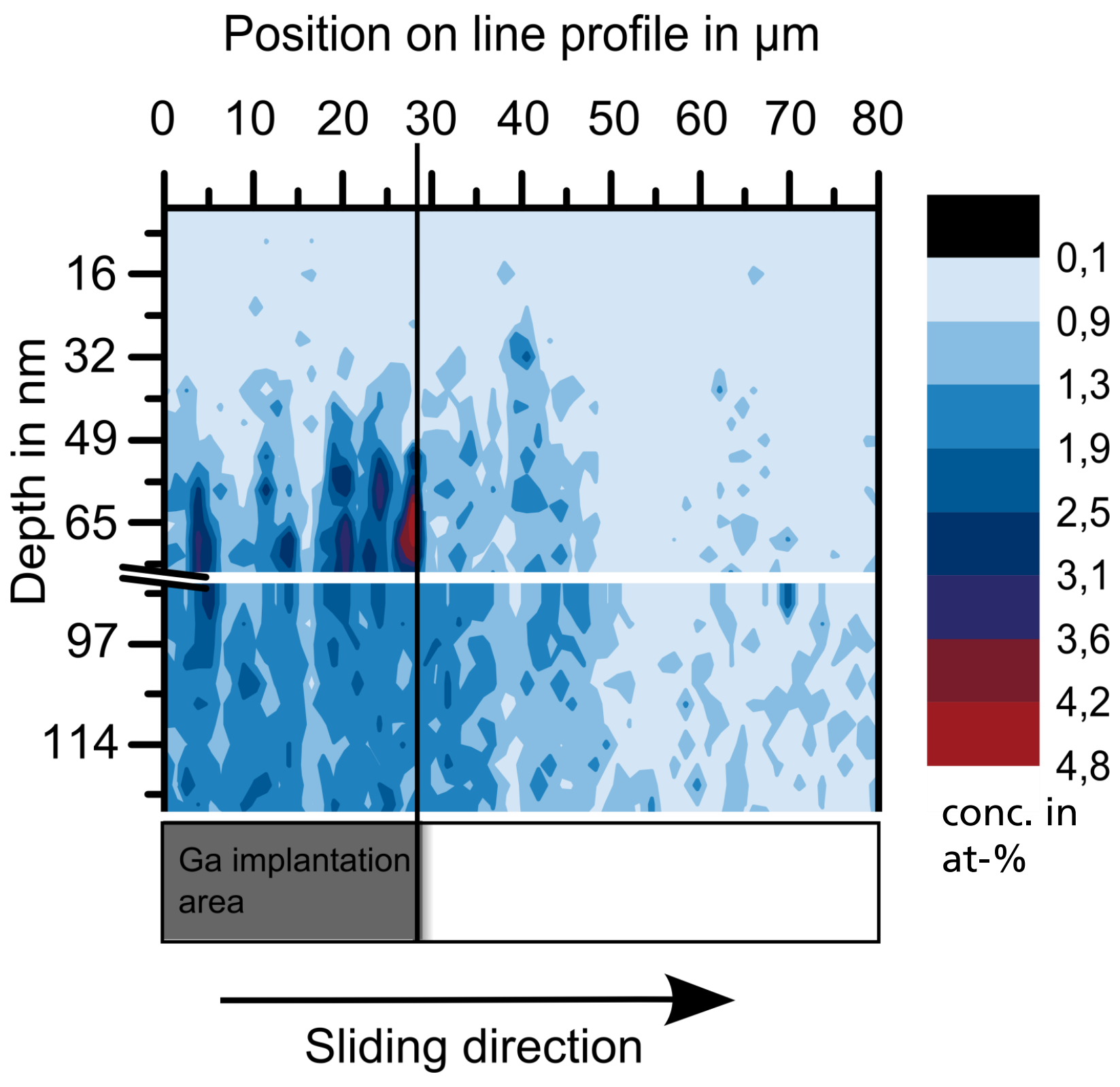


Fig. 7: Ga line profiles over depth [1]

Analysis of the gallium markers with Auger electron spectroscopy (AES) visualizes the material displacement of 20 µm in the first 100 nm depth of the first bodies. Additionally, the existence of a third body of Al-oxide and oil constituents but without gallium is shown. Prone to wear, the method only works for initial stages of experiments in the ultra-low wear regime. It is susceptible to inhomogeneities in the microtopography caused by sliding contact. Thus, it displays the shear only locally.

Platinum marker verification with unfilled trenches

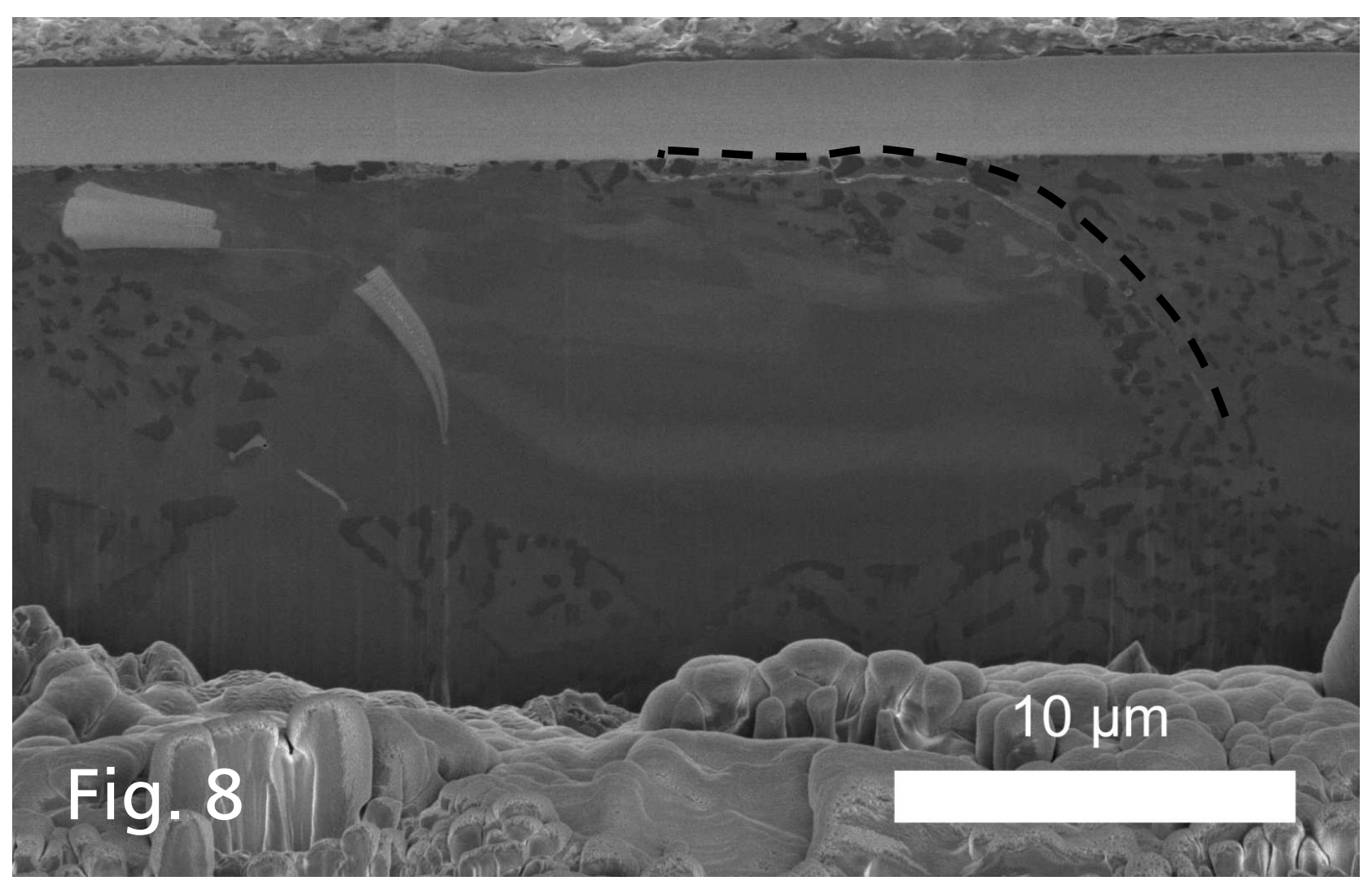


Fig. 8: Platinum marker (left) and unfilled trench (right) after shear

Comparison of platinum markers and unfilled trenches reveals good correlation of displacement in depth > 1µm below the surface. Differences in displacements within 1 µm under the surface are due to crack or bending of the platinum markers.

Platinum markers were found in the wear track for sliding distances of up to 10 000 m. Inhomogeneities in the sliding contact have to be considered in marker analysis. A 100 % variation of shear was found for markers with a distance of 100 µm.

Conclusion

Different marker techniques display the subsurface plastic deformation due to tribological contact. By comparison of different markers, it could be shown that microbore displacements are only useful for relative comparison. Platinum markers reveal the shear in depth of more than 1 µm below the surface, whereas gallium markers are sensitive to displacements in the first 100 nm of depth. The markers show local displacements. Thus, interpretation of results has to take into account the inhomogeneity of the tribological contact.

Literature

[1] Linsler, D. et al.: Influence of subsurface microstructure on the running-in of an Al-Si alloy; Wear 2015; DOI: 10.1016/j.wear.2015.02.044

[2] Persson, D.: On the Mechanisms behind the tribological Performance of Stellites; PhD-Thesis; Uppsala University, 2005; ISBN 91-554-6420-3