MICROTRIBOLOGY CENTER µTC

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Formation and analysis of reaction layers in tribological contact of cutting ceramics and inconel 718

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MOTIVATION: UNDERSTANDING THE WEAR MECHANISMS OF CERAMIC CUTTING TOOLS

- Machining of nickel-based alloys is a tough challenge for manufacturers
- Ceramic cutting materials perform extremely well but they still feature a high potential of improvement
- Wear mechanisms of ceramic cutting materials have to be analyzed, understood and taken into account for further material development.

MATERIALS	**Al_2O_3/SiC** (whisker) commercial grade	**SiAlON** (Yb-stabilized) commercial grade
4-Point bending strength	700 MPa	890 MPa
Hardness HV10	2000	1640
Fracture toughness K_{Ic}	7.7 MPa*m$^{1/2}$	4.8 MPa*m$^{1/2}$
Elastic Modulus	360 GPa	334 GPa
Phase compositions	≈ 30 wt% SiC	α/β ≈ 30/70

EXPERIMENTAL SETUP AND INVESTIGATION

- Sliding experiments to model the contact situation of ceramic tool faces on workpieces of nickel-based alloy (Inconel 718)
- Unlubricated pin-on-disc experiments were carried out at room temperature and 1.1 GPa initial contact pressure (F_N = 100 N)
- In each experiment, the sliding distance was 2000 m was and the velocities were 1, 5, 10, and 25 m/s

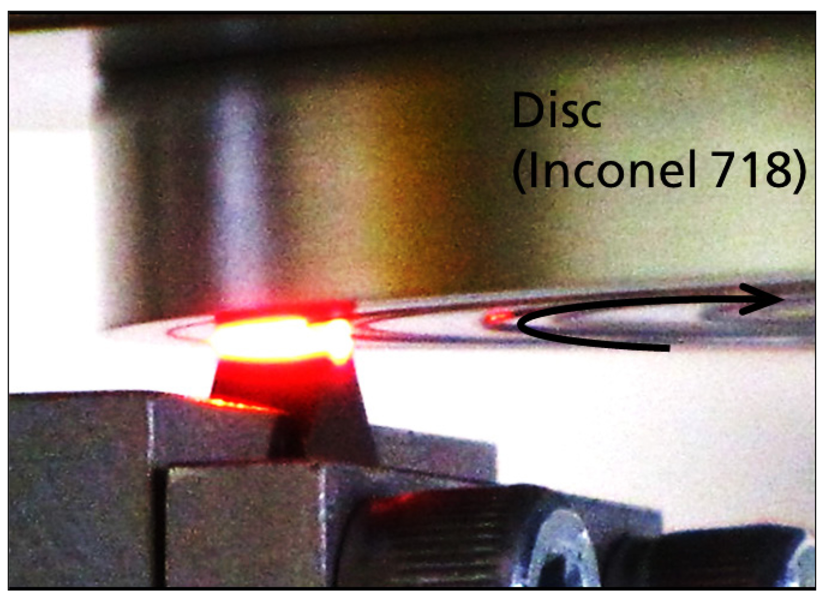


Fig. 1: Pin-on-disc wear experiment.

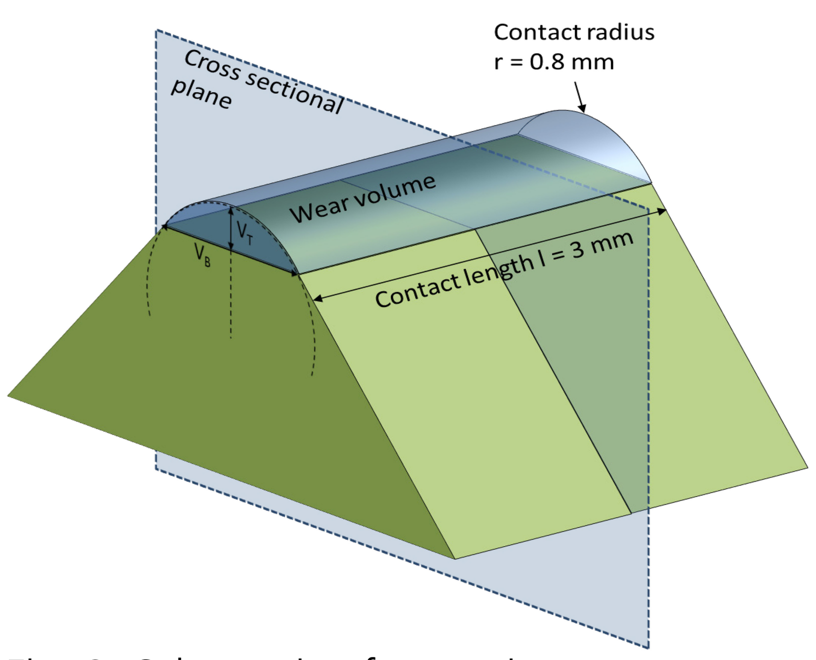


Fig. 2: Schematic of a specimen.

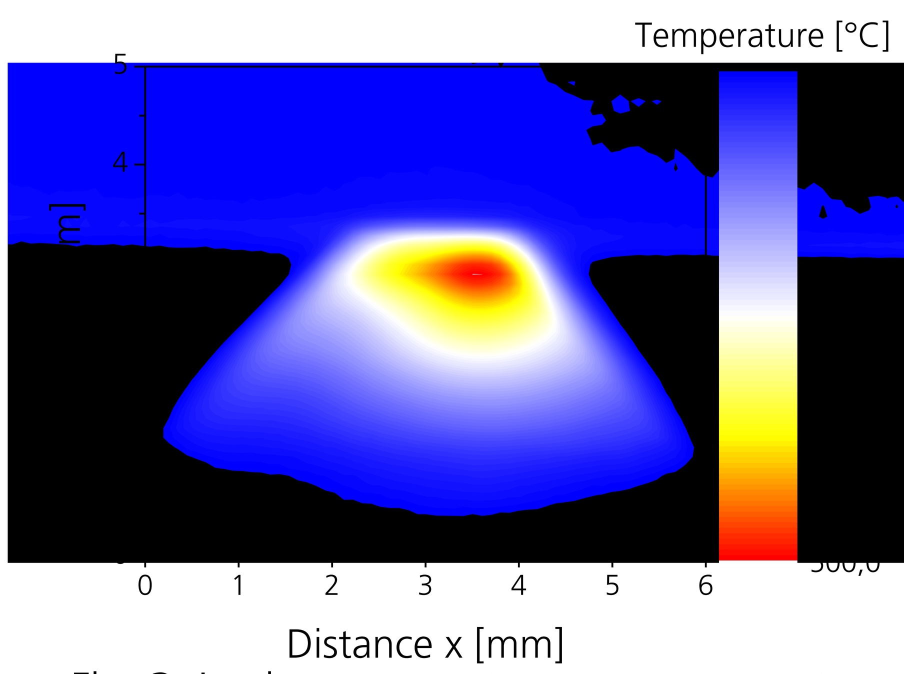


Fig. 3: In-situ temperature measurement during sliding experiment (10 m/s).

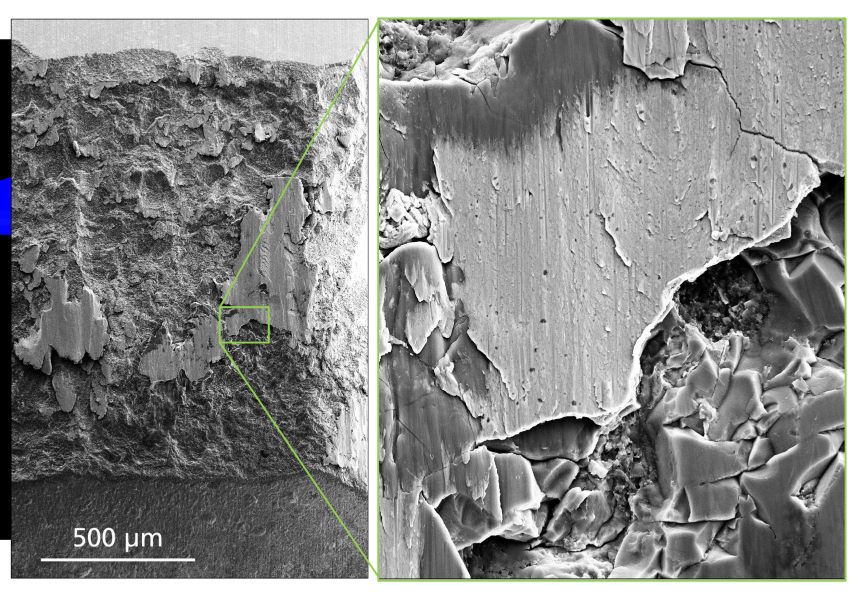


Fig. 4: Worn ceramic surfaces with visible tribochemical layer below deposited alloy.

RESULTS – Al_2O_3/SiC

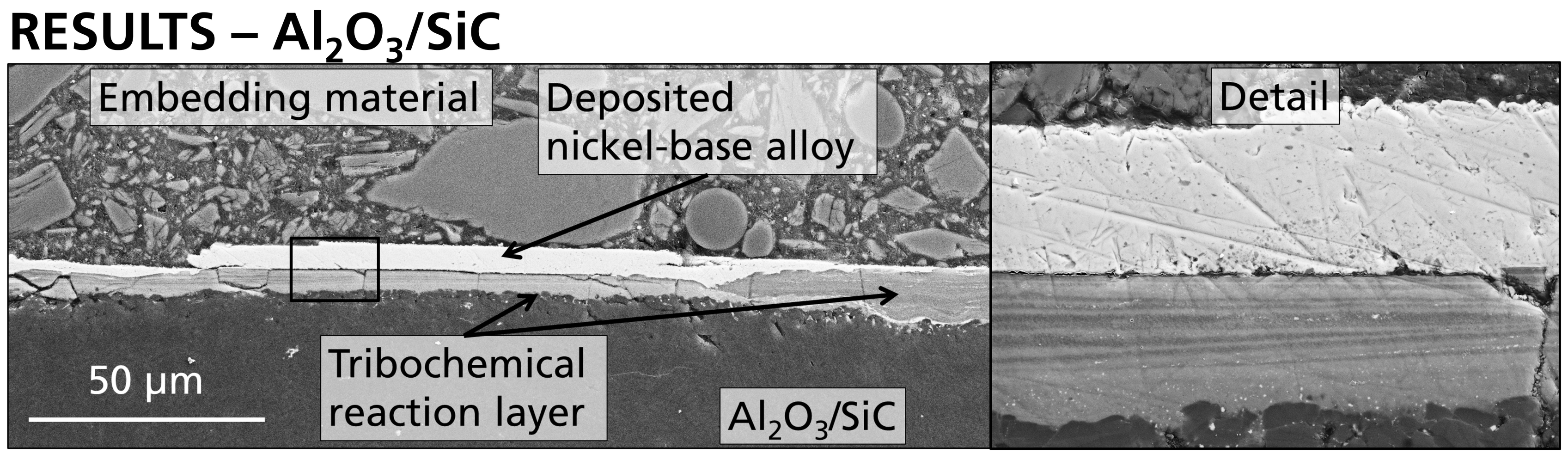
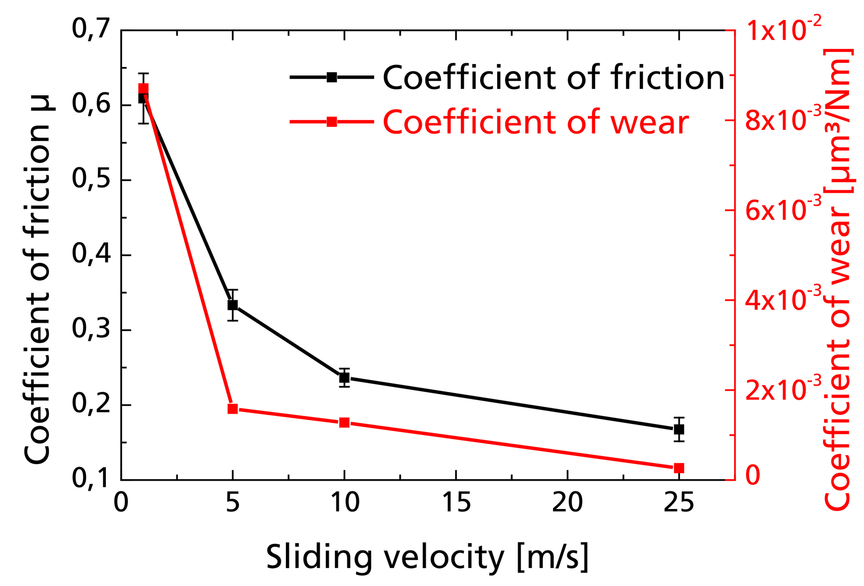


Fig. 5: Cross section of a Al_2O_3/SiC-composite specimen showing deposited alloy and tribochemical reaction zones on top of the bulk material (sliding speed v_c = 25 m/s).

- Morphology: rough surface profile of the bulk material; cracked tribochemical layer with thickness of 6 to 11 µm; deposited alloy on top
- Composition of tribolayer (at%): Ti(10), Cr(15), Al(17), O(55)
- Temperature reaches maximum of around 350 °C at 10 m/s.



RESULTS – SiAlON

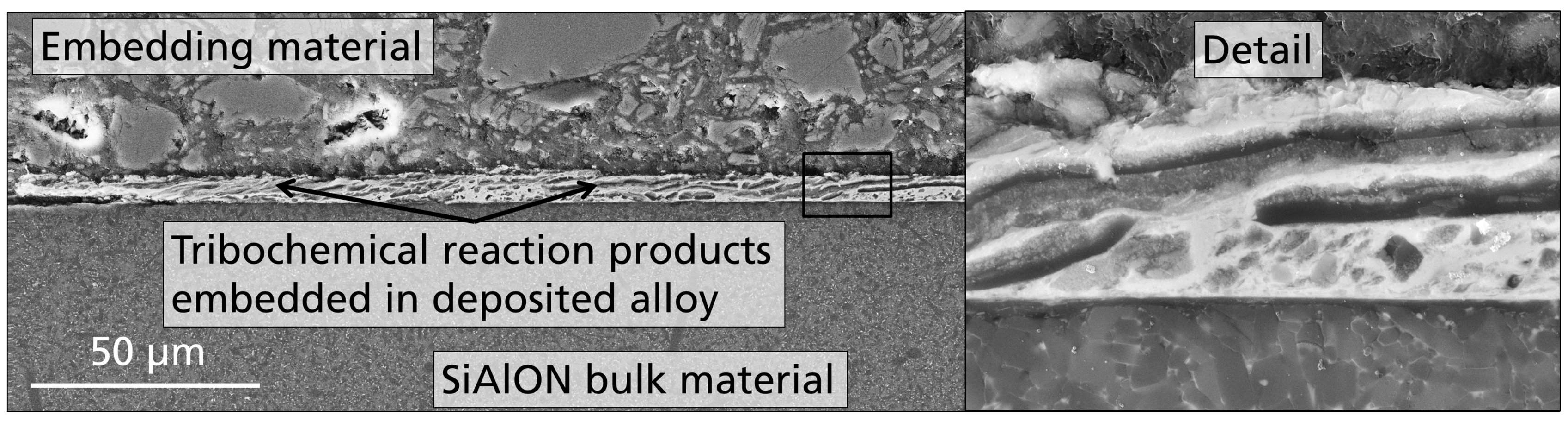
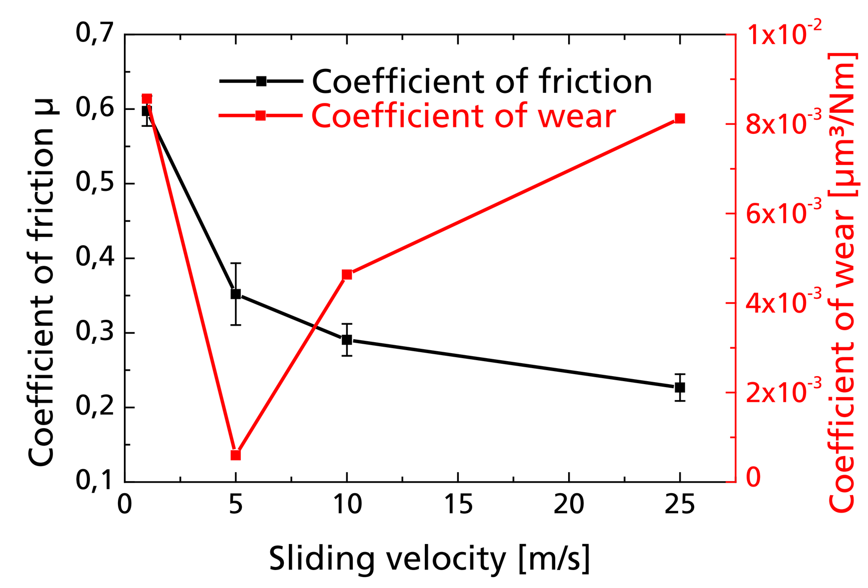


Fig. 6: Cross section of a SiAlON specimen showing deposited alloy and tribochemical reaction products on top of the bulk material (sliding speed v_c = 25 m/s).

- Morphology: smooth bulk surface profile; layered structures (tribochemical products) embedded in deposited alloy
- Composition of tribolayer (at%): Cr(11), Fe(6), Si(20), O(45), Ni(7)
- Temperature rising with speed up to 850 °C at 25 m/s.



CONCLUSIONS

- Frictional heat leads to chemical reaction of alloy and ceramic specimen.
- Tribochemical reaction products are glassy phases that soften at high temperatures and are easily removed by shearing.
- Formation of tribochemical layers lowers the COF for both ceramics
- The shear zone of the tribologic contact is composed of and influenced by
  - the interface between the alloy disc and deposited alloy layer
  - the interface between the alloy layer and tribochemical phase
  - the interface of the tribochemical ly formed phase and ceramic surface
- SiAlON shows strong wear by layer removal with increasing speed, whereas coefficient of wear drops for the composite ceramic