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Study of the tribological behavior of SnO_2 coatings under low atmospheric ethanol contamination

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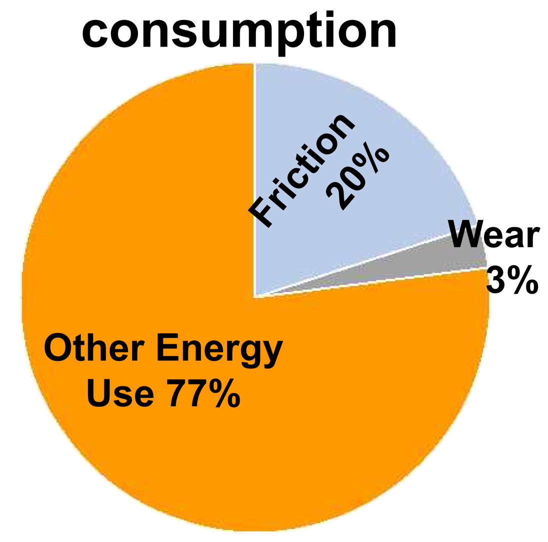
Context

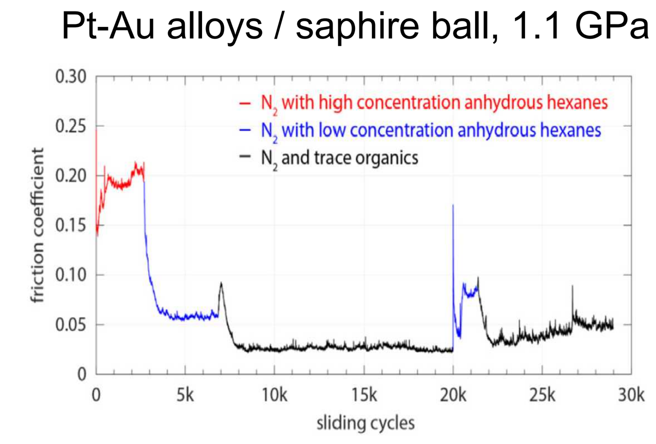
Tribology is the study of friction, wear, and lubrication, focusing on how surfaces interact when they move relative to each other, which is crucial for optimizing energy efficiency and reducing environmental impact. [1,2]

Global energy consumption



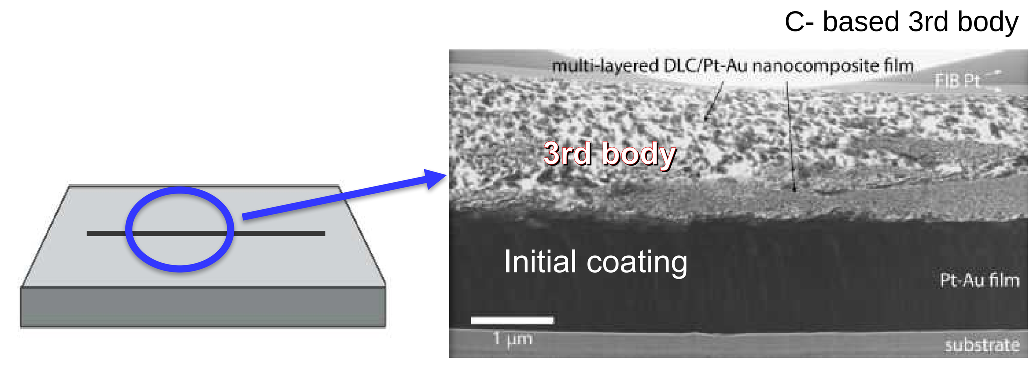
Airborne contamination impacts lubrication performance

Pt-Au alloys / saphire ball, 1.1 GPa



(Argibay, Carbon, 2018)

A tribofilm forms from trace airborne organics during sliding, acting as a lubricating third body



Objectives

Develop a method to understand the mechanisms by which friction and wear evolve under controlled air contamination, which may reduce friction through tribochemical reactions. The goal is also to characterize the third body and interfacial materials formed during friction.

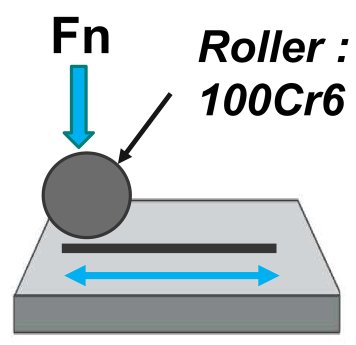
Experimental Approach

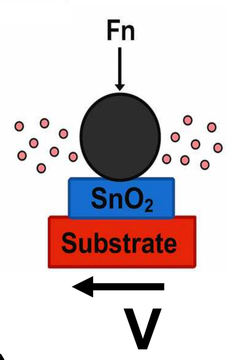
1 Surface coating

- PVD (GLAD) **SnO_2 films on Si wafers**
  - Thickness: 500 nm
  - Casserite crystalline phase (XRD)

2 Tribological test:

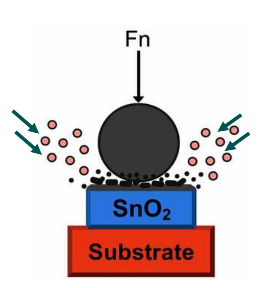
- **Reciprocating friction tests** 100Cr6 steel ball in contact with SnO_2-coated Si wafers.
- Duration: 500 cycles
- Normal load: 0.55 N => 330 MPa
- Sliding speed (V): 8 mm/s
- **Testing Environments:**
  - Laboratory Air (HR = 41.7% ± 1.9)
  - Laboratory Air + 1000ppm ethanol
  - Dry nitrogen (alpha 5)
  - Dry nitrogen (alpha 5) + 1000ppm ethanol
- **Temperature: Room Temperature (28.9°C ± 0.9)**





3 Surface Characterization:

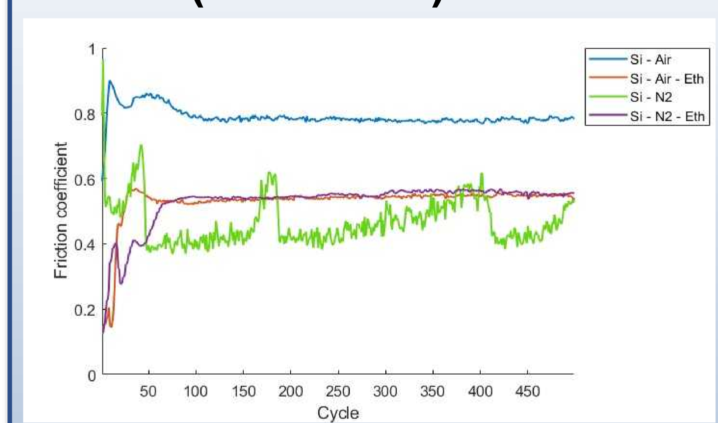
- Optical Microscopy, SEM/EDX
- Raman spectroscopy
- Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS)



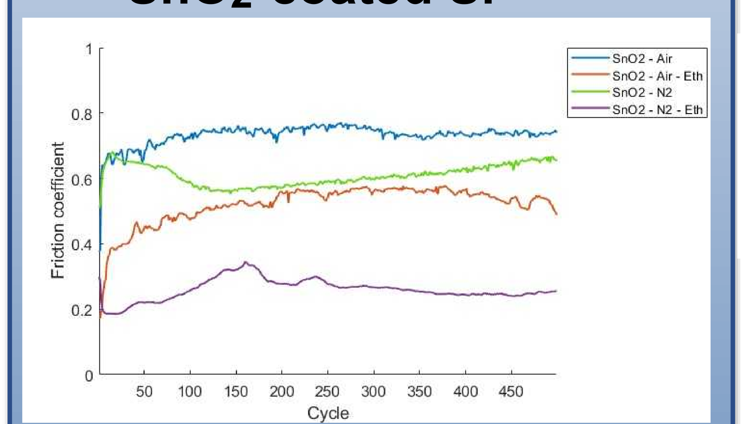
Results & Discussion

Friction coefficient

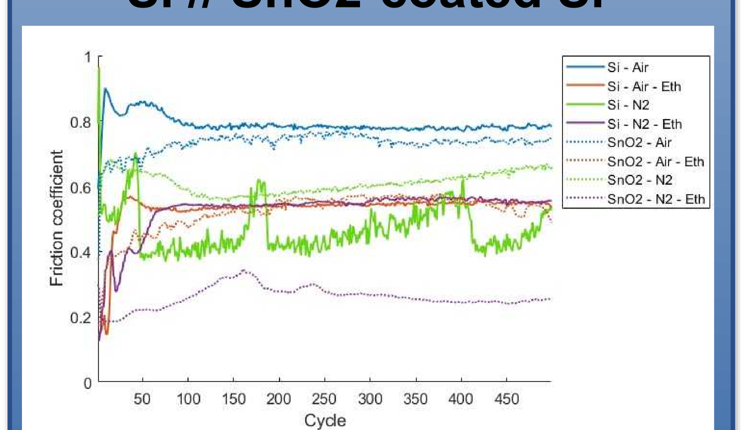
- **Si (uncoated)**



- **SnO_2-coated Si**

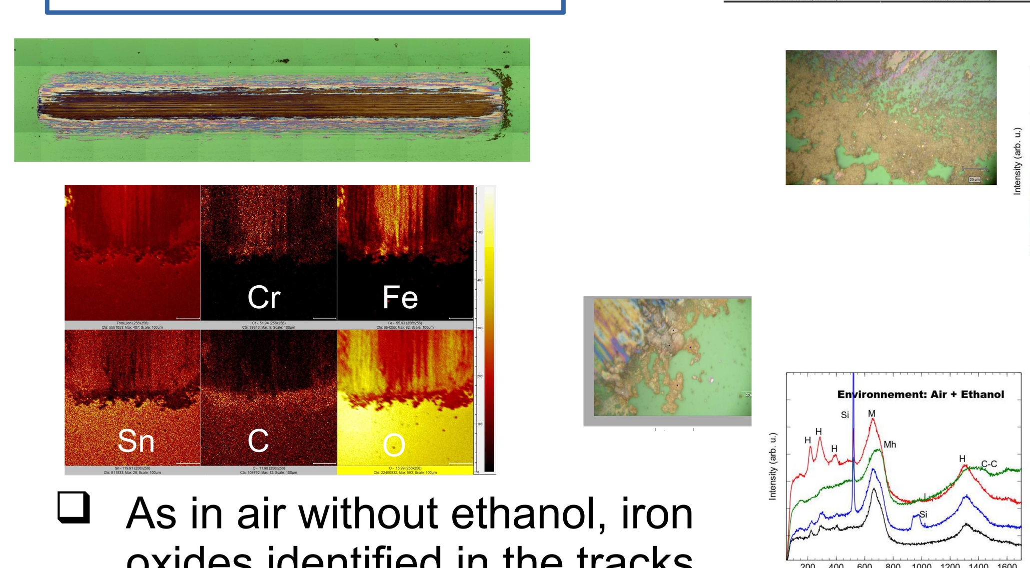


- **Si // SnO2-coated Si**



- Ethanol "contamination" reduced friction coefficient and wear.

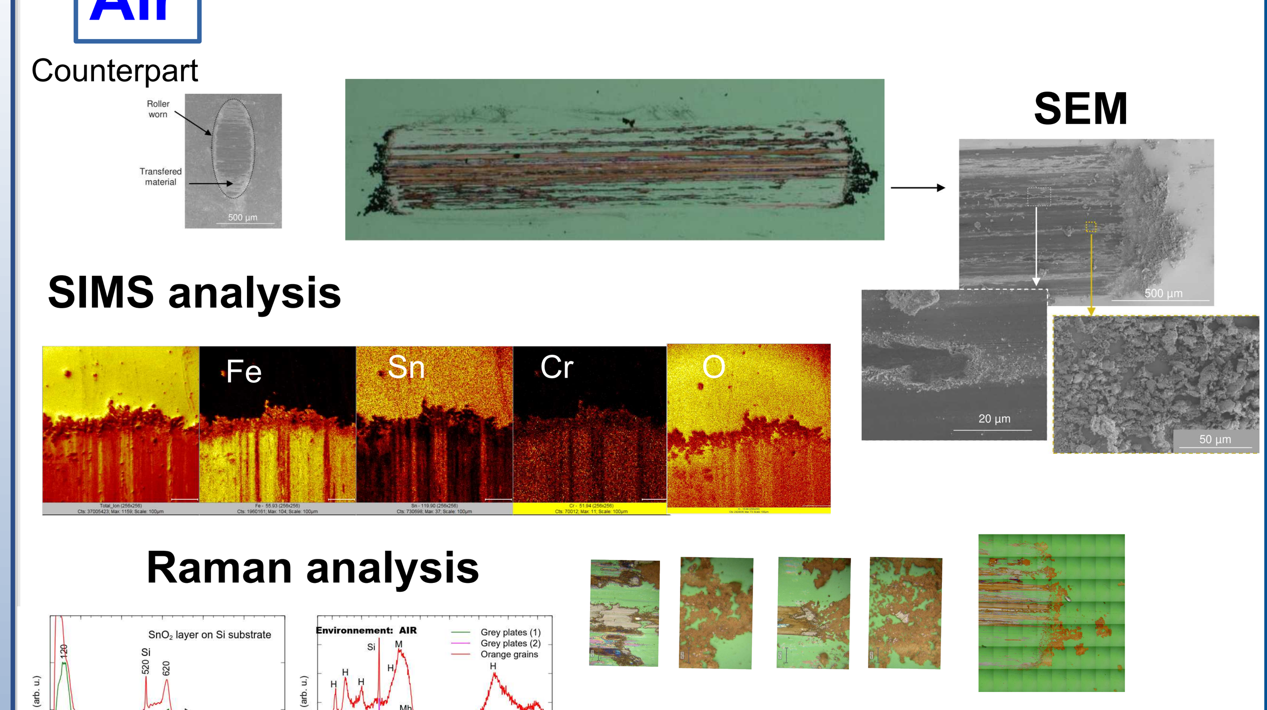
Air + Ethanol



- As in air without ethanol, iron oxides identified in the tracks.

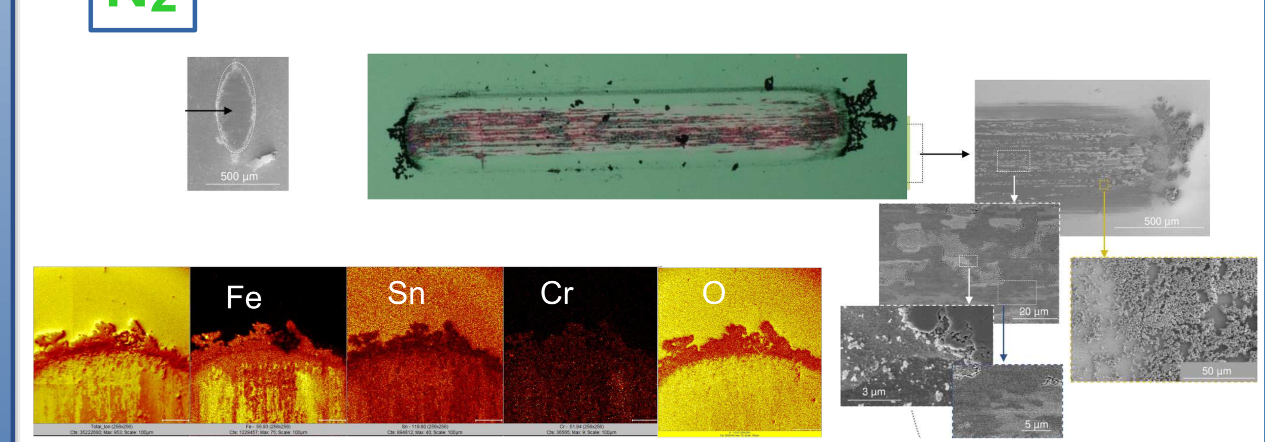
Surface analysis

Air

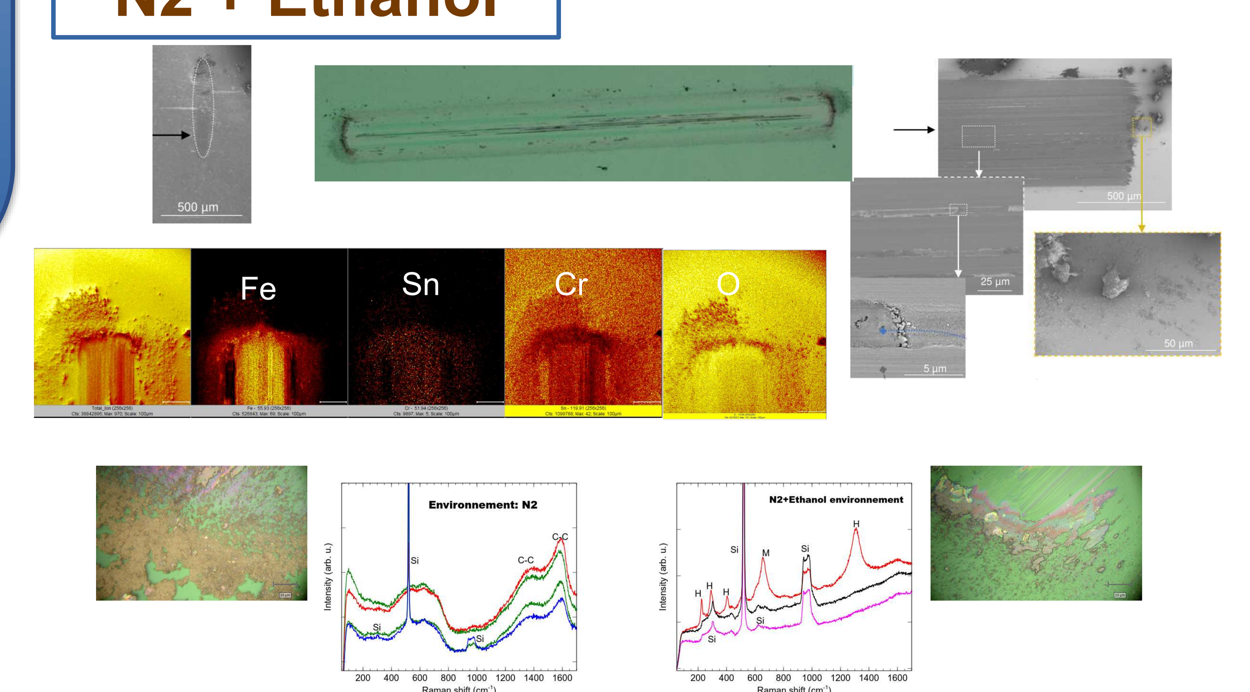


- Tracks composed of iron oxides: hematite (H), magnetite (M), maghemite (Mh)

N_2



N2 + Ethanol



- Iron and oxygen are still detected in the tracks by SIMS, but Raman spectra mainly show peaks from the Si substrate.

Conclusion

- **Friction tests in controlled environments reveal that low-level contamination can promote reduction in friction and wear.**
- **In the case of SnO2-coated Si :**
  - **Removing oxygen and water (air)** wear decreases, but Fe is still present, and a large amount of oxygen is detected.
  - **When ethanol is added,** carbon is detected in the tracks.
  - **Under nitrogen**, wear is minimal, but an optically transparent but iron-laden layer covers the trace. This is totally counter-intuitive and demonstrates the importance of understanding these phenomena in order to control them and control wear.
- **These films help in friction reduction and surface protection, highlighting environment-driven tribochemistry.**

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References

[1] Jost, P. M. *Lubrication (Tribology) – A report on the present position and industry's needs*. UK, 1966.

[2] Holmberg, K., & Erdemir, A. *Influence of tribology on global energy consumption, costs and emissions*, Friction, 2017.

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