Georgia Institute of Technology, Technion - IIT

Tribology Labs @ Mechanical Engineering

Mechano-Chemical Surface Modification With Cu_2S: Inducing Superior Lubricity

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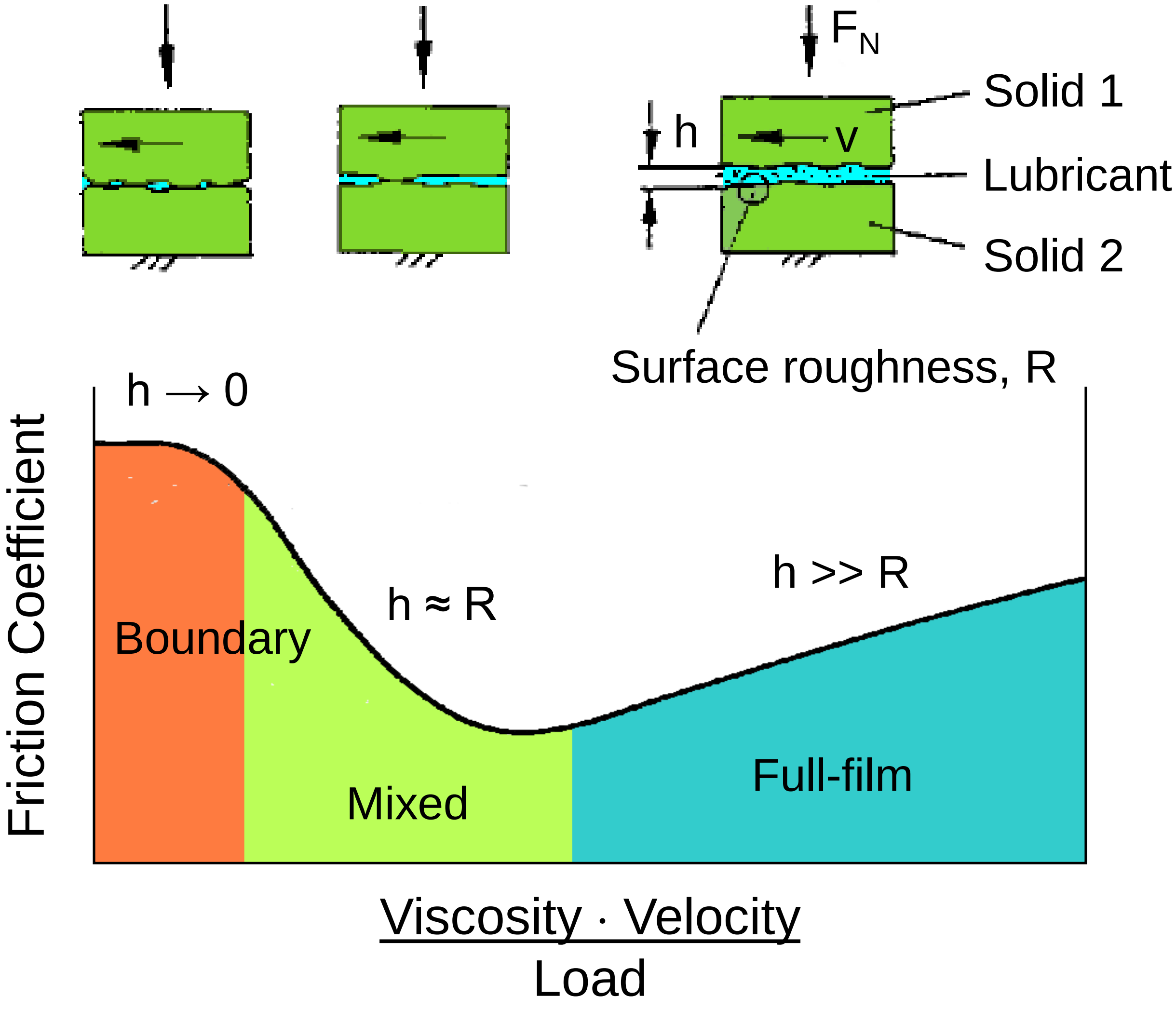
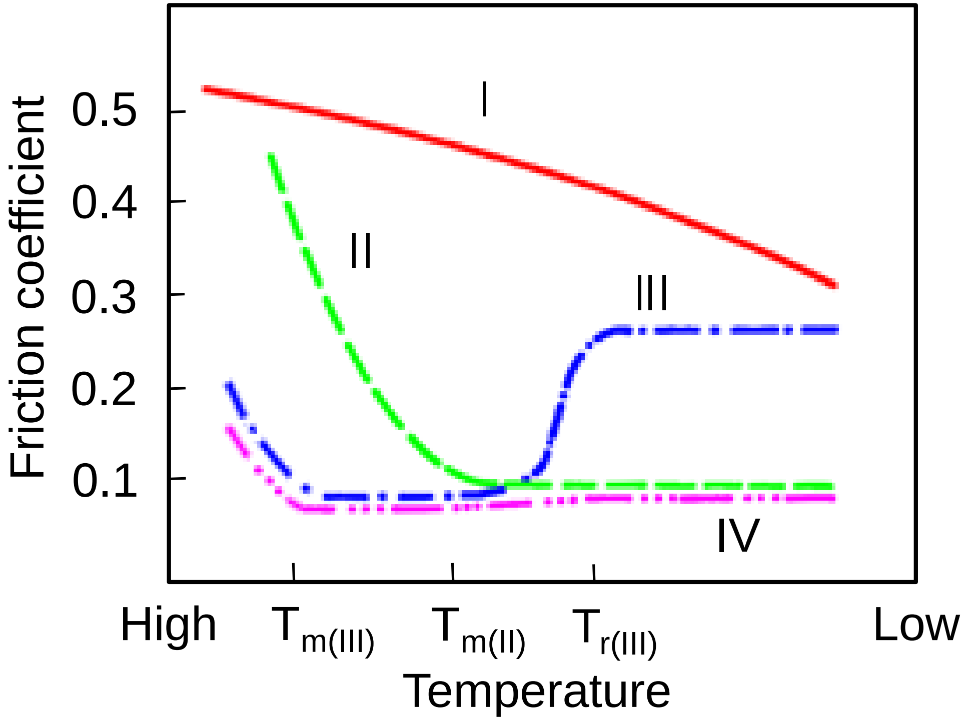
Lubricated Friction



Friction in Boundary Lubrication



I – Nonpolar base oil

II – Fatty acid dissolved in the base oil: reacts with the metallic surface forming a metallic soap

III – EP additive dissolved in the base oil: reacts when T_r is reached

IV – Hypothetical curve for an effective combination of II and III

Surface Film Formation

Approach	State-of-the-art	Hypothesized
Input	Extreme pressure and anti-wear agents containing S, Cl, P, etc.	
Methods and means	**Complex** formulation of **general-purpose** oil as a means of transportation **Uncontrolled** interaction during service	**Simple direct tailored** surface treatment during manufacture
Outcome	**Non-uniform** surface film	**Uniform** surface film
Impact	**Good oil lubricity** leading to low friction and wear	**Superior oil lubricity** leading to ultra-low friction and wear

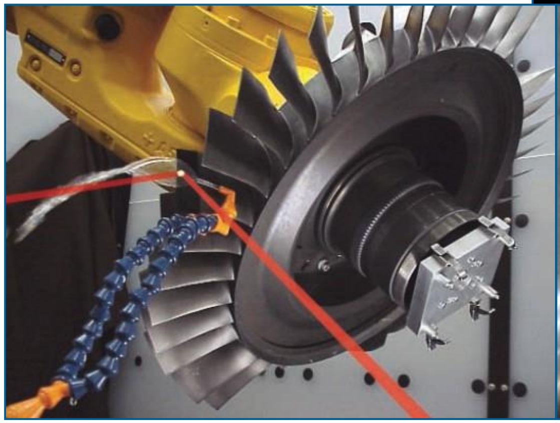
Surface Finishing Processes

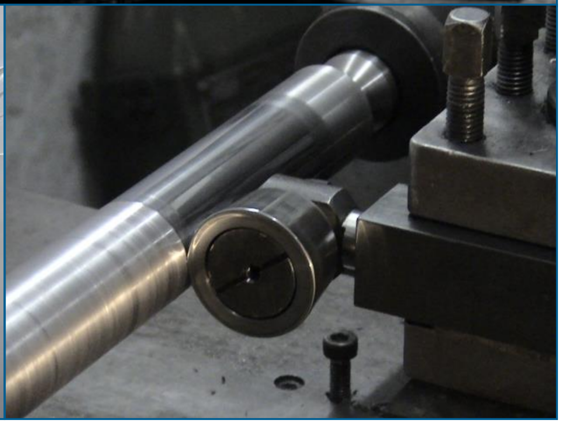
Abrasive processes

Grinding, honing, lapping, polishing, etc.

Cold-working processes

Shot peening, laser-shock peening, burnishing, etc.

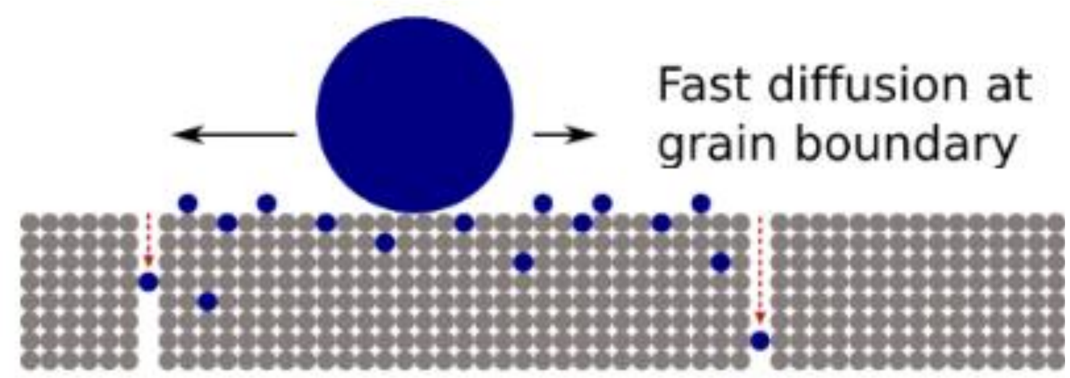




Deformation Induced Diffusion

The surfaces are activated by heat and rupture of atomic bonds at newly generated grain boundaries and dislocations.

This leads to anomalous acceleration of the diffusion activity.

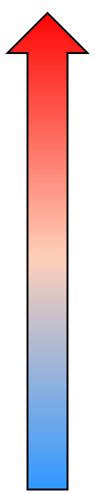


Given the presence of such elements as sulfur, chlorine or phosphorus in the immediate environment DURING the finishing mechanical treatment, stable lubrication-beneficial subsurface layers can be formed in advance

Potential Pathway

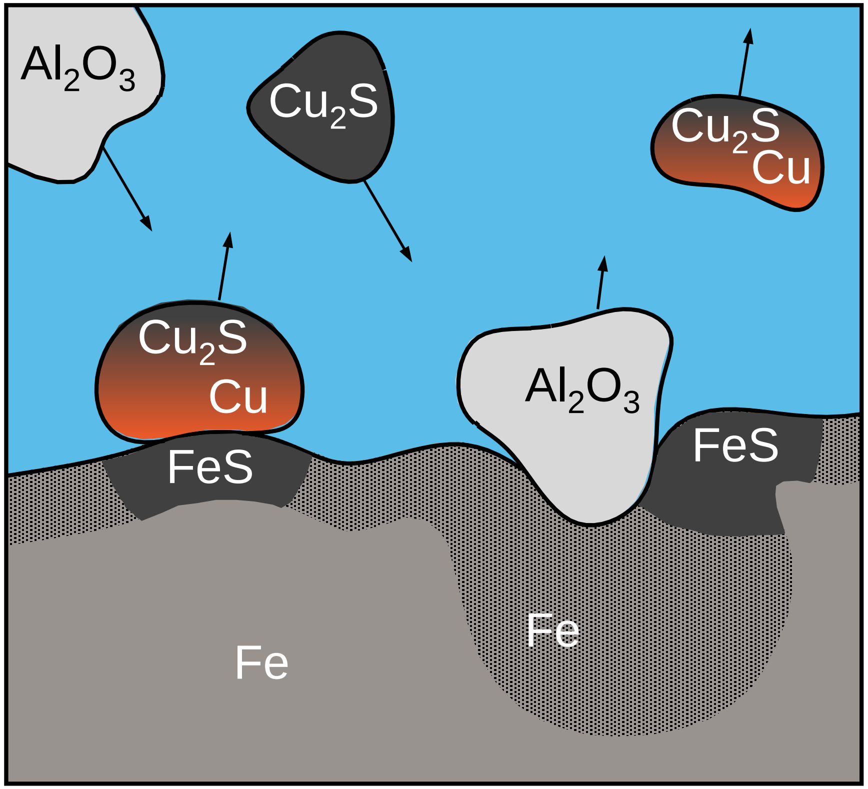
Displacement reaction

Most reactive

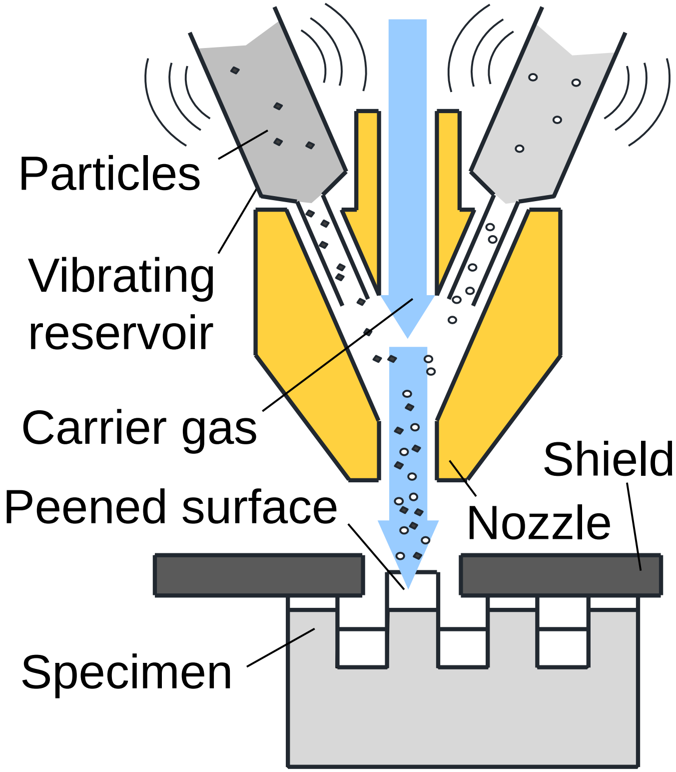


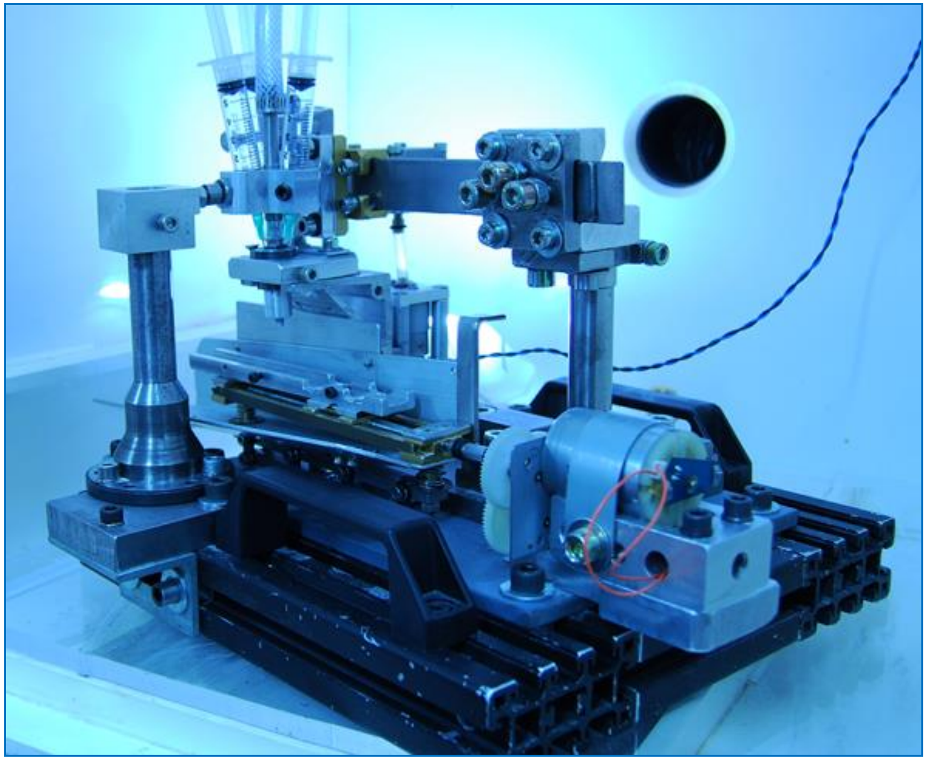
Al	(-1.662)
Fe	(-0.447)
Mo	(-0.200)
W	(0.100)
Cu	(0.342)

Least reactive



Surface Treatment



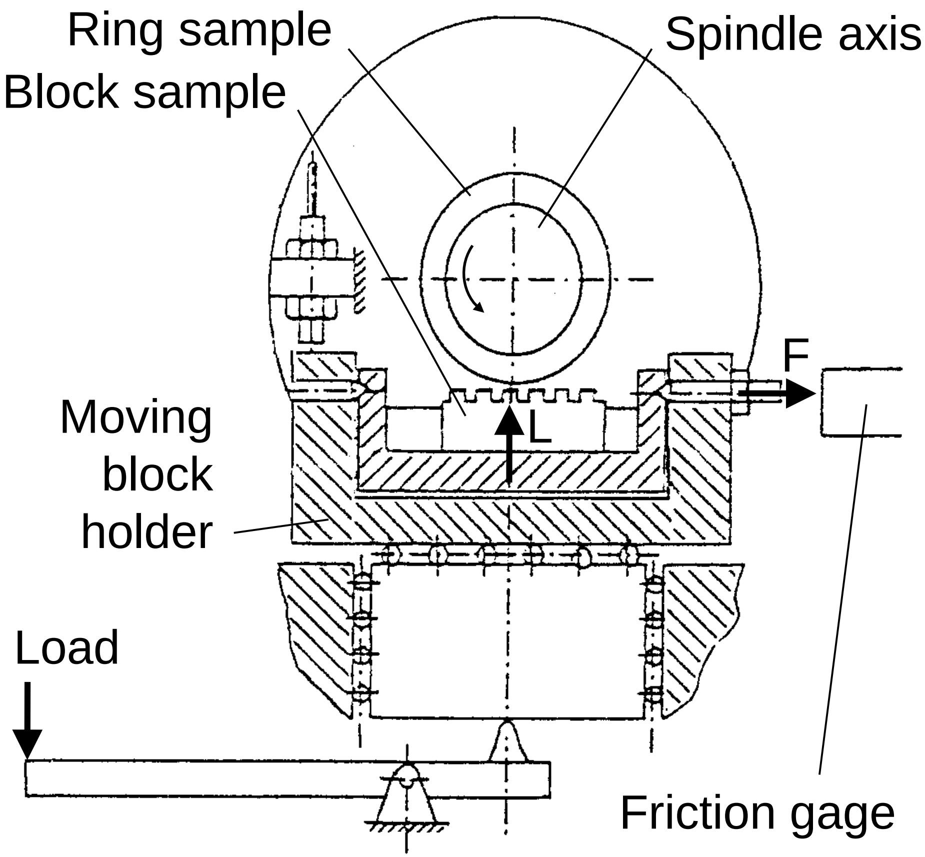


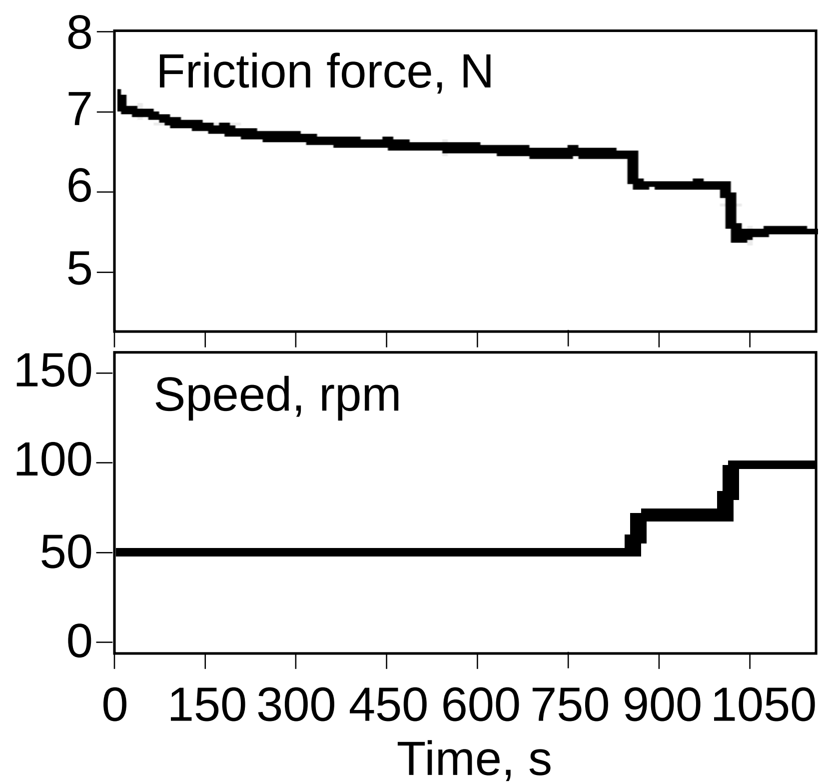
Treated surfaces: Ground cast iron
Shot peening media: Al_2O_3, size 44-75 μm, and Cu_2S, size <44 μm
Carrier gas: N_2, pressure 2 bar

Material and Surface Properties

Material	Al_2O_3	Cu_2S	Cast iron (CI)	CI after Al_2O_3	CI after Cu_2S	CI after Al_2O_3+ Cu_2S	Mild steel
Use	Shot peening media		Tested surfaces				Counter surface
Hardness, HV	2,600	90	191±16	250±35	214±52	256±25	307±39
R_a, μm	-	-	2.3	1.0	0.7	1.0	0.3

Experimental Details





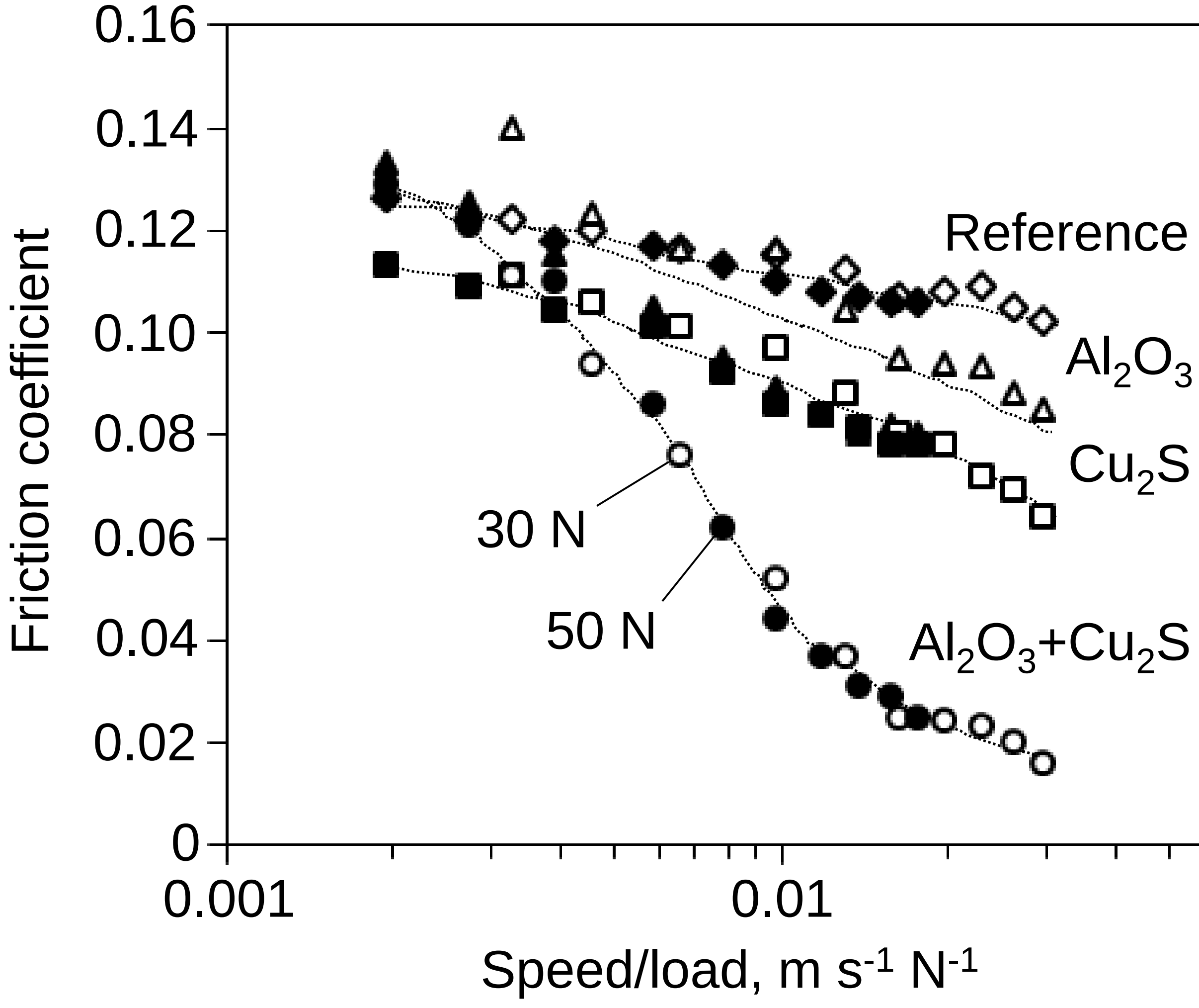
Rings: Mild steel

Blocks: Grey cast iron

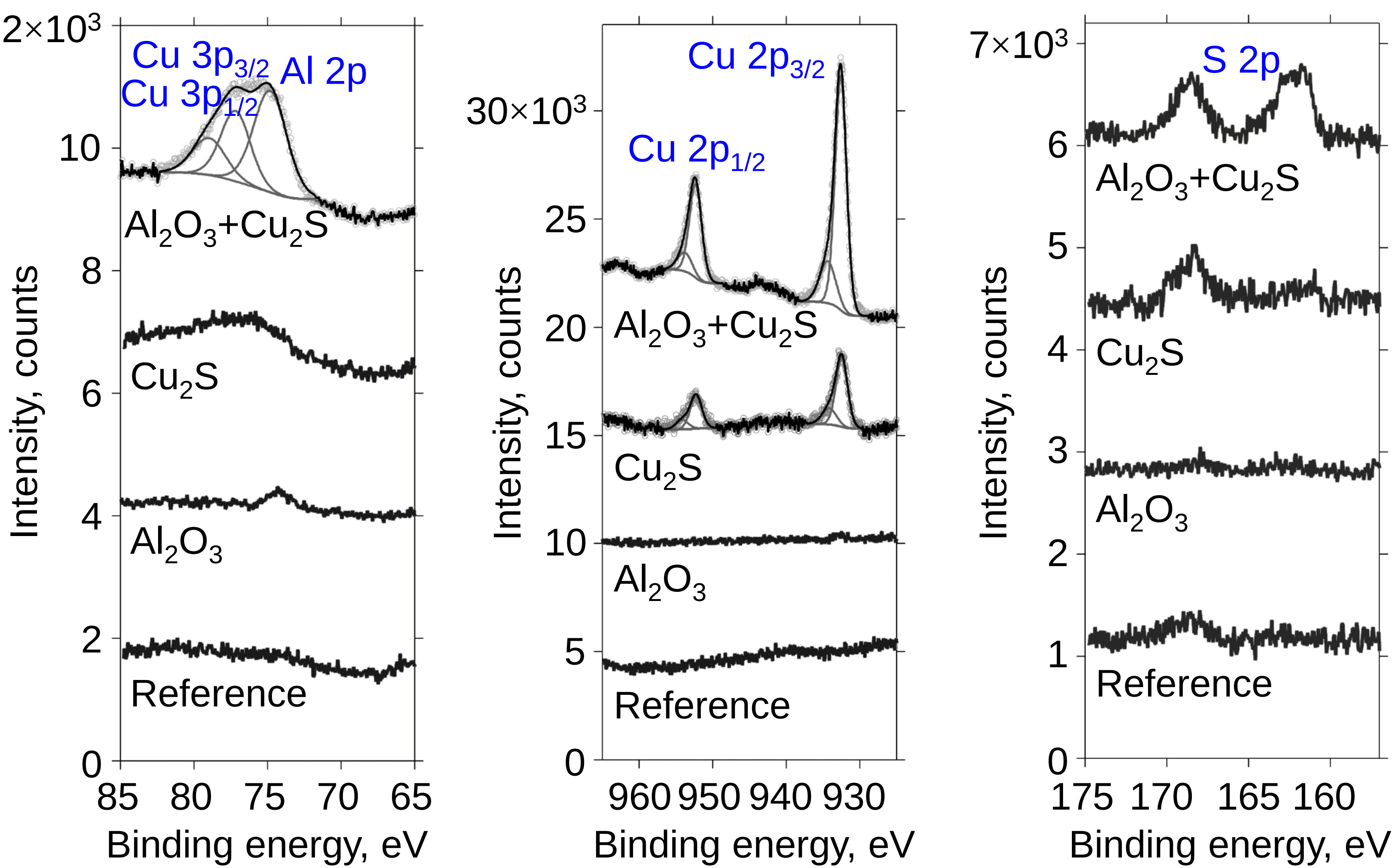
Loads: 30, 50 N   Speeds: 0.1-0.9 m/s

Lubrication: SN90 base oil, 55 cPa s @ 30 °C, 2 drops/min

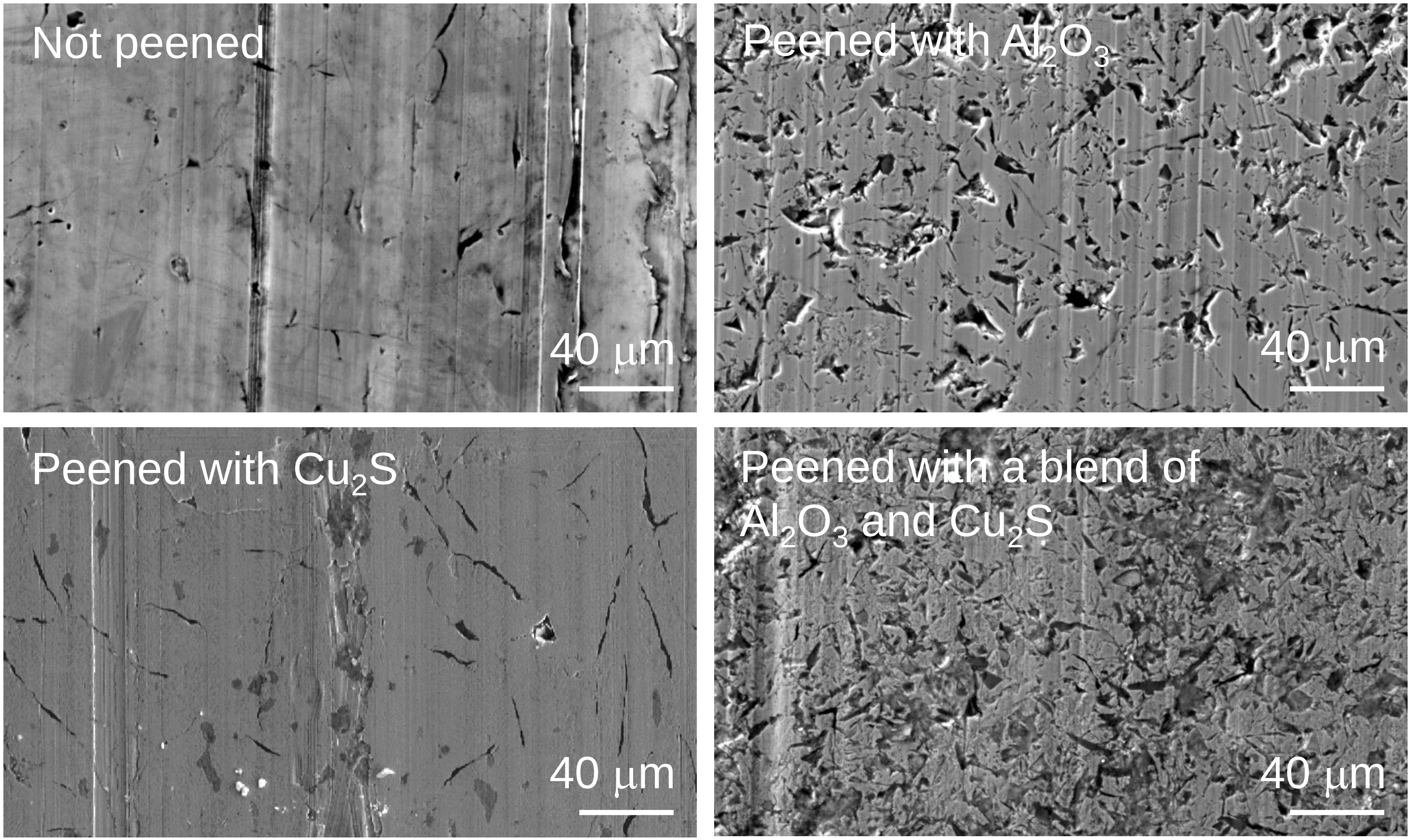
Frictional Performance



X-ray Photoelectron Spectra



Worn Surfaces



Summary

- A direct route to the formation of a surface layer of superior lubricity is presented as an alternative to the use of oil additives for friction reduction
- An ultra-low friction coefficient of about 0.01 is obtained with base oil lubrication after shot peening the surface using a mixture of Cu_2S and Al_2O_3
- Preliminary results suggest that the surface treated with a blend of Al_2O_3 and Cu_2S particles exhibits high wear resistance

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