Unlocking Tribological Performance of Silver-Infused $Cu-Al_2O_3$ Self-Lubricating Cermet

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Introduction

Background & Significance

- Cold spray (CS) is a solid-state process through supersonic deposition for metal or composite powders without material oxidation.

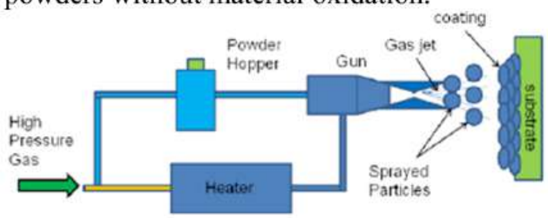
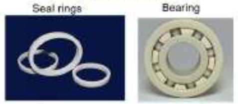


Fig 1. Schematic diagram of CS process

- Cermet materials blend hardness of ceramics with toughness of metals for tribological applications.
- Cu-based cermet coatings ($Cu-Al_2O_3$, $Cu-Al_2O_3$-Ag) find high temperature tribological applications due to their mechanical strength, wear resistance, and self-lubrication.
- **Potential applications:** The development of long-life self-lubricating bearings used in harsh environment.

Tribological Applications

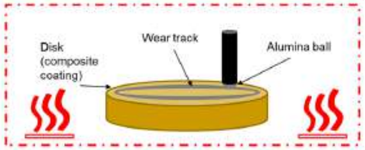


Key Challenges

- Optimizing the trade-off between hardness and lubrication.
- Understanding the role of Ag in tailoring cermet microstructure, and thus friction reduction.
- Design of cermet system for a wide range of tribological conditions.

Materials and Methods

Coating designation	Constituents (vol.%)		
	Cu	Al_2O_3	Ag
Cu	100	-	-
$Cu-Al_2O_3$	50	50	-
$Cu-Al_2O_3$-Ag5	45	50	05
$Cu-Al_2O_3$-Ag10	40	50	10



- Normal load: 50N
- Sliding speed: 50mm/s
- Sliding distance: 50m
- Temperature: 25 and 450 °C

Fig 3. Schematic of experimental setup

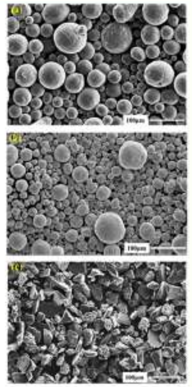


Fig 4. SEM images of feedstock powders (a) Cu, (b) Ag, and (c) Al_2O_3

Results: Microstructure and hardness

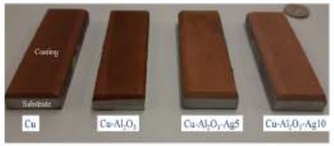


Figure 5. The cold spray deposited coatings on the Al6061 substrate.

Phase determination through Microstructure

Coating	Cu (%)	Al_2O_3 (%)	Ag (%)	Porosity (%)
Cu	98.98±0.12	-	-	1.02±0.10
$Cu-Al_2O_3$	89.77±1.97	8.6±1.03	-	1.62±0.10
$Cu-Al_2O_3$-Ag5	82.4±1.62	7.83±1.03	8.46±1.18	1.31±0.11
$Cu-Al_2O_3$-Ag10	74.62±1.70	6.51±0.96	17.94±0.95	0.93±0.14

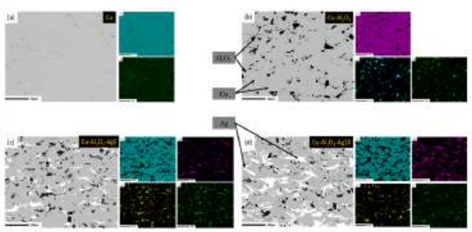


Fig 6. Cross-section SEM images and EDS map of cold sprayed composite coatings with different powder blend ratios (a) Cu, (b) $Cu-Al_2O_3$, (c) $Cu-Al_2O_3$-Ag5, and (d) $Cu-Al_2O_3$-Ag10.

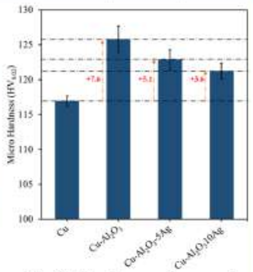


Fig 7. Hardness of sprayed coatings

Results: Tribology and hardness

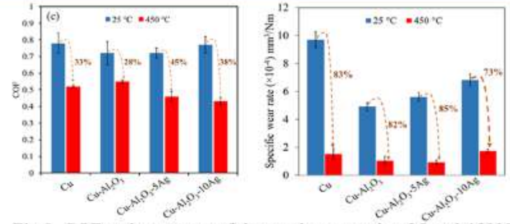


Fig 8. COF and wear rate of the coatings tested at 25 and 450°C

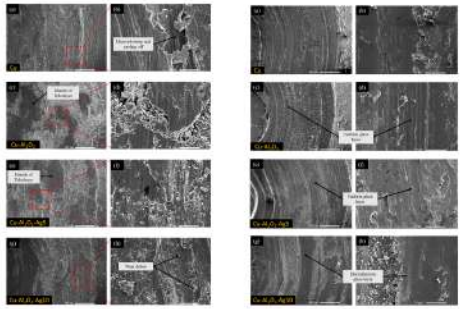


Fig 9. SEM images of the wear track at 25 and 450°C of different compositions (a, c, e, g) at 50X and (b, d, f, h) at 500X magnification.

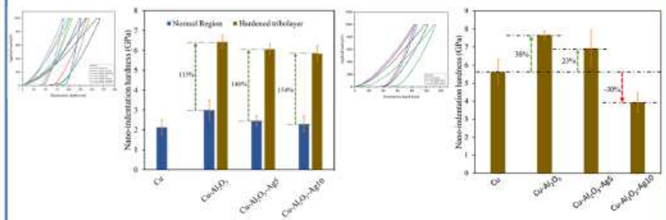


Fig 10. The load-displacement curve and measured hardness values of the wear track at 25 and 450°C from the nano-indentation test

Conclusions

- Al_2O_3 addition increased coating hardness (~8%), but Ag reduced ceramic retention and hardness.
- At 25°C, Al_2O_3 hardened the tribolayer, lowering COF and wear rate.
- High Ag caused ceramic dislodging, increasing both COF and wear rate at 25°C.
- At 450°C, wear rate decreased for all; $Cu-Al_2O_3$-Ag10 had the lowest COF (~0.4), but increased wear.
- $Cu-Al_2O_3$-Ag5 showed the best tribological properties, highlighting composition's role in CS coatings.

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