



Carbon-Containing Bronzes for Self-Lubricating Bushings and Bearings

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Background

Lead has long been used in metal parts due to its ability to make alloys easy to machine and process, while also providing high lubricity for sliding components. However, recent worldwide legislation has limited lead usage in industry due to its impacts on the environment and human health.

Bushings and bearings are widely used in automotive and engineering applications. Billions of these parts are produced each year with lead-containing alloys. **The aim of this project is to maximize carbon content (as a substitute for lead) in a novel Cu-Mn-Ni-Al bronze alloy for use in bushings and bearings.** Because carbon is typically insoluble in copper, the project reveals how alloy composition and heat treatments can retain carbon in the microstructure as a viable lead-free alternative.

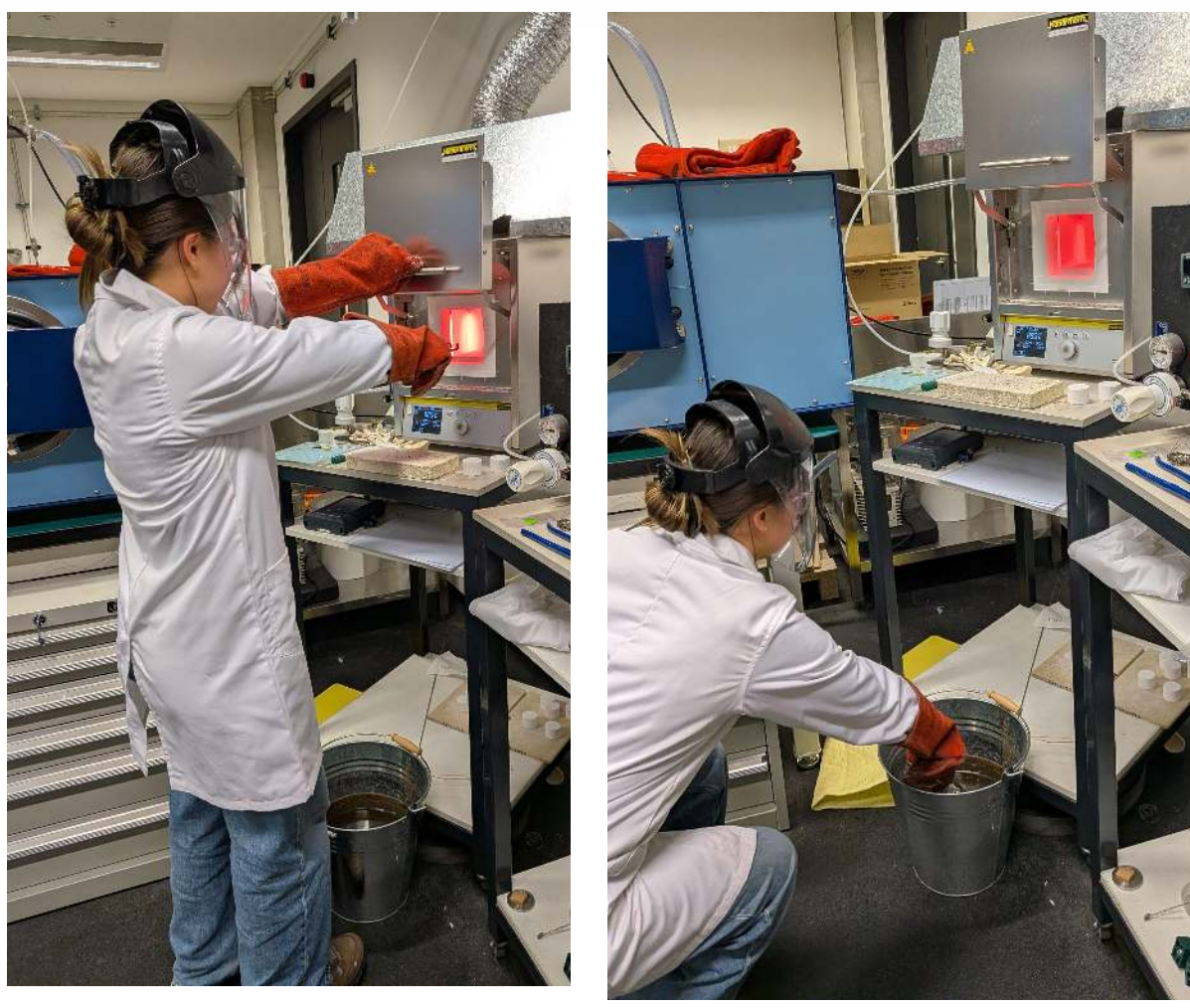


	Leaded Bronzes	Carbon Alternative
Inexpensive	✓	✓
Self-lubricating	✓	✓
Non-toxic	✗	✓
Easy to Incorporate	✓	✗



Methods

- 1. Charge Preparation**
Cut and weigh pure elements to create alloys of specific compositions
- 2. Arc & Induction Melting/Casting**
Combine elements into a homogenous alloy using arc melters and an induction furnace.
- 3. Heat Treatments**
Hold alloy at temperatures as high as 900°C in a muffle furnace to achieve equilibrium microstructures.
- 4. Grinding and Polishing**
Grind and polish sections of alloy to 1µm finish for analysis
- 5. Optical Imaging & Processing**
Examine the distribution and amount of carbon within the alloys' microstructure



Katie is taking the 900°C heat treated samples from the furnace and quenching them in water!

- 6. SEM Imaging**
Determine phase compositions, and if the alloy has undesirable carbides
- 7. Hardness Testing**
Identify trends in hardness across compositions and heat treatments
- 8. Pin-on-disk Friction Testing**
Characterise surface friction/lubricity

Alloy Production

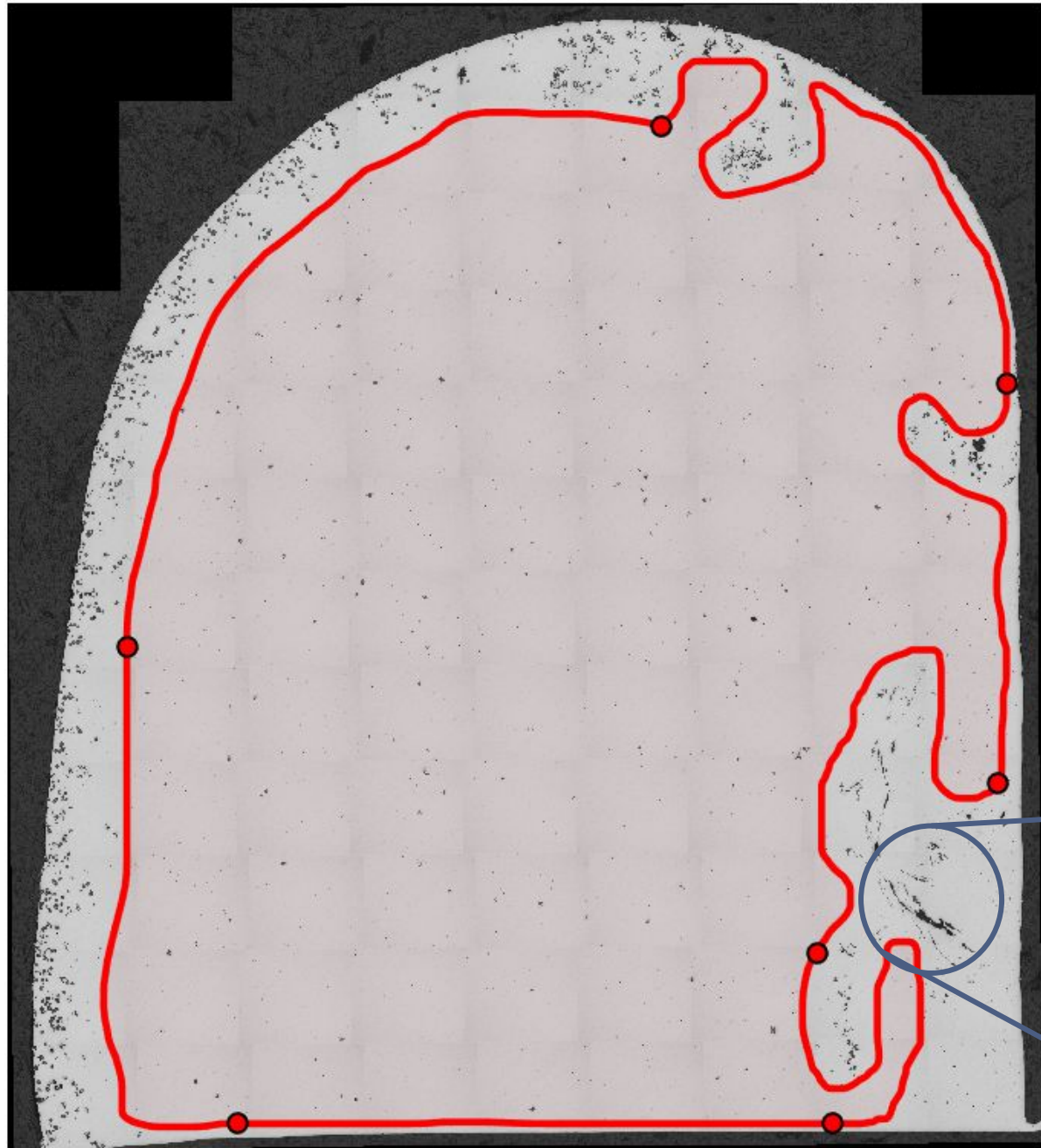


Metal alloy buttons of different sizes (small for optical analysis, large for friction testing) were made by arc melting metal components in a mini arc melter (left), a big arc melter (middle), and an induction furnace (right).

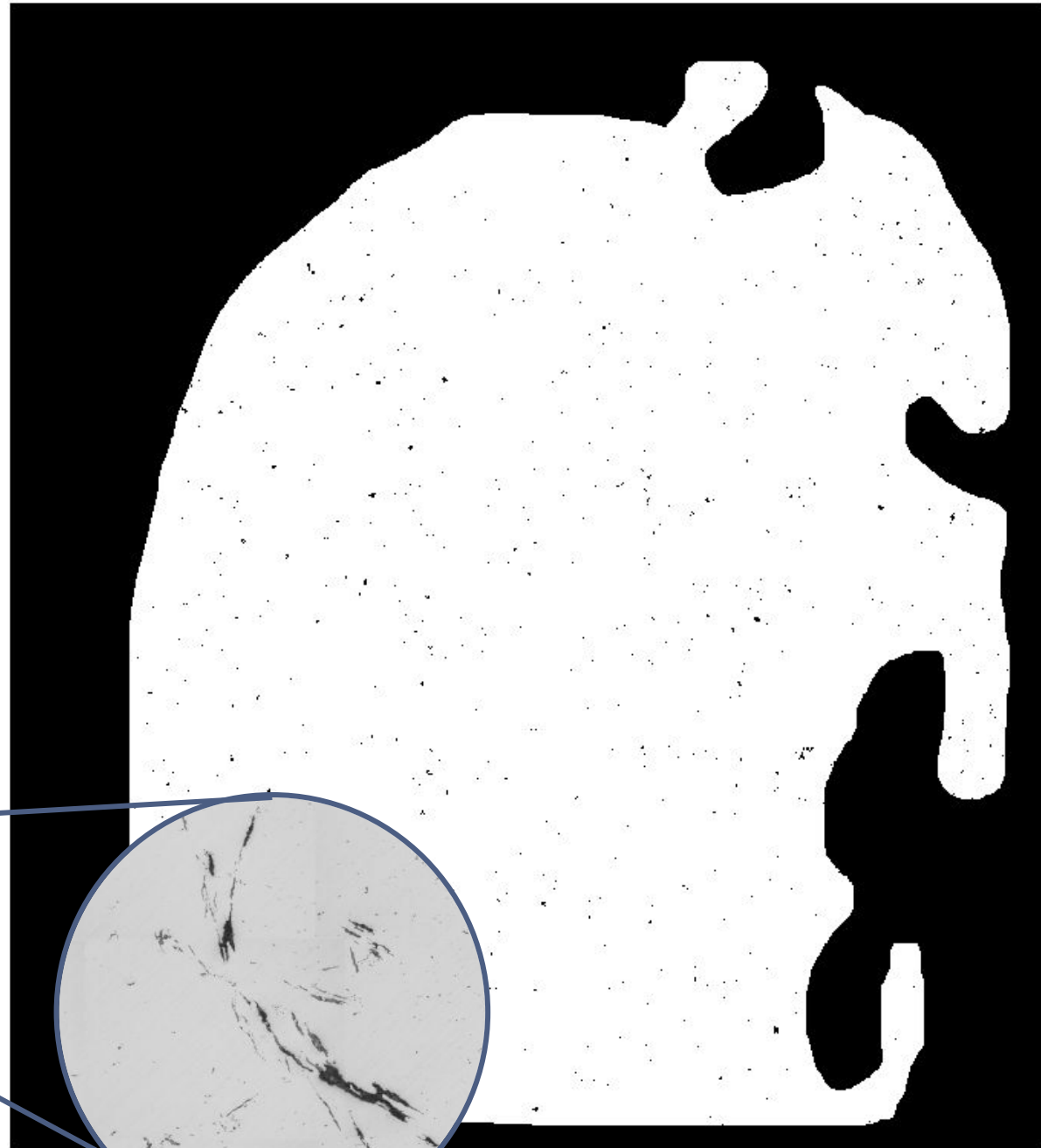
We made 21 novel alloys!



Analyzing Carbon Content

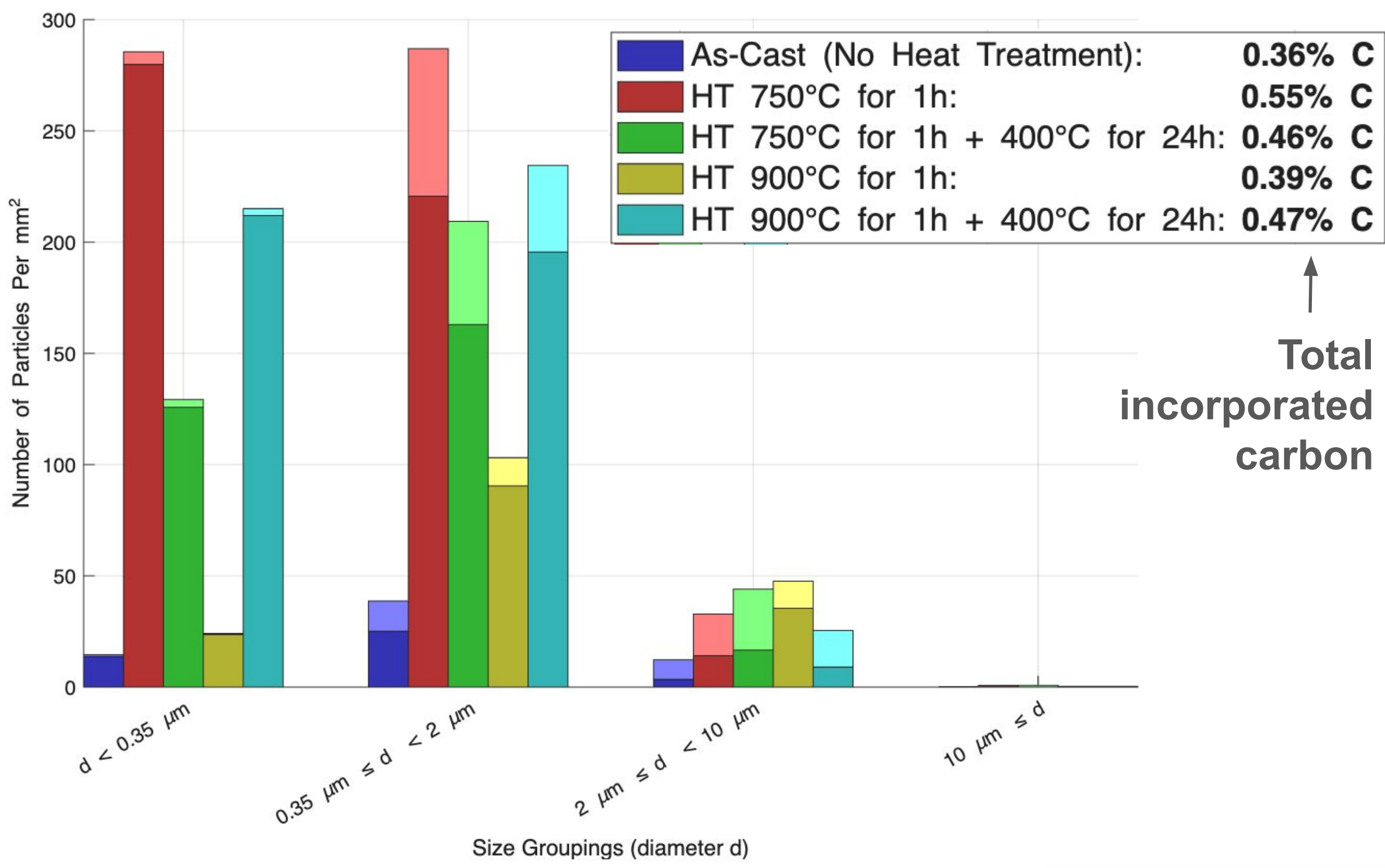


(Left) Stitched image of sample surface on optical microscope with ROI outlined, and (right) processed ROI after MATLAB thresholding.



Magnified view of a carbon mass not incorporated during the melt, thus excluded from analysis

Optical images are processed through MATLAB using a custom thresholding algorithm to analyze how much carbon has been incorporated within the alloy microstructure. Regions of interest (ROIs) are selected to represent the bulk alloy containing carbon precipitates, while excluding large carbon regions not incorporated during the melt. The area percentage of detected carbon within each ROI is then used to estimate the atomic percentage of carbon.

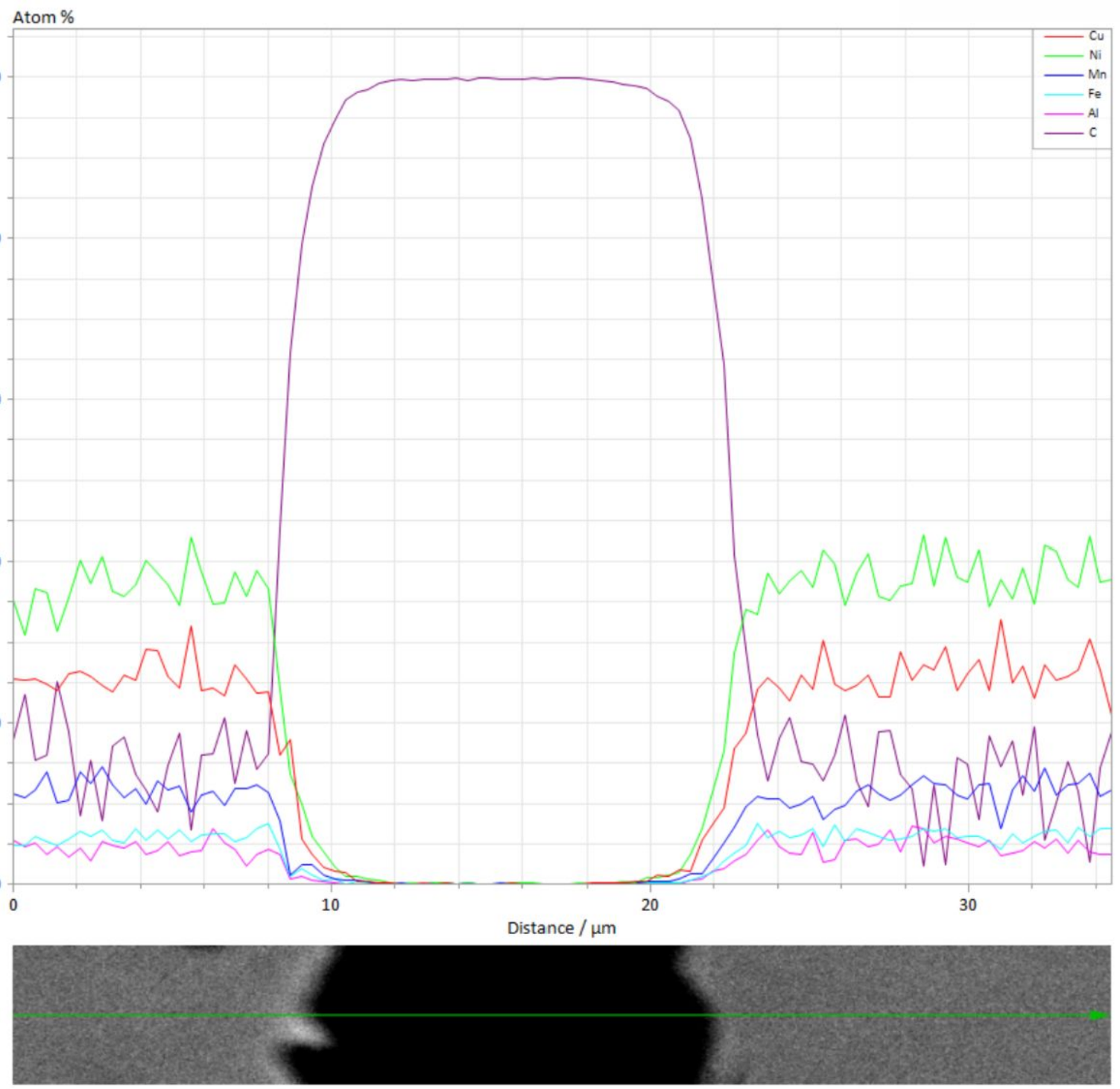
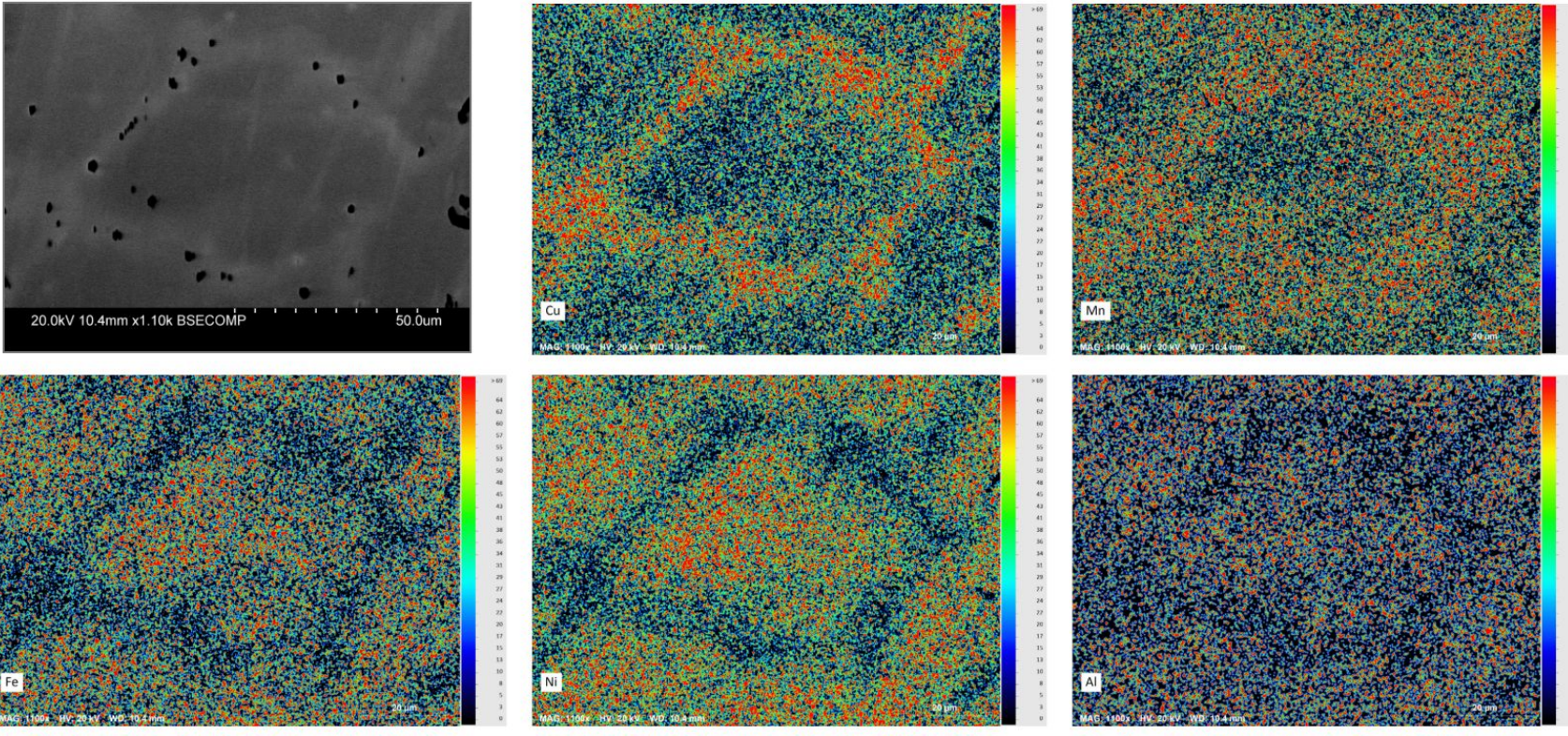


Histogram of a Cu-Mn-Ni alloy capturing carbon particle counts per mm² across four C particle diameter groups for each heat treatment ("HT")

Microstructural Analysis

A scanning electron microscope (SEM) captures images of alloy microstructures. Energy dispersive spectroscopy (EDS) shows compositions of the phases. A key goal for EDS was to confirm that the black dots were lubricating graphite (C), rather than hard, abrasive carbides (a compound of C with a metal).

EDS was also used to characterize and investigate the pattern of C across two phase structures that appeared in alloys with Al.



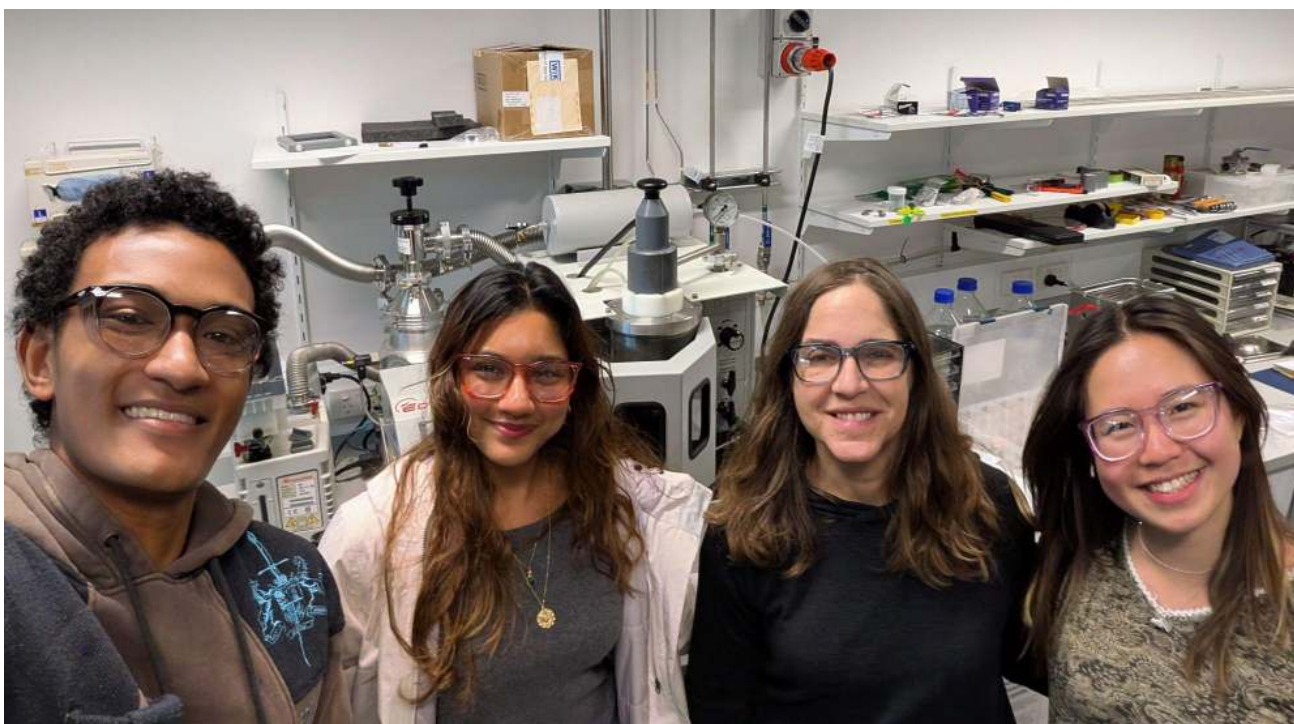
(Top) EDS line scan data confirming that the scanned black shape is graphite, not a carbide.

(Left) SEM image in the top left, next to EDS area maps distinguishing 2 phase compositions in an Al-containing alloy.



Acknowledgements

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Conclusions



Through the use of carbon-compatible elements, significant amounts of carbon were incorporated into several unique bronze alloys. Like graphite pencils, our alloys leave behind a trail of carbon when smeared on a sheet of paper; a promising indication these alloys hold the self-lubricating properties that are essential for bushings and bearings. Testing with pin-on-disk friction tests will evaluate these properties.

