Melt Processing of Covetic Materials

CPS Agreement 28419

National Energy Technology Laboratory-Office of Research and Development

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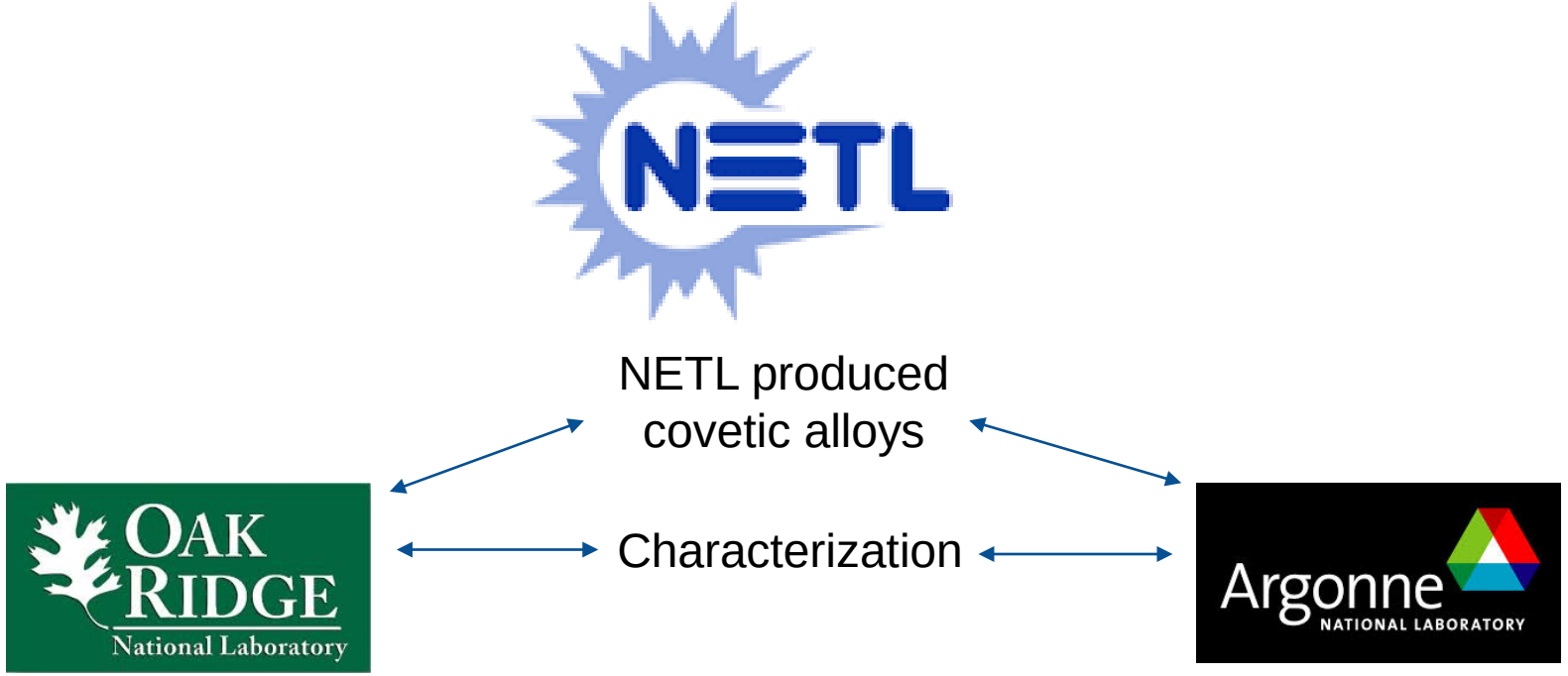
Technical Approach— Overarching Approach

- NETL's overall approach is to:
  - Evaluate and re-melt existing materials. This will provide information on: (a) the stability of nano-carbon and (b) the ability to recycle these unique materials—which is important for life cycles.
  - Replicate the IM methodology to produce these alloys in order to determine reasons for variability in the product
  - Improve current IM methodology and develop alternative melt process methods to produce more uniform alloys.
- NETL melted/fabricated covetic materials have been made available to ORNL and ANL for advanced characterization.

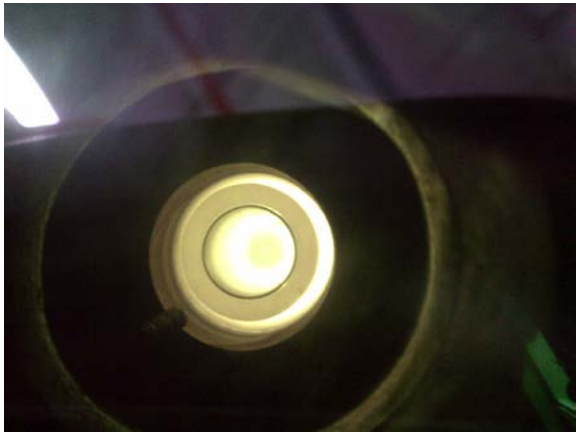


Results and Accomplishments

Evaluation of Existing Materials

- Small melts of existing covetic materials were made and compared to conventional Cu.

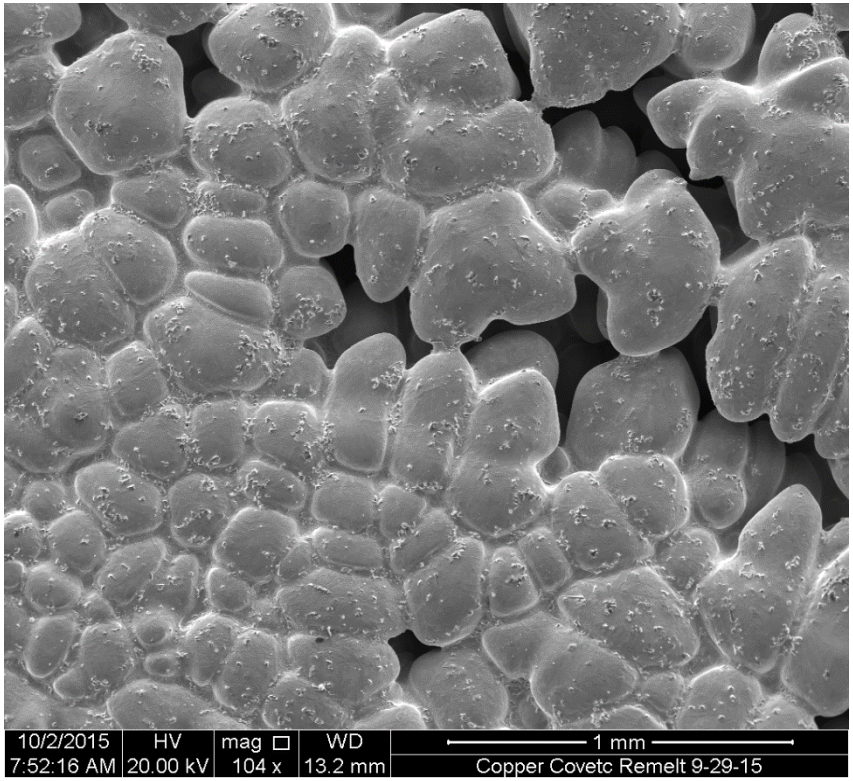
High purity Copper



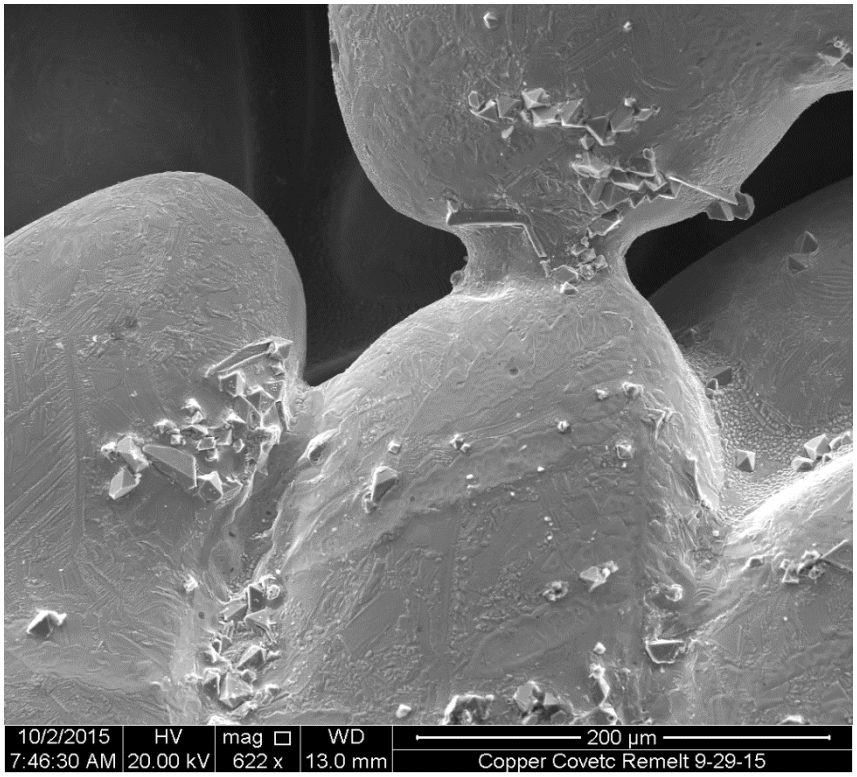
Covetic Copper

Results and Accomplishments

Evaluation of Existing Materials



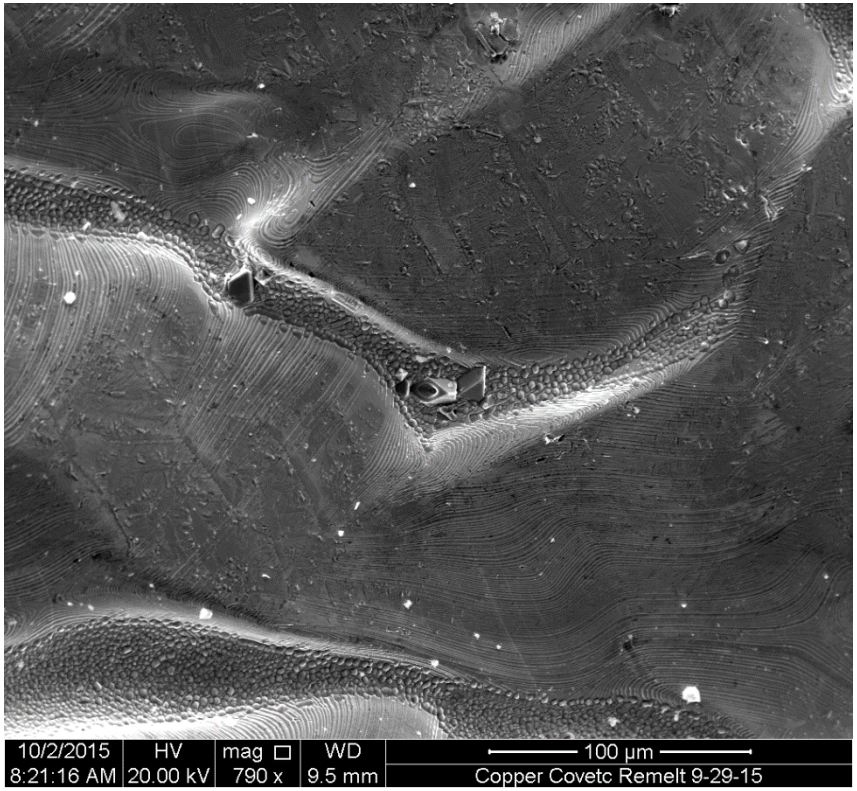
Top surface of the re-melted copper covetic ingot showing a dispersed particulate (secondary electron image).



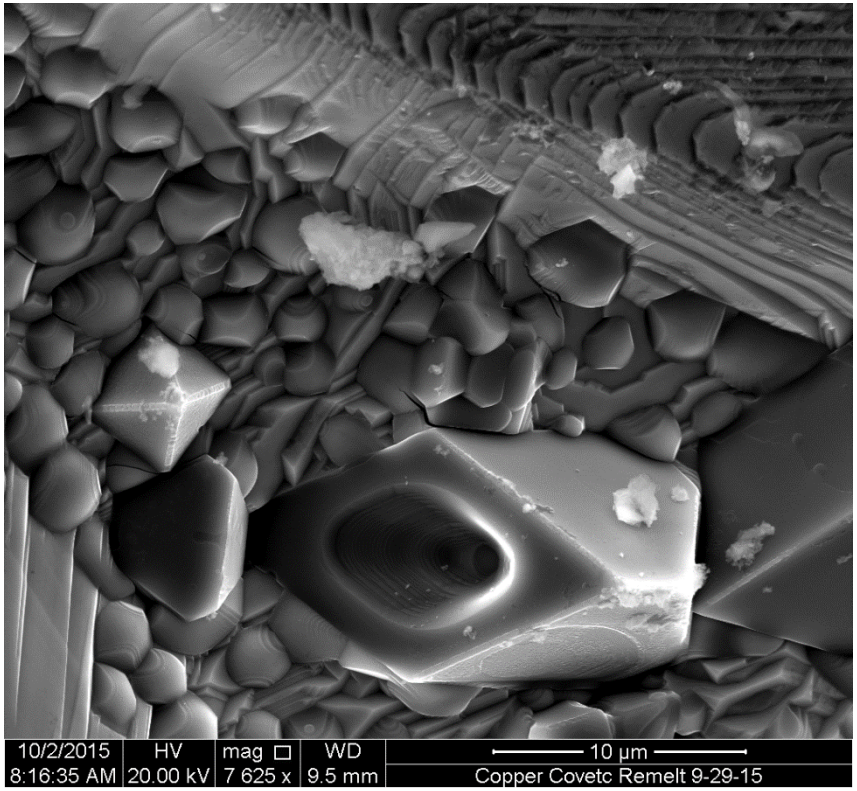
Closer examination revealed the particles were angular and composed primarily of iron and oxygen. This could possibly be a contaminant from melting or other processing steps (either at NETL or the supplier). The top surface of the pure copper ingot (not pictured) had no anomalous features.

Results and Accomplishments

Evaluation of Existing Materials



In addition to the randomly dispersed particulate, several interdendritic regions were observed having bands of particulate and an interdendritic product.

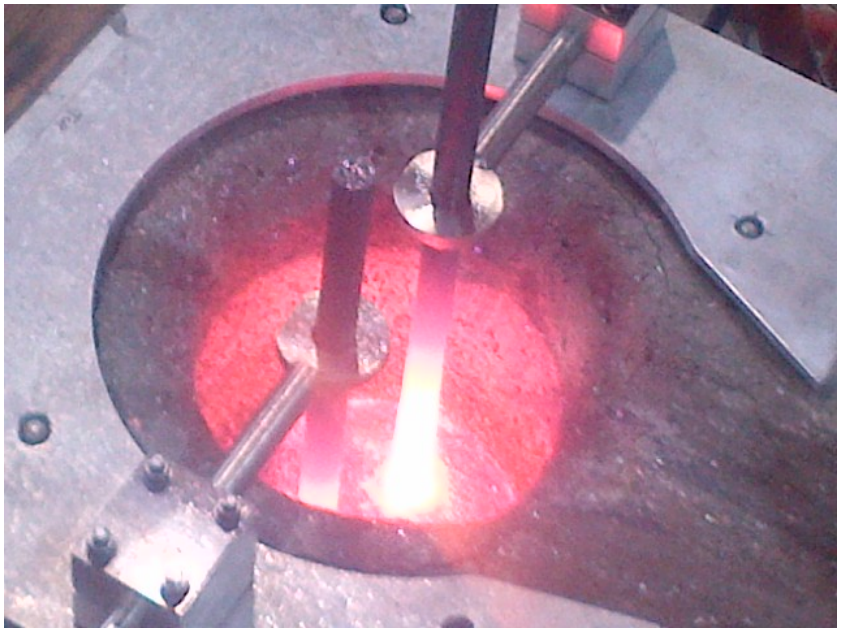


Within the interdendritic regions, the angular particles (shown above) were once again high in iron and oxygen, while EDS scans on the rounded interdentritic particles registered only copper, oxygen, and carbon.

Results and Accomplishments

Refinement of Existing Melt Practice

- Modified NETL's 300 pound air induction furnace to replicate conventional covetic melt practice.
  - Dedicated 100KW induction power supply.
  - Secondary power supply (1000A) for covetic reaction.
  - Current lead fixtures have been built.
  - Multiple melt trials have been made.
  - Portions of ingots have been fabricated.



Results and Accomplishments

Refinement of Existing Melt Practice

- Improvements over initial trials include digital readout of externally applied DC current.
- Further plans are to incorporate active stirring and continuous recording of DC current.

Results and Accomplishments

Alternative Melt Processing

- NETL has explored alternative methods to achieve covetic carbon. These methods apply current to the melt through different means than the induction melting method. (Patent application pending).
- To our knowledge, NETL was the first to apply this technique to making covetic material.
- Considering its uniqueness and potential value as an invention, NETL has chosen not to disclose the technique here but rather present some of our early findings.

Results and Accomplishments

Alternative Melt Processing

- Alternative melt trials produced material.

This melt had problems with porosity which is often observed in covetic alloys—ingot sections fabricated well

This melt produced a solid ingot (116lb) and was subsequently hot worked in 20-30lb sections.

Results and Accomplishments

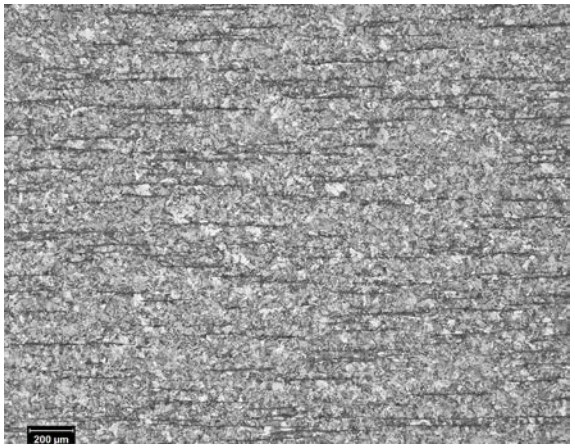
Alternative Melt Processing

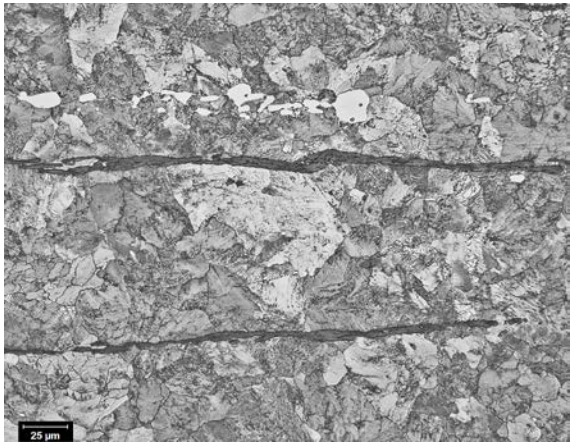
- Several sections were hot worked into plate by forging and rolling.
- This material had good hot work characteristics.

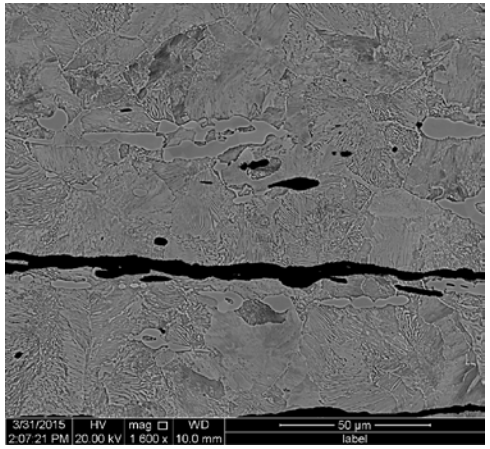
Results and Accomplishments

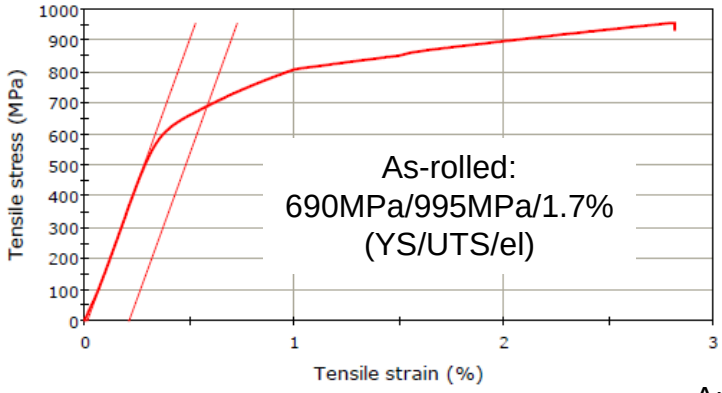
Alternative Melt Processing

- Microstructure: α-Fe with some Fe3C
- TEM analysis is ongoing to determine the level of covetic carbon
- Tensile ductility is improved by post rolling heat treatment.



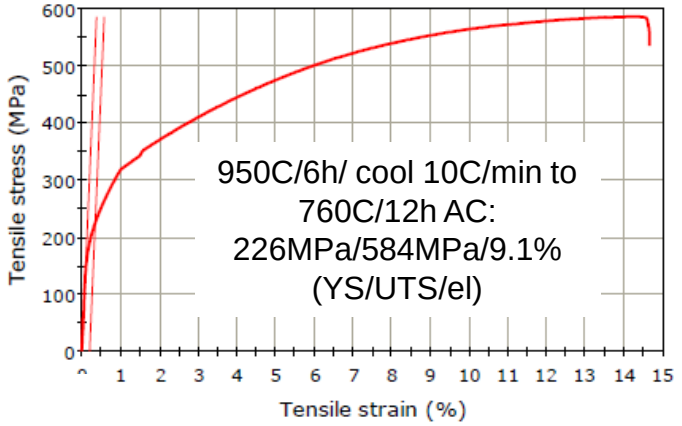






As-rolled

Annealed 1018:
295MPa/395MPa/40%
(YS/UTS/el)



Heat treated

Next Steps

- Our next covetic induction melting trial will incorporate DC current recording and active stirring.
- Cold rolling covetic copper is planned to provide samples for ANL.
- Hot worked material will continue to be evaluated at NETL and made available to ORNL and ANL.