A direct process for wire production from sulfide concentrates

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Prof. Antoine Allanore, MIT

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Overview

Timeline:

Project Start Date:
08/01/2018

Budget Period End Date:
07/31/2019

Project End Date:
TBD

Barriers and Challenges:

- Large scale and long operation to evaluate copper product purity
- Management of concentrate impurities (Fe, S)
- Evaluate process for wire production

AMO MYPP Connection:

- Process heating and/or intensification

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$1,893,941	$478,562	$2,372,503	20.2
Approved Budget (BP-1)	$684,782	$214,324	$865,241	25
Costs as of 3/31/19	$487,019	$168,143	$655,162	25.6

Project Team and Roles:

- MIT: Prof. Antoine Allanore PI
- Support from Freeport McMoran, JX mining
- Exchange initiated with Rio Tinto

Project Objective

Problem

- Principles for copper extraction are >5,000 years old
- Process consists of numerous steps with slow recovery for valuable elements
- Sulfuric acid is a by-product

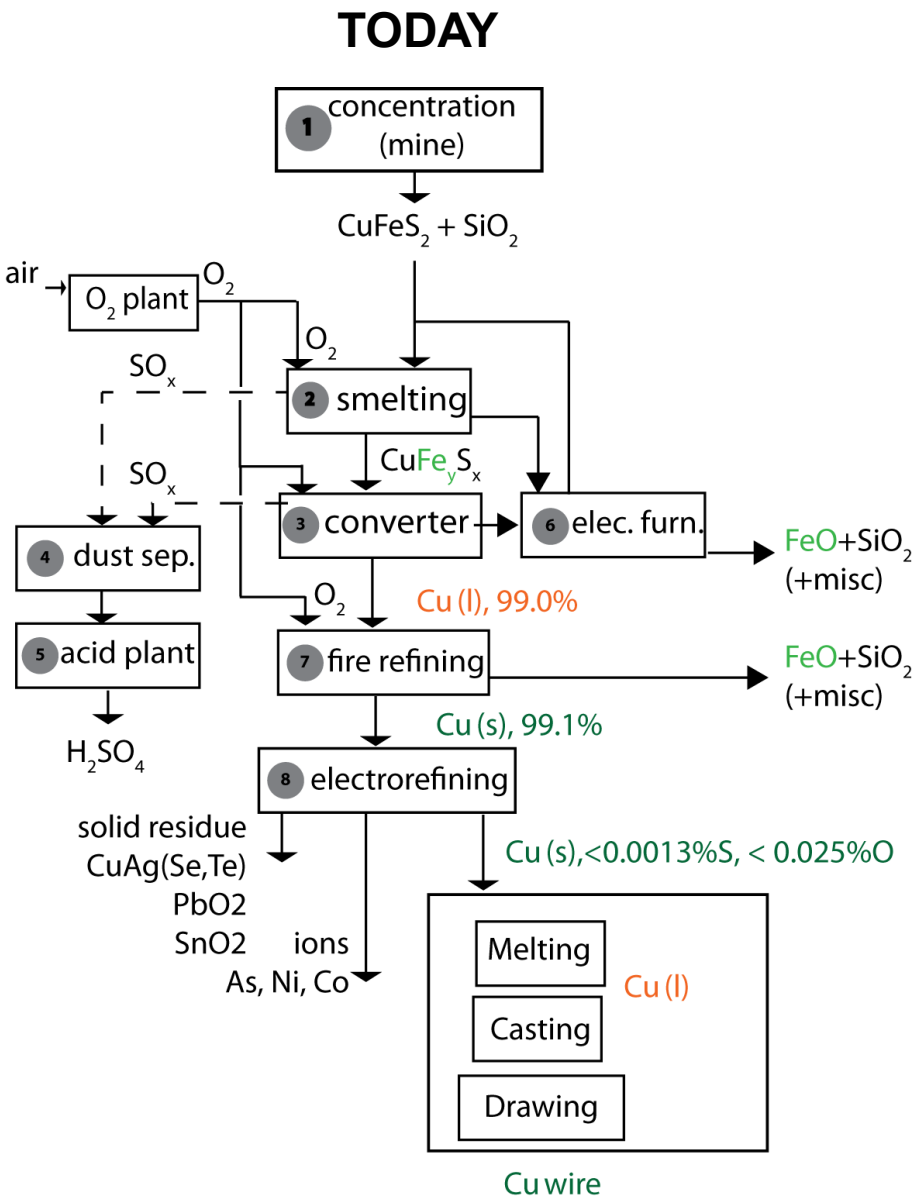
Objective: evaluate, construct and demonstrate performance of novel process to directly convert copper sulfide concentrate ($CuFeS_2$) to copper wire using solely electricity. Simultaneously produce elemental Fe, elemental S, ancillary elements in ore (Au, Ag, Se, Te, Mo, Re, Bi…).

- Demonstrate high productivity (6x Hall Heroult) with experimental reactor, and model operations of pilot scale plant to inform cost-model
- Decrease energy consumption by 5 to 20% with optimized electrolyte
- Investigate novel copper wire casting and refining processes

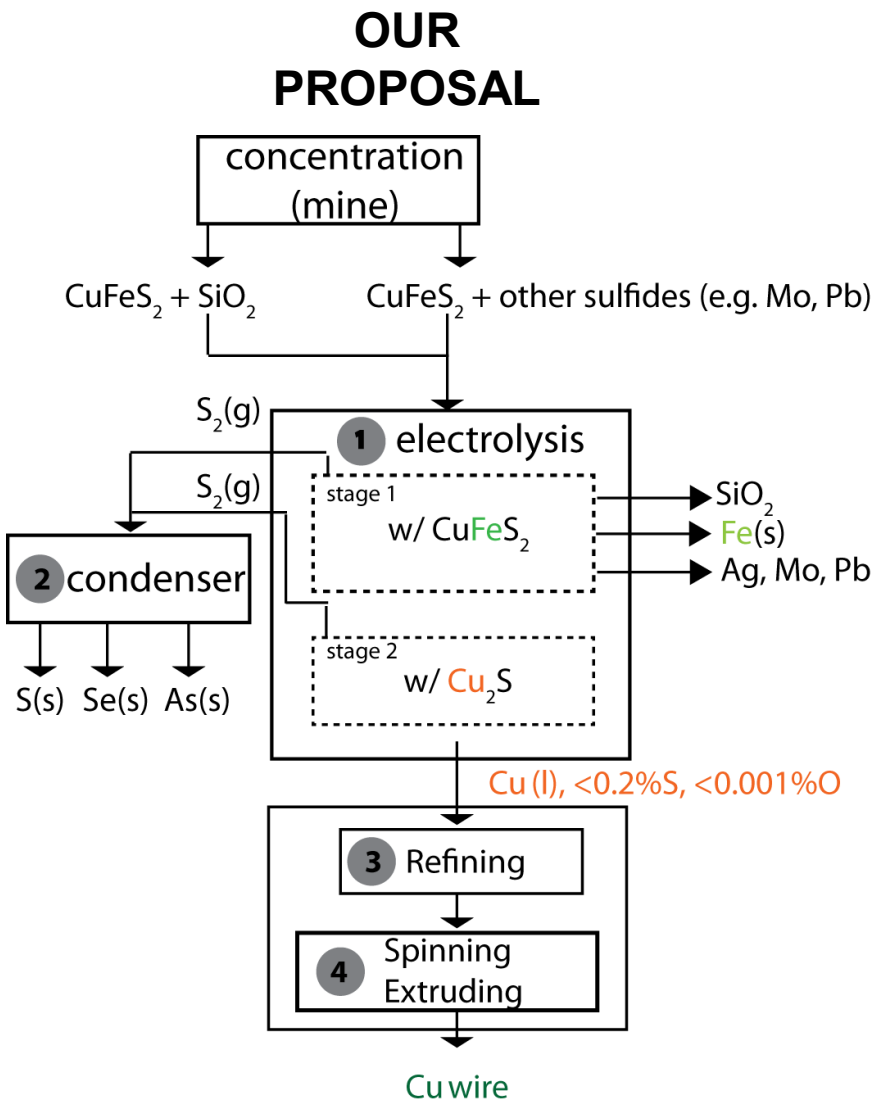
Alignment with AMO strategic goals

- Reduce high energy-consumption of conventional process (today 3600kWh/t_{Cu})
- Increase productivity from ore to wire
  - Expected surge in demand for wires with electrification
  - Expected surge in demand for Cu by-products (Te, Se, Mo, Ag…)

Technical Innovation



Technical Innovation



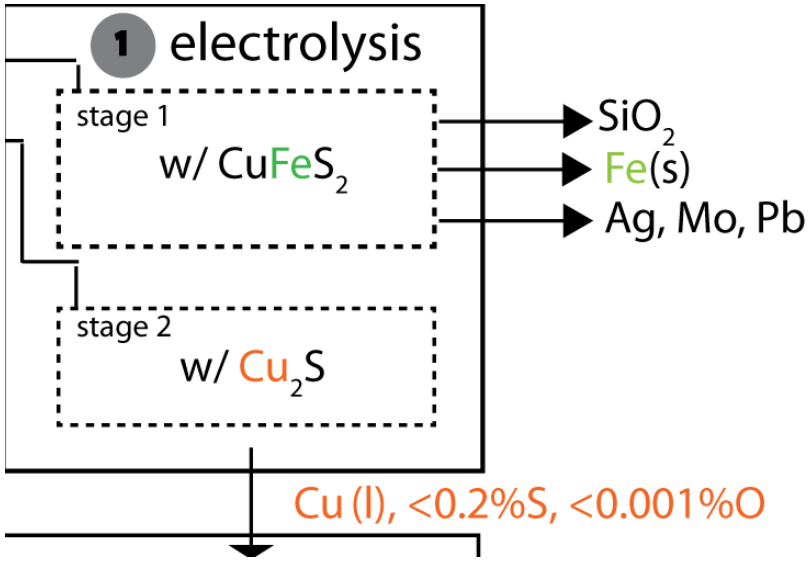
Molten Sulfide Electrolysis of Copper Concentrate

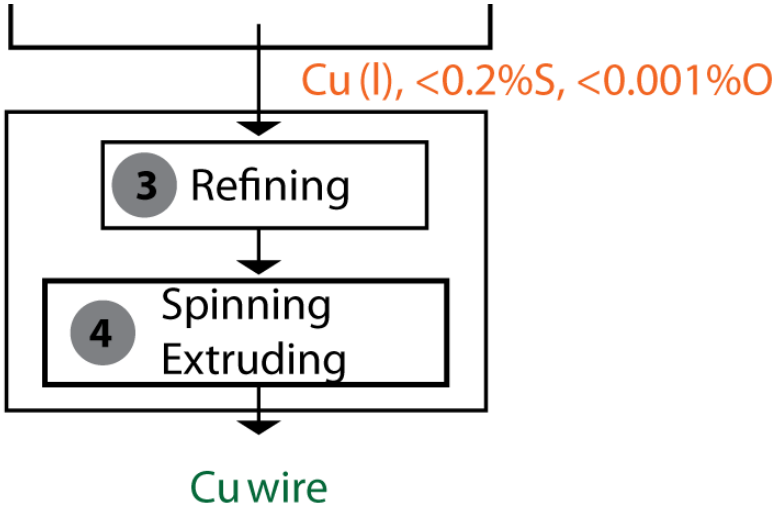
- Electrolysis reactor operates solely with electricity at 330okWh/t_{Cu}
- Same reactor principle applies to all elements from the concentrate (Fe, Mo, Ag… and S, As, Se, Te…) and make liquid copper
- Liquid copper is the last product, recovered in absence of oxygen, amenable to novel wire production processes

Technical Approach

Pursue in parallel laboratory scale electrolysis and process/cost models to produce quantitative results that support pilot-scale deployment

- Demonstrate existing approaches are compatible with concentrate from mines
- Produce sufficient amount of Fe, Cu and S for quantitative characterization (1 t/y Cu capacity)
- Demonstrate path forward for recovering Fe first, then Cu
- Evaluate possible Cu wire production process based on Cu product purity
- Provide design and operating parameters for 1t/day Cu pilot from concentrate





Technical Approach

MIT – Allanore Research Lab

Vision and competence to translate ideas into implementation

- innovative high temperature electrolysis for steel
- demonstrated experience from materials processing fundamentals to engineering and reactor design and operation (ArcelorMittal pilot, Novelis casting, MOE reactors at MIT)
- only laboratory in the world combining in-situ/containerless electrolysis of melts with advanced thermodynamic and pilot up to 1000A
- in-house reactor modeling (finite elements), design (CAD) and construction capability
- founder of Boston Electrometallurgical Corporation (BEMC, now Boston Metal)

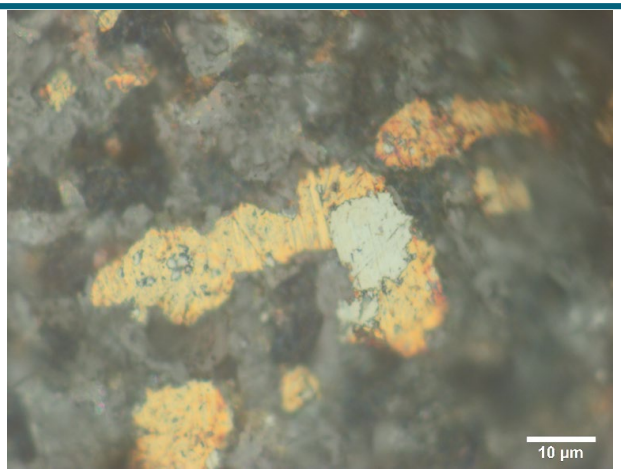
MIT – Other supports

- Extrusion and mechanical machines construction for laboratory testing of selected copper wire production methods (Prof. Slocum)
- Advising researcher staff using experience in aluminium small-scale operation (Prof. Sadoway)

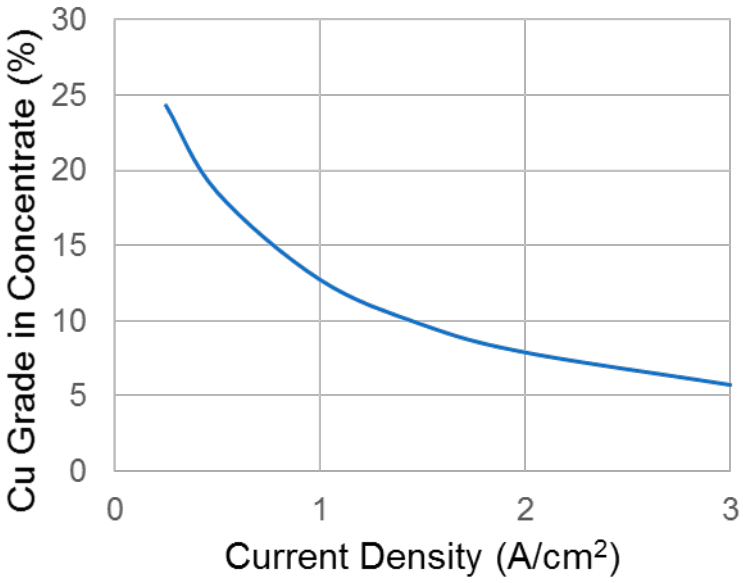
Results and Accomplishments

Project Status / Accomplishments

- Achieved set milestones:
  - >70% faradaic efficiency of iron from $CuFeS_2$ and copper from Cu_2S
  - Mass, energy and process modeling of 2A and 50A cells
- Both Cu and Fe deposited from $CuFeS_2$ experimentally (10g scale) confirming thermodynamic models
- Production strategy to recover both Cu & Fe
- Quantification of anodic efficiency *in operando*
- Experimentally determining key properties (melting point, density, surface tension) of supporting electrolyte
- Bibliographic and thermodynamic review of refining and casting processes for liquid Cu product
- Designing 50A cell to treat 2 kg concentrate (produce 600g Cu, 600g Fe), to be constructed in coming months



Liquid Cu deposited from electrolysis in presence of $CuFeS_2$



Example sensitivity analysis for 50A cell

Transition

Next step is a pilot (at least 3Y – $6M): who will fund this and where will it operate?

- Existing mining companies with interest in on-site production
- Existing smelters with interest in incremental capacity increase or diversification
- $: large network of VC, individuals, venture arms, etc… very LME dependent

Approach existing parties that expressed interests with proof of concept (experimental results) and models/projection results for the larger scale pilot

- Demonstrate the ability to recovery Fe and Cu, with lower energy consumption, indicative of cost effectiveness of the concept
- Provide evidence of performances for Te, Se or As handling/recovery
- Evaluate additional cost benefits for unconventional ores (e.g. high As, high Fe, Mo recovery)
- Provide key dimensions and performances metrics of the 100t/y Cu reactors to partner with domestic players for scale-up and technology transfer

Implement a cost model coupled with the process model to enable quick evaluation of value for other products than Cu wires, or other metals