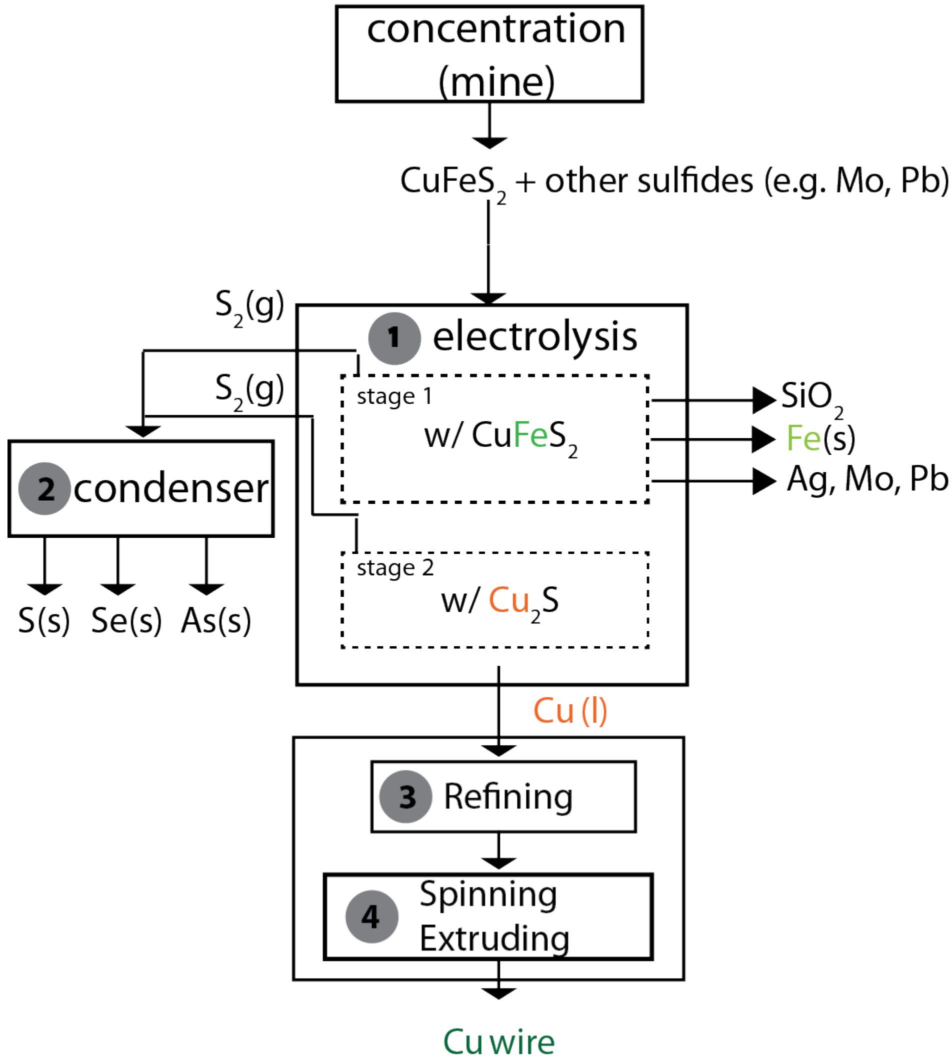
A Direct Process for Wire Production from Sulfide Concentrates

Copper (Cu) and its byproducts are essential to modern life as part of critical components in consumer electronics and other advanced materials. Nearly half of the copper used in wires and electrical applications is derived from chalcopyrite ($CuFeS_2$), a sulfide contained in copper ore. The demand for copper wire is anticipated to grow worldwide as electricity consumption increases.

Currently, the supply chain from copper mining to copper wire production is highly energy intensive. The smelting process requires pyrometallurgy to transform copper sulfides into sulfuric acid and a solid copper product (cathode). Oxidation removes molten iron (as FeO) and sulfur dioxide (SO_2) gas from the ore. Several reactors upstream and downstream are needed to remove and handle hazardous SO_2 gas, which is then transformed into sulfuric acid that requires further safe handling. The liquid copper is then refined in two more steps to produce solid copper anode and cathode products that are shipped to manufacturers outside of the smelter, for example, to copper wire producers. These producers then return the copper to liquid form in order to fashion it into wire and other finished products.

This project seeks to advance a new production flow-sheet that uses only electricity to produce copper products directly from ore and recover valuable metal and elements. An electrolysis step changes the chemical basis of copper extraction and enables a direct



Molten sulfide electrolysis of copper concentrate involves a reactor that operates solely on electricity to produce liquid product amenable for a novel wire production process.
Graphic image courtesy of the Massachusetts Institute of Technology.

liquid-to-wire extrusion/melt spinning process. This direct process also avoids the extra steps needed to remove and handle sulfuric acid by capturing sulfur in its elemental form (S_2), which is easy to condense and transport. The project will bring a core reactor technology to a size ready for pilot-scale implementation. Accompanying experimental and modeled data will confirm energy and cost savings predictions.

Benefits for Our Industry and Our Nation

This innovative production process offers a competitive advantage over current technologies by relying solely on electricity, minimizing the consumption of chemicals, and increasing selectivity. This streamlined new process promises to increase productivity and generate the following benefits:

- Reduce energy consumption for copper production by up to 25%
- Reduce production costs by about 20%
- Increase purity of the liquid copper product

Applications in Our Nation's Industry

In addition to benefiting the copper industry, concepts from this project could be utilized in markets for lead, polymetallic, and other sulfide concentrates such as nickel, cobalt or precious metals. The elemental sulfur generated through this process can be utilized for the production of valuable products including fertilizer, remote sulfuric acid production, and the generation of electricity.

Project Description

The project objective is to evaluate, construct, and demonstrate the performance of a novel molten sulfide electrolysis (MSE) process to directly convert copper sulfide concentrate to copper wire using only electricity. The proposed innovation uses a direct MSE process to make liquid copper of high purity and is coupled with a novel extrusion/casting approach that makes efficient use of electricity and improves productivity. The technology will also recover elemental sulfur with high selectivity, avoiding the production and handling of sulfuric acid.

In particular, this project will bring this process to its next level ready for pilot-scale implementation. The project will operate a one metric tonne per annum (tpa) reactor operation and propose design parameters for a 100 tpa reactor. Data to be compiled will provide mass and energy balance, more precise cost projections, and specifications of the metal and anodic products.

Barriers

- Achieving high metal purity and selective removal of impurities
- Achieving predicted energy and cost savings as the process is scaled up

Pathways

The two main areas of technical work are devoted to electrolysis and the copper product. These work areas will provide quantitative elements for demonstrating this MSE process. A third work area is dedicated to cost modeling and implementation.

The electrolysis work will include experimental demonstration, modeling, and basic data collection. The production of copper (Cu), iron (Fe), and sulfur (S) will be demonstrated at the scale of 1 tpa capacity at a cell voltage of few Volts and high faradaic efficiency.

The second work package will study the chemical and physical metallurgy of the liquid copper transformed into a solid copper product. The role and behavior of impurities will be revisited to identify the best refining conditions toward a commercial copper product. Wire products will be drawn and extruded from the liquid copper and tested for mechanical performance and conductivity.

The third pathway will generate a cost model to demonstrate capital and operational cost advantages. A simple cost model will enable separate visualization of the costs related to upstream extraction, refining, and shaping, with possible integration of a revenue analysis.

Milestones

This three-year project began in 2018.

- Develop mass and energy balance for MSE that demonstrates electrolysis operating conditions necessary to recover critical elements (2019)
- Demonstrate an electrolyte optimized for Fe, Cu, and S production and achieve advanced construction of the 1 tpa reactor (2020)
- Demonstrate the 1 tpa reactor with one or multiple copper wires that demonstrate final product quality, along with samples of Fe and S (2021)
- Complete parameter development and implementation plan for 100 tpa pilot cell (2021)

Technology Transition

The Massachusetts Institute of Technology (MIT) project team has previously shown promising results of this process at the laboratory scale. Key global copper extractors have expressed positive support of the approach and have suggested further pilot-scale development. Upon successful completion of this project, this innovative process will be at a stage for these industrial companies to engage further in process development, both financially and technically.

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