New technologies emerging in copper mining

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The International Copper Association

• Industry trade association representing the majority of the global copper production and some of the largest copper and copper alloy fabricators

• A credible independent advocate for issues critical to copper demand

• Emphasis on sustainable development

• Conducts programs on health and environmental science, codes and standard setting, direct promotion, technical innovation, market intelligence, and strong communications
Four key contributions by ICA

• Public Affairs
  Maintain copper industry license to operate in complex regulatory environments
  Ensure market access for copper products

• Market defense/growth:
  Prevent or slow substitution by alternative materials
  Increase intensity of copper use in equipment and in buildings

• Image/reputation building:
  Communicate messages showing copper has a positive contribution to society
  Position copper industry as a trusted partner of governments and non-governmental organizations
  Align copper and the copper industry with global sustainable development goals

• Copper information:
  Ensure market commentators use accurate data and informed analyses on copper end use
The world needs more copper

• Copper is necessary to the global movement toward clean energy.

• There is perhaps no metal or material as closely linked to sustainable development challenges worldwide as is copper.

• Copper’s inherent recyclability provides it with advantages over competitive materials making it important to a global movement toward a circular economy.
Copper applications are linked to sustainable development
Copper stock and flows in the circular economy

A dynamic model by the Fraunhofer Institute tracks copper through time and concludes that copper recycling alone cannot satisfy demand for copper.
The complication – more sustainability

- While current technology for mining and processing copper are good there is significant room for improvement
- Many ways to improve innovation in this space
- Will describe copper-centric venture fund approach
The Aurus III copper venture fund

• Based in Santiago, Chile
• Provides access to funding: $65 million total with ~$40 million from government of Chile
• Has a single-minded purpose: create profitable new technology companies for the benefit of the copper industry
• Conducts comprehensive evaluation of business plans
• Helps improve technical concepts, shape business plans and management teams, make connections
• Investing globally in startups aiming to prove out/introduce their solutions to the Chilean copper industry
Premise of the venture fund

• Many ideas arising from research activities

• Governments have policies to support innovation and technical enterprise development but they don’t go far enough

• No copper-centric fund to support new ventures

• An important link in the chain from idea to implementation

• Difficult for startups to relate to/partner with large mining companies

• Mining companies facing many challenges for which an open innovation + startups + VC approach could be of help
ICA involvement in Aurus III venture fund

• Participated in creating the fund and raising capital
• Member of the investment committee
• Provides some of the dealflow
• Connects to other investors
• Supports due diligence activities
• Networking for the investees
• Communications to stakeholders
• Next Fund - $100 million USD
Investment strategy

- Solutions to improve upstream processes, competitiveness and sustainability

- Key supplies/services to mining operations

- New applications for copper
Some new technologies for copper mining

- EcoTR: recycling of mining tires
- Vizutire: mining tire inspection
- Scarab Recovery Technologies: recovering valuable materials from tailings
- Novamineralis: sulfide ore leaching
- Minesense: in-shovel or conveyor sensing of ore quality and impurities
- MIT: electrolytic refining of sulfide ores concentrate
- GlassPoint: Solar thermal desalination and/or concentration system
- TIMINING: 3D geotechnical software to manage pit and hauling fleet
EcoTR – mining tire recycling

- About 38,000 mining trucks in use globally
- In Chile, 25% of scrap tires arise from the mining sector
- Until now, no effective way to recycle or upcycle OTR tires

First plant to be installed at CODELCO’s Chuquicamata Division
EcoTR – Solving one of the mining industry’s environmental challenges

- Scrap OTR (Off The Road) tires used as input for producing high quality carbon black and CO₂-free biofuel
  - EcoCB: 95% reduction in CO₂ versus virgin carbon black
  - EcoFuel: CO₂ neutral due to natural rubber origin
  - 32% fuel, 31% carbon black, 20%,13% gas, 4% waste

- Proprietary modified low temperature continuous pyrolysis
  - Highly efficient in removing hydrocarbons from the carbon black thereby producing high quality products

- No CAPEX/ OPEX requested from mining companies
The mining industry in Chile spends $60 million/year replacing OTR tires before expected.

The result is more than 10,000 units disposed as waste for recycling.

The standard inspection method of “hammer knocking” does not effectively detect or predict damage.

Current inspection method: “Hammer knocking”

70% of retirements due to principle “in case of doubt, retire”
VIZUTire

- On site detection and assessment of non-visible damage to mining tires
- Patented 3D ultrasonic imaging technology and analysis software
- Increases life of service of OTRs from 4.5k operating hours to 6k
  - 100% analysis of tire belt, carcass, inner liner, bead, chafer, sidewall and tread
  - Early detection and location of potential failure
- Equipment operated on site by VIZUTire or by mining company
Scarab Recovery Technologies – recovering calcium oxide from tailings

• Calcium oxide (CaO) is used to adjust the pH in the hydrocyclones used to produce concentrate
• CaO is about 17% of the operating costs of this processing step
• The material is not recovered; it goes into the tailings
• Investigated many technologies; needed to develop a better approach
• Formed new company to develop unique approach for CaO recovery
• Other valuable materials being investigated
Minesense – An enabling technology for selective ore extraction and processing

- A proprietary multi-sensor technology and analytics platform for real time ore grade measurement
- Ruggedized High Frequency ElectroMagnetic Spectroscopy and High Speed X-ray Fluorescence; plus other sensors
- Maximizing resource conversion and metal recovery
- Demonstrated: 20% increase in margin; 25% less energy; 25% less water; 40% less tailings
- Need to change mine operations to take full benefit of this technology

Shovel sensing provides on-site bulk ore classification and sorting
Novamineralis – a new approach to leaching of sulfide ores

- Proprietary technology for a leaching solution combining compatible microorganisms, oxidative agents and other chemical additives
- Especially designed to process primary ore (Chalcopyrite and other copper mineral refractory species)
- Same operation as traditional leaching process at ambient temperature (leaching solution irrigation on top of the ore pile/heap)
- PLS able to be processed directly into the existing SX/EW facilities
- Microorganisms to be adjusted according to the specific mineral species
- MOUs/cooperation with three mining companies
- Joint evaluation and investment with Solvay Ventures

Chalcopyrite ($\text{CuFeS}_2$)
What is different: Local bacteria catalyze the action of oxidative agents and other environmentally benign chemicals.
A potential breakthrough in sulfide ore leaching

- Process requires about 1/3 the time usually required for alternative chalcopyrite bioleaching solutions
- Pregnant Liquor Solution (PLS) processed in standard SX/EX facility
- Column testing results with chalcopyrite ore from three different customers:
  - Consistent Cu recovery rate: 70%+
  - PLS characterization: PH: ~3; Cu: 6 - 8 grams/liter
- Total cost estimate: US $0.83/lb to US $1.45/lb to produce cathode; similar to oxide ore
Electrolytic copper refining – concentrate to wire in a single process

- $1.9 million in funding from US DOE awarded to MIT to explore molten sulfide electrolysis as a potential replacement for the traditional pyro-metallurgical copper smelting process [DE-FOA-0001465]
  - Breakthrough is method of changing molten solution to ionic conductor where electricity can be used to separate copper from sulfur and other elements
  - Lanthanum sulfide and barium sulfide added to the copper sulfide
  - Anticipate 50% energy savings and ability to operate with renewable energy
  - Eliminates smelter emissions and recovers other elements (e.g. Ag, Mo, Se)
- Expect long development time

Schematic copper wire production with the sole use of electricity and gravity. Stage 1 and 2 operate in the same reactor in sequence. Aluminum uses a similar production process.
GlassPoint - Solar thermal desalination and/or concentration system

- Combines dust-sealed concentrating solar steam generation and thermal storage system
- 24/7 operation with zero CO$_2$ emissions
- All are equipment is proven; not previously combined; a new venture
- Cost competitive against LNG-powered reverse osmosis solutions in Chile
- Lower cost than open air lithium brine concentration

GlassPoint systems produces 28MW thermal from each 6 hectare modular block using curved mirrors in dust-sealed greenhouse.
GlassPoint technology – originally developed for enhanced oil recovery

Trough weight reduction: from 30 kg/m$^2$ to 2.3 kg/m$^2$

1 GW thermal avoids 300,000 tonnes CO$_2$ per year; equivalent to removing 63,000 cars

Fully automated washing with 80% water recapture significantly reduces cleaning cost.
GlassPoint - Solar thermal desalination and/or concentration system

Venture fund role in establishing local company
- Introduced to GlassPoint by a co-investor in another company
- Developed Chilean company business idea
- Assembling local management team
- Assembling local engineering / technical team

Next steps
- Partner with EPC / main contractors companies for desalination / energy projects
- Participate in biddings / tenders conducted by mining companies
- Develop pilot test and trials
TIMINING - 3D geotechnical software to manage pit and hauling fleet

• Initially developed and validated at Collahuasi in Chile
• Integrates with mine’s existing pit design, geotechnical model and sensor network
• Provides real time, AI-enabled, 3D monitoring and management of geotechnical conditions, hauling system, slope control, structural instabilities
• Permits immediate comparisons with actual situation versus mining plan and ability to develop and evaluate alternatives
TIMINING – Immersive AI

- Software tools and 3D visualization to rapidly identify deviations to the mining plan and implement corrective actions
- Simulate multiple scenarios/alternatives for constructing/operating the mine and hauling fleet
TIMINING - Team

Carlos Calderon  
(Founder)  
Innovation & Commercial Mng.  
Civil Engineer in Informatics (UChile)  
15 yr experience in software development for the mining industry.

Nolberto Contador  
(Founder)  
Director  
Mining Civil Engineer (UChile)

Nicolas Jubera  
(Partner)  
General Manager  
Industrial Engineer, MBA PUC

Roberto Catalan  
Project Manager  
Electric Civil Engineer PUC

10 yr experience in project management in technology and innovation.

10 yr experience in business development and innovation.

35 yr experience in geotechnical engineering. Founder of E-Mining.
Extensive technical capabilities needed for innovation

Technology Initiatives in mining (ordered by technical reach for partial implementation)

1. **Precision mining**
   - Extract only specific ore grades from ore deposits

2. **Decision automation**
   - Make optimized production decisions using AI and deep learning applied to digitized mine data

3. **Mine autonomy**
   - Enable mining vehicles to operate without operators

4. **Low emissions**
   - Implement methods to eliminate CO₂ emissions

5. **Advanced processing**
   - Create breakthrough methods to recover metals from ores

6. **In-situ mining**
   - Extract metals from ore deposits without excavation

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Cross-cutting needs

- **Ecosystem management**: Processes and methods to manage relationships and projects with external development resources
- **Proving grounds**: Facilities to demonstrate, test and evaluate new processes to advance technology readiness

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 Mine as digital manufacturing facility
Ventures and innovation in sustainable development

- Adelaide and South Australia – innovation hub for copper and copper mining?
- Recommendation: establish a venture fund for copper related startups
- Experience in Chile: $65 million USD fund; working well
- SA has suitable environment for start-ups
- Support the Australian mining equipment, technology and services (METS) industry
- An important link between research result and commercialization
Copper technology and innovation

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