USING MINERAL PROCESSING TECHNIQUES TO UNLOCK VALUE FROM WASTE

The transition to net zero is mineral-intensive.

The critical minerals and metals needed are predominantly sourced from depleting ore sources around the world. Given securing access to critical minerals and other strategic minerals is becoming increasingly difficult, more expensive and sometimes culturally and environmentally challenging, their future supply is now a geopolitical hot topic for Australia and many other nations around the world.

At the same time, the volume of e-waste stockpiles – which is a relatively untapped source of metals - is increasing. Despite their value, recovering those metals and minerals from e-waste has proven to be highly complex, at times environmentally harmful and expensive.

That's a compelling situation for COEMinerals to explore. Building on the promising findings in 2024 and using their extensive knowledge and experience of new mineral separation and recovery techniques, including flotation, our researchers are now helping to find new approaches that are economical, less impactful on the environment and which unlock the opportunity for recovered metals to be recycled and reused in new technologies.

The following examples show how COEMinerals, in close collaboration with industry, is tackling the challenges and improving the economics of e-waste recycling with the potential to enhance supply chains for valuable metals and enabling a circular economy for silver, graphite and potentially other metals and minerals in Australia.

A fast, new way to recover high-grade silver from end-of-life solar panels

Australia is a world leader in solar uptake, with the highest solar capacity per capita. However, by 2050, more than one million tonnes of waste panels are expected in Australia, containing an estimated 300–500 tonnes of silver.

Building on preliminary experiments in 2024, COEMinerals researchers have contributed to the development of a fast, safe and highly effective method to recover high-grade silver from end-of-life (EoL) solar panels, without using acid.

The new approach recovers more than 97% of the silver from an EoL photovoltaic (PV) panels in just a few minutes, using a physical separation technique.

This is a stark contrast to commonly used recovery methods today, which take hours and rely heavily on chemical-intensive processes, creating significant environmental and safety challenges for large-scale application.

The new method combines comminution — where the panels are mechanically crushed and ground into fine particles — followed by flotation, a separation technique that uses water, air bubbles and a small amount of standard flotation reagents to float valuable metals to the surface while waste materials sink.

Chief Investigator (CI) A/Prof Mahshid Firouzi (UON) said solar panels and the valuable minerals they contain, do not need to end their life as waste:

"By using flotation – a fast and well-established minerals beneficiation technique – we have developed a way to recover almost all of the silver in an EoL solar panel in just a few minutes, without using any acid."

From PV chip to ground materials for processing

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ENABLING ECO-EFFICIENT BENEFICIATION OF MINERALS

EoL PV panels can contain high silver concentrations of 300–500 parts per million (ppm), comparable to – and in some cases exceeding – the cut-off grade of primary silver mines. To put this in perspective, the silver content in a 20kg PV can be around 6-10g, which is equivalent to 2-3 pea-sized pieces of silver.

"*While froth flotation is widely used in mining to separate valuable minerals from ore, this is, to our knowledge, the first demonstration of froth flotation for recovery of metallic silver from recycled, ground solar panels – something many in the field believed was not feasible,*" A/Prof Firouzi shared.

COEMinerals PhD Hamidreza Saffarian (UON) played a key role in developing the technique, supported by supervisors A/Prof Mahshid Firouzi and L/Prof Kevin Galvin.

Solving the problem with academic-industry collaboration

Researchers tested and refined the mineral-recovery technique using EoL PV samples provided by industry partner Circular Solar Solutions. Also supporting the research – via a CRCP funding grant - is industry partner KGM Services Pty Ltd/The Solar Professionals.

Jeremy Grant of Solar Professionals said: "*We are impressed with what the researchers have achieved in such a short timeline, which exceeded our expectations. We're excited about the opportunities to further refine and apply the technique to advance metal recovery from EoL PVs in future.*"

Next steps

Ultimately the project aims to commercialise sustainable EoL solutions for recovering valuable metals and minerals from PV panels and other materials and as a result, help to create employment opportunities associated with recovery and repurposing valuable materials for new applications.

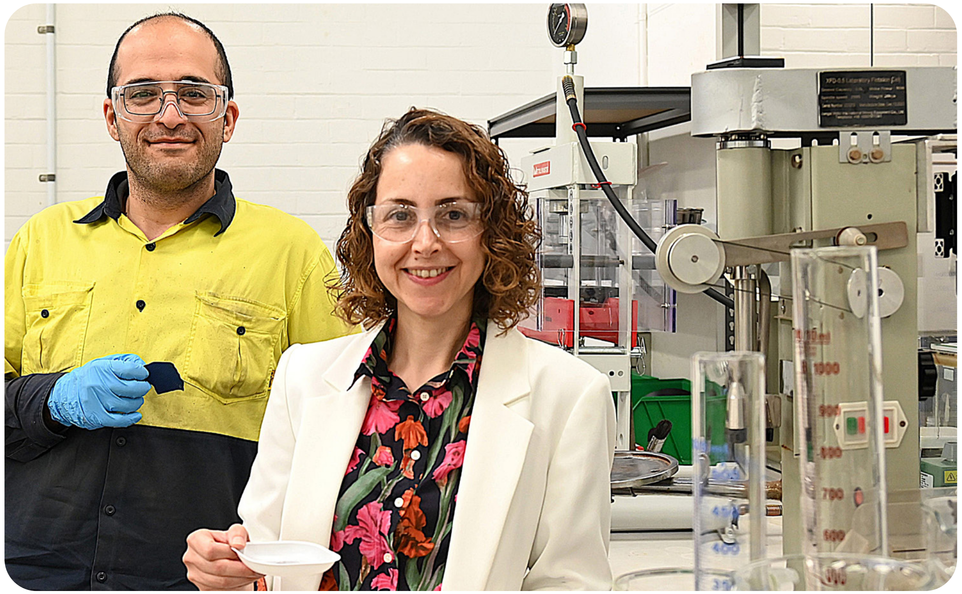
A/Prof Firouzi concluded: "*Silver was our first test case, but there are likely other opportunities associated with applying comminution, flotation science and hydrodynamic techniques to unlock the billions of dollars' worth of other materials trapped in urban and mining waste today.*"

Explainer: Flotation

Flotation is a commonly used mineral separation method for separating minerals from ore, with many flotation technologies available and already in use in Australia and around the world

Post-processing, A/Prof Firouzi holds silver sparkles in the tray

PV solar panel chips



UON members PhD Hamidreza Saffarian and A/Prof Mahshid Firouzi in the lab

Minimising energy costs and emissions when recovering critical minerals from recycled lithium-ion batteries

Australia produces around 3,300 tonnes of lithium-ion battery (LIB) waste each year[1], with the total amount expected to exceed 136,000 tonnes by 2036. Critical materials lithium, nickel and graphite are common electrode materials contained in end-of-life (EoL) LIB waste.

COEMinerals researchers are developing a new path to recover electrode materials, inlcuding graphite from LIB e-waste that avoids the economic and environmentally challenging step of 'roasting' the battery at 500-550°C, which is common practice today.

- Roasting ('pyrolysis') uses large amounts of energy and can create carbon monoxide, nitrogen oxides and sulphur dioxide emissions
- Roasting EoL LIB materials enables the Polyvinylidene fluoride (PVDF) – a binding glue used in LIB electrodes – to be removed before the next stage. While PVDF is necessary for battery performance, it becomes a liability when it comes to recycling

Instead of roasting, COEMinerals researchers are using a solvent-based process first to dissolve the PVDF, removing it from the shredded EoL LIBs referred to as 'black mass'.

COEMinerals researchers then use flotation separation principles to enable graphite recovery from black mass in a simple, fast and effective way that enables the rapid recovery of electrode materials/minerals (in a similar way to how mineral particles are recovered from ore).

"*When PVDF is in the recycling mix, basically all surfaces behave the same way, making specific mineral separation very challenging,*" shared COEMinerals researcher Dr Wei Sung (Will) Ng (UOM).

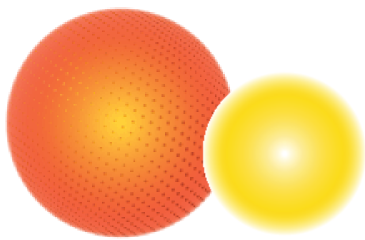
"Our approach removes the PVDF, enabling effective floatation separation of the graphite and non-graphite components. We envision that this will provide a more sustainable alternative to roasting because it lowers energy consumption as well as lowering process-related emissions," said Dr Ng.

While graphite from battery e-waste is not currently recovered in Australia, the research and technique could move Australia a step closer to a more eco-efficient, effective and less pollutive approach to recovering LIB electrode materials, including high-grade graphite.

Circularity opportunities for recovered graphite

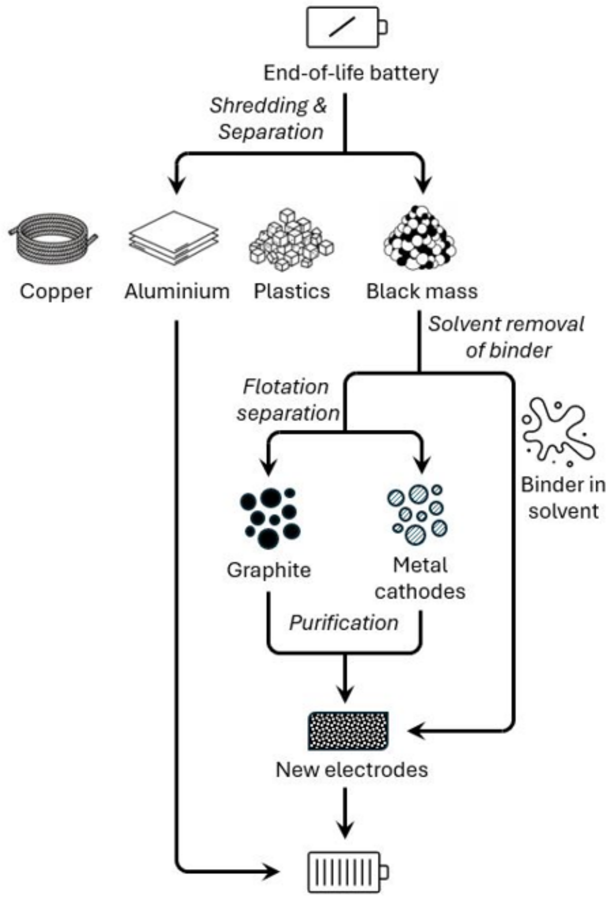
The approach COEMinerals researchers are using enables the recovered graphite to remain 'high-grade', meaning it can be recycled and re-used in new LIBs, which can be a challenge with existing recovery methods used today.

"*Our work draws on some of the fundamentals of mineral-from-ore recovery to deliver a practical new path for highly effective and efficient LIB electrode-element recovery and a truly circular economy solution for multiple LIB components including graphite,*" said COEMinerals Deputy Director Prof George Franks (UOM).



Explainer: Black mass from LIB

In this context, 'black mass' in LIB waste, is a shredded mix of EoL LIBs, after copper, aluminimum and plastics have been removed. Black mass contains highly valuable metals and minerals, as well as other ingredients such as PVDF.



Lithium ion battery - A new path to recover electrode materials from LIB e-waste

[1] https://www.csiro.au/en/research/technology-space/energy/decarbonising-industry-transport/energy-in-the-circular-economy/battery-recycling

Industry-academic collaboration

The COEMinerals researchers at UOM, including Dr Junnan (John) Lu are testing the technique on black mass samples provided by Envirostream, an Australian battery recycling company/subsidiary of Livium Ltd (ASX: LIT).

Mark Griffiths, Engineering Manager at Envirostream shared: "*We are excited by the potential of this new approach to recover battery-grade graphite and proud to be contributing to shaping the future of LIB recycling processes and the circular economy industry in Australia and around the world.*"

Envirostream receives and recycles EoL LIBs recovered from EV cars, energy storage systems (ESS), power tools and consumer electronics. Our Victorian operations use proprietary processes to safely discharge, dismantle, shred and recover critical minerals from these batteries in the form of black mass.

Next steps

The graphite recovery approach is attracting interest and accolades from academics and industry around the world. Prof Franks says he hopes it will spur its adoption by the e-waste industry in Australia and beyond, adding: "*Our work may also lead to new techniques to recover other valuable minerals and metals from recycled LIBs given it tackles the problem of PVDF being present in the black mass mix. We are keen to continue exploring the opportunity to move this forward with government and industry*".

Explainer: What's the go with Graphite?

High-grade graphite is in high demand as a key battery ingredient given it is a good electrical conductor with properties similar to metals. Future demand for graphite is projected to remain high[2].

Graphite is a critical mineral in Australia given its use in electronic devices, importance to the Australian/global economy, national security and/or the potential supply chain disruption risk[3].

Despite Australia having significant graphite resources, it is a low producer. China dominates mine supply and the global market.

UOM node members Dr Will Ng, Prof George Franks and Dr John Lu with Mark Griffiths, Engineering Manager at Envirostream

[2]Geoscience Australia: https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/australian-resource-reviews/graphite
[3] Geoscience Australia: https://www.ga.gov.au/scientific-topics/minerals/critical-minerals