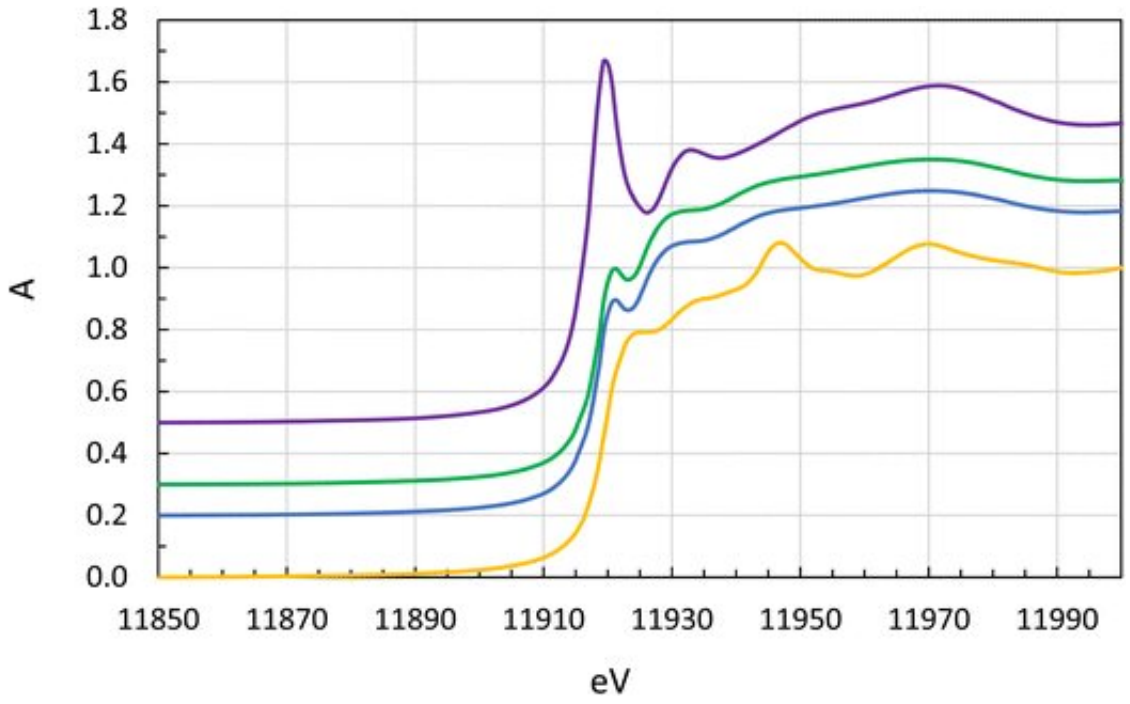
Major environmental benefits of recycling gold with biodiesel

March 22 2024



Normalized XANES spectra of metallic gold (yellow line, no offset), gold(i) $[AuCl_2]^-$, in chloride containing organic solvents (blue line, offset +0.2, no acid in the aqueous phase, and green line, offset +0.3, acid in the aqueous phase) and gold(iii), $[AuCl_4]^-$, in chloride containing aqueous solution (purple line, offset +0.5). Credit: *RSC Sustainability* (2024). DOI: 10.1039/D3SU00078H

Researchers at Chalmers University of Technology in Sweden have developed an environmentally friendly method for recycling and purifying metals. Using gold earrings from a pawnshop in Gothenburg

and biodiesel from the nearest filling station, the discovery could change an industry that is currently dependent on large amounts of fossil oil.

"Pure metals have a number of uses in a modern society, not least for the development of green technologies. Our research shows how the metal industry can accelerate the transition from fossil to bio-based solvents," says Mark Foreman, associate professor of chemistry at Chalmers.

The scientific article "Sustainable solvent extraction of gold and other metals with biomass chemicals" has been published in the journal *RSC Sustainability*.

Gold is not only a precious metal that is a symbol of wealth in the form of jewelry and gold bars. A regular smartphone contains slightly more than 0.03 grams of gold, and the metal is found in most of the everyday electronics we have around us. It is also an important material in components for the aerospace industry. For many applications, gold is mixed with other metals, which then need to be removed when the valuable gold sheet is to be recycled. In this process, organic solvents, such as fossil diesel, are used.

"Even if the diesel used in the production and recycling of metals is not incinerated, there are many good reasons to switch to fossil-free alternatives. For example, in the production of oil, methane, which is a worse greenhouse gas than carbon dioxide, often leaks into the atmosphere. A lot of crude oil also contains toxic aromatic hydrocarbons, which damage the nervous system and are therefore dangerous for humans and animals to breathe in," says Foreman.

The gold scrap is completely clean using biofuel

Together with his research colleagues at Chalmers, Foreman has found a way to use biodiesel instead of fossil diesel, which can be produced from

residual products from the forest and pulp industry, and which is sold commercially as fuel under the brand name HVO100. Biodiesel contains virtually no aromatic hydrocarbons at all.

In the researchers' method, gold scrap—usually in the form of small earrings that Foreman buys at his local pawn shop—is dissolved in a mixture of hydrochloric acid and nitric acid (aqua regia). The gold found in jewelry is an alloy with other metals, including silver, and this leads to the silver depositing in solid form as silver chloride.

In just two more steps, pure gold is then extracted from the solution. First, HVO100 and the chemical malonamide are added, and second the entire mixture is shaken with ordinary salt water. The method used by the Chalmers researchers is even more "green," since the malanomide was made from renewable biomass, which replaces more toxic and carcinogenic chemicals that are traditionally used to purify gold scrap.

"Our method is an environmentally friendly way of extracting pure gold from a mixture of many metals. Similar studies have been carried out in the past but have not achieved such a high purity of gold. The combination of biodiesel and malanomide is also special because it replaces both fossil diesel and other problematic chemicals. HVO100 is also very clean and works great in a laboratory, you don't need to make a special order, you just have to go to the nearest station and refill your canister," says Foreman.

A method to purify many metals

Normally, when metals are mined or recycled, large amounts of fossil solvents are needed, but this doesn't have to be the case, and the method developed by Chalmers researchers can be used for more metals than just gold.

An important example is copper, a metal that is very common as a conductor in electronic components. In 2022 alone, more than 26 million tons of copper was used in the world, and according to the analysis company GlobalData, there are more than 695 active copper mines globally.

About 75% of the world's copper mines use fossil solvents to purify the metal, and depending on the size, a mine needs up to 1,000 tons of solvent to purify the copper mined there. Solvents that could be replaced by biodiesel.

The same method can be used to purify and recycle many other socially important metals, such as platinum, which is used in catalysts; nickel and cobalt in batteries; uranium and plutonium for the nuclear industry; and rare earth elements. The latter are a prerequisite for the rapid development of everyday electronics such as smartphones and tablets, and are important for modern green technology, such as in wind turbines and electric vehicles.

"Our study is also the first to show that the method we have developed is general and can be applied to a variety of metals. So far, I have not found a single metal that cannot be purified with environmentally friendly biodiesel instead of fossil solvents. The metal industry is conservative, but here we can show a simple and effective method to achieve a green shift for the industry," says Foreman, who will now continue to develop and refine his method for being able to recycle household batteries.

More information: Mark R. StJ. Foreman et al, Sustainable solvent extraction of gold and other metals with biomass chemicals, *RSC Sustainability* (2024). DOI: 10.1039/D3SU00078H

Provided by Chalmers University of Technology