

Graphene and other carbon nanomaterials can replace scarce metals

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Scarce metals are found in a wide range of everyday objects around us. A survey at Chalmers University of Technology now shows that there are potential technology-based solutions that can replace many of the metals with carbon nanomaterials, such as graphene. Credit: Jonas Sandwall

Scarce metals are found in a wide range of everyday objects around us. They are complicated to extract, difficult to recycle and so rare that several of them have become "conflict minerals" which can promote

conflicts and oppression. A survey at Chalmers University of Technology now shows that there are potential technology-based solutions that can replace many of the metals with carbon nanomaterials, such as graphene.

They can be found in your computer, in your mobile phone, in almost all other electronic equipment and in many of the plastics around you. Society is highly dependent on scarce metals, and this dependence has many disadvantages.

Scarce metals such as tin, silver, tungsten and indium are both rare and difficult to extract since the workable concentrations are very small. This ensures the metals are highly sought after - and their extraction is a breeding ground for conflicts, such as in the Democratic Republic of the Congo where they fund armed conflicts.

In addition, they are difficult to recycle profitably since they are often present in small quantities in various components such as electronics.

Rickard Arvidsson and Björn Sandén, researchers in environmental systems analysis at Chalmers University of Technology, have now examined an alternative solution: substituting [carbon](#) nanomaterials for the scarce metals. These substances - the best known of which is graphene - are strong materials with good conductivity, like scarce metals.

"Now technology development has allowed us to make greater use of the common element carbon," says Sandén. "Today there are many new carbon nanomaterials with similar properties to metals. It's a welcome new track, and it's important to invest in both the recycling and substitution of scarce metals from now on."

The Chalmers researchers have studied the main applications of 14

different metals, and by reviewing patents and scientific literature have investigated the potential for replacing them by carbon nanomaterials. The results provide a unique overview of research and technology development in the field.

According to Arvidsson and Sandén the summary shows that a shift away from the use of scarce metals to carbon nanomaterials is already taking place.

"There are potential technology-based solutions for replacing 13 out of the 14 metals by carbon nanomaterials in their most common applications. The technology development is at different stages for different metals and applications, but in some cases such as indium and gallium, the results are very promising," Arvidsson says.

Metal	Current main application	Carbon nanomaterial substitute
Antimony	Flame retardants	Graphene, carbon nanotubes, fullerenes
Beryllium	Conductive materials	Graphene, carbon nanotubes
Chromium	Corrosion protection	Graphene, carbon nanotubes, fullerenes
Cobalt	Strong materials	Graphene, carbon nanotubes, fullerenes
Gallium	Semiconductors	Graphene, carbon nanotubes
Germanium	Optical fibres	Graphene, carbon nanotubes
Gold	Jewellery	-
Indium	Transparent electrodes	Graphene, carbon nanotubes
Niobium	Alloys	Graphene, carbon nanotubes, fullerenes
Platinum	Catalytic converters	Graphene
Silver	Electronics	Graphene, carbon nanotubes
Tantalum	Capacitors	Graphene, carbon nanotubes
Tin	Solders	Carbon nanotubes
Tungsten	Strong materials	Graphene, carbon nanotubes, fullerenes

Rickard Arvidsson and Björn Sandén at Chalmers University of Technology have investigated whether the carbon nanomaterials graphene, fullerenes and carbon nanotubes have the potential to replace 14 scarce metals in their main areas of application. They found potential technology-based solutions to replace the metals with carbon nanomaterials for all applications except for gold in jewellery. The metals which we are closest to being able to substitute are indium, gallium, beryllium and silver. Credit: Rickard Arvidsson and Björn Sandén

"This offers hope," says Sandén. "In the debate on resource constraints, circular economy and society's handling of materials, the focus has long been on recycling and reuse. Substitution is a potential alternative that has not been explored to the same extent and as the resource issues become more pressing, we now have more tools to work with."

The research findings were recently published in the *Journal of Cleaner Production*. Arvidsson and Sandén stress that there are significant potential benefits from reducing the use of scarce metals, and they hope to be able to strengthen the case for more research and development in the field.

"Imagine being able to replace scarce metals with carbon," Sandén says. "Extracting the carbon from biomass would create a natural cycle."

"Since carbon is such a common and readily available material, it would also be possible to reduce the conflicts and geopolitical problems associated with these metals," Arvidsson says.

At the same time they point out that more research is needed in the field in order to deal with any new problems that may arise if the scarce metals are replaced.

"Carbon nanomaterials are only a relatively recent discovery, and so far

knowledge is limited about their environmental impact from a life-cycle perspective. But generally there seems to be a potential for a low environmental impact," Arvidsson says.

Facts:

Carbon nanomaterials consist solely or mainly of carbon, and are strong materials with good conductivity. Several scarce metals have similar properties. The metals are found, for example, in cables, thin screens, flame-retardants, corrosion protection and capacitors.

Rickard Arvidsson and Björn Sandén at Chalmers University of Technology have investigated whether the carbon nanomaterials graphene, fullerenes and carbon nanotubes have the potential to replace 14 scarce metals in their main areas of application (see table in attached image). They found potential technology-based solutions to replace the metals with [carbon nanomaterials](#) for all applications except for gold in jewellery. The metals which we are closest to being able to substitute are indium, gallium, beryllium and silver.

More information: Rickard Arvidsson et al, Carbon nanomaterials as potential substitutes for scarce metals, *Journal of Cleaner Production* (2017). [DOI: 10.1016/j.jclepro.2017.04.048](https://doi.org/10.1016/j.jclepro.2017.04.048)

Provided by Chalmers University of Technology

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