No future without scarce metals

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It is not just in laptop computers, mobile telephones and LED screens that scarce metals are to be found but also in solar cells, batteries for mobile technologies and many other similar applications. The rising demand for these metals increases the risk of a bottleneck in supplies.

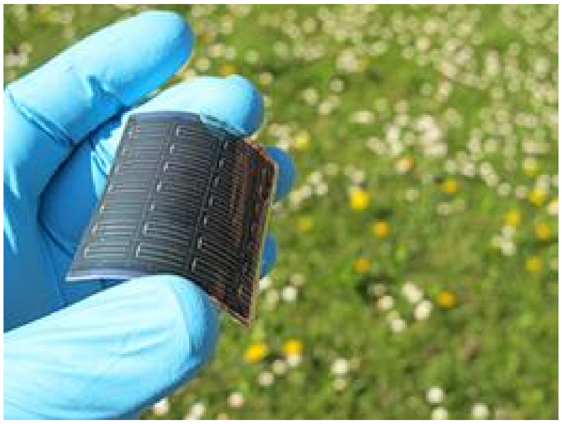
Empa researchers and representatives from industry explained at the Technology Briefing why scarce metals are essential for many key technologies and how an impending scarcity might be avoided.

"There is no future without scarce metals!" This was the very clear message with which Peter Hofer, a member of Empa's Board of Directors, greeted guests at the recent Technology Briefing on scarce metals held at the Empa Academy. After all, it is scarce metals in batteries and motors that keep electric vehicles rolling and which, in automobile catalytic converters, clean up the exhaust gases. Hofer again: "Materials with special properties are essential if we are to find solutions to the problems caused by our ever-increasing mobility requirements."

The term scarce metals includes gallium, indium, cobalt and the platinum metals, in addition to the rare earth metals which are used (together with iron and boron), for example, to make the very strong magnets needed in wind turbines. And manufacturers like to use tantalum for the capacitors on mobile telephone printed circuit boards (PCBs) because this transition metal, when used in these tiny components, enables them to store and release large amounts of electrical energy. The demand is high, with more than 60 per cent of the tantalum mined being used for this application.

The darker side

But, as Patrick Wäger, the initiator of this Technology Briefing and an expert on scarce metals, explained, everything has a darker side to it. Raw materials which can only be mined and refined in a few countries, for which alternatives are not easy to find and which have a low rate of recycling must are considered to be critical. China, for example, almost completely controls the supply of rare earth metals from which high-performance permanent magnets are manufactured. Wäger, who is a staff member of Empa's Technology and Society laboratory, added that by imposing export restrictions the Chinese government has forced prices to rise, leading to delivery bottlenecks. Currently great efforts are being made to reduce this dependency by expanding supply capacities outside of China, such as in the USA, Australia or Greenland – with implications also for the environment.



Flexible CIGS solar cells developed at Empa.

Tantalum, required for high-performance micro-capacitors, is viewed in the microelectronics industry as a material which is difficult to substitute, and to date it has not been possible to recover it from end-of-life products. Particularly worrying are the facts that tantalum is illegally mined in certain Central African countries under degrading conditions, and the profits from its sale are used to finance civil wars.

"Swiss companies also need to think closely about how they can reduce this dependency and avoid the possibility of delivery bottlenecks," remarked Jean-Philippe Kohl, the head of Swissmem's Economic Policy Group. A recent survey of the industry association's members in the Swiss mechanical engineering, electrical and metal sectors showed that every single company contacted used at least one of the critical raw materials. In order to protect themselves from possible shortages many of the companies had signed long-term delivery contracts with their suppliers. The others are cooperating with research institutions, either to develop alternative raw materials and technologies, or to optimize existing processes.

Alternatives from research labs

As an example of this approach, Stephan Buecheler explained how Empa's Thin-Films and Photovoltaic laboratory was working to reduce the thickness of the critical tellurium layer in flexible solar cells which use cadmium telluride (CdTe) as the active material. Similarly, efforts are being made in solar cells based on copper-indium-gallium-diselenide (CIGS) to replace the critical indium oxide with zinc oxide. In making these changes no loss of performance is expected. Quite the opposite, in fact – the aim is to increase the efficiency of these devices by optimal use of raw materials and fast processes. Researchers have already shown that this is possible, having set a new efficiency record last year.

Again with the aim of reducing scarce metal usage, the institution's Internal Combustion Engine laboratory has developed an extremely efficient and economic foam catalyst. Changing the form of the ceramic substrate has enabled the use of less of the noble metals palladium and rhodium in comparison to conventional catalysts. In collaboration with Empa's Solid-State Chemistry and Catalysis laboratory, the motor scientists are conducting research work on regenerative exhaust gas catalysts which employed perovskites instead of scarce metals. The former are multifunctional metal oxides which, because of their special crystal structure, are capable of transforming heat directly into electrical energy.

The recycling challenge

Despite all the doom and gloom, we will not have to do without scarce metals entirely. As Heinz Boeni, head of the Technology and Society laboratory, maintained there is of course a reserve of scarce metals to be found in end-of-life electrical and electronic products. While natural primary deposits are being used up, the anthropogenic secondary deposits created by man are increasing continuously. In a ton of natural ore as mined there is typically about 5 g of gold. In a ton of discarded mobile telephones, on the other hand, there is about 280 g, while the same weight of scrap PCBs contains as much as 1.4 kg of the precious metal.

But recovering scarce metals is anything but easy. "You can't just pull them out from electronic waste with a screwdriver and a hammer. The recovery process is at least as complex as the design and development of the old appliances themselves", recycling expert Christian Hagelüken made clear. A large percentage of scarce metals are to be found in the form of very thin layers or mixed with other substances in the form of alloys, added Hagelüken, whose employer, Umicore, is one of the largest recycling companies involved in the recovery of precious metals from complex waste material. Recycling scarce metals demands the use of complicated recovery processes.

Furthermore, suitable recovery processes alone are not enough to guarantee high recycling rates. According to the experts it is necessary to keep an eye on the whole recycling chain, from collection, disassembly and sorting of the scrap to the actual recovery process itself. The greatest efforts are in vain if, as is the case in certain countries, end-of-life computers and other electronic appliances are exported to developing and threshold countries where the scarce metals are lost through the inappropriate treatment of the electronic waste, which also represents a danger to human health and the environment. Or, if with a mechanical disassembly - which is common today in Switzerland – the scarce metals are dissipated into fractions from which they cannot be recovered.

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