Materials scientist Olivier Guillon sees great potential in materials processing with electric and magnetic fields. →

Microwaves instead of ovens

Achieving more with less energy – this is an important goal of the energy transition. New procedures could reduce consumption in the case of particularly energy-intensive processes in the industry – with the help of electric and magnetic fields.

Every child knows it: the microwave. It can be found in almost every modern kitchen. A cup of milk can be heated quickly and easily with this device. Nothing gets hot on the outside and the microwave oven stays cold on the inside as well. The trick behind it: electromagnetic fields cause the water molecules in the milk to oscillate. The friction of the water molecules against each other creates heat, the milk heats up.

Prof. Olivier Guillon, Director at the Institute of Energy and Climate Research (IEK-1), wants to use this principle to save energy – not in the kitchen, but in production processes in industry. "Electric and magnetic fields could help to drastically reduce energy consumption, especially in the processing of metals and high-performance ceramics – we believe by more than 50 per cent in some cases," says the materials expert. High-performance ceramics are not exotic materials. We use them in household appliances, in vehicles or in communication. They are regarded as key materials for the conversion and storage of energy. However, processing them consumes a lot of energy. About 7 per cent of the primary energy demand in Germany is used for industrial heat treatment.

This is mainly due to the high melting points of ceramics. High temperatures must be generated to process the materials as it is only at high temperatures that they can be compressed and deformed as desired. Today, this is usually done in accordance with the "oven principle": as when baking a cake, an oven is preheated. It gets hot both inside and out and will be warm long afterwards. "This involves a great deal of energy, only a fraction of which flows into the actual processing of the workpiece," explains Guillon.

This is exactly what can be avoided with the help of electromagnetic fields. As with the milk in the microwave, the heat is generated solely in the component part. "This makes more efficient use of the energy supplied. It also accelerates the manufacturing process, because the component part reaches its desired working temperature much faster with this method than by heating it according to the oven principle," says the scientist. Jülich researchers have already tested a possible field of application for the method: they have manufactured ceramic components for solid-state batteries using this principle.

The new manufacturing processes could help Germany achieve its ambitious goals for the energy transition: in addition to switching to renewable energies, energy consumption is to be reduced by 20 per cent by 2020 compared with 2008, and even halved by 2050. The International Energy Agency (IEA) as well has defined energy efficiency as one of four key measures to limit global warming to a maximum of two degrees by 2100.

"However, materials processing with electric and magnetic fields opens up even more possibilities," says Olivier Guillon, who has been in charge of the Priority Programme of the German Research Foundation (DFG) on this topic since 2016. Together with colleagues from the programme, he recently summarised the state of research in a study. For example, scientists are working on improving the properties of certain materials by means of electric and magnetic fields that activate the movement of atoms. This allows materials to be compressed and formed better or the atomic structure to be systematically influenced.

Raw materials can also be saved, for example with permanent magnets. Nowadays, these are installed in almost every electronic device: in refrigerators, mobile phones or even in the generators of wind turbines. Powerful magnets in particular often contain valuable raw materials, such as the rare earth metals neodymium and dysprosium, which are extracted almost exclusively in China under precarious environmental conditions.

THE WORLD'S STRONGEST MAGNETS

Neodymium can be used to build the currently strongest magnets in the world, while dysprosium makes the magnets heat-stable. The quantities used are considerable: one 3 megawatt wind turbine alone contains 1.8 tons of neodymium iron boron magnets. Colleagues from the DFG Priority Programme use external electromagnetic fields to direct atoms in the magnets' microstructure: "The properties of the magnet are thus improved and less rare earth metals used," says Guillon.

However, such procedures will probably only be ready for practical use in about 10 to 15 years' time. The basics still need to be researched. For example, more needs to be found out about the interactions between electric or magnetic fields and the material. "The processes take place on different time scales and in different orders of magnitude: from nanoseconds to hours, from the atom to the macroscopic part," explains the Jülich scientist. "The DFG Priority Programme is an important step forward here: It brings together the research groups, which have so far independently investigated the different phenomena." There is no doubt: This is efficient research to advance energy efficiency and, thus, the energy transition.

KATJA LÜERS

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