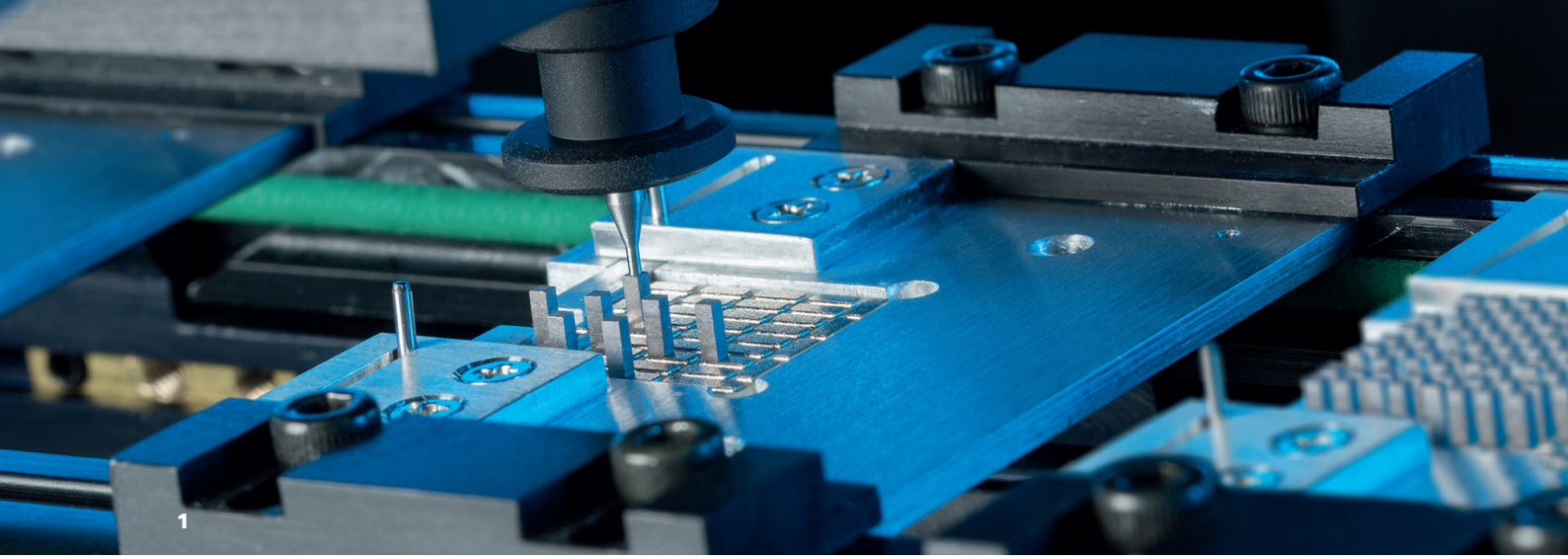

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THERMOELECTRICS

High-temperature modules – on the path to industrial production

Thermoelectric modules are high-tech products, which are still fabricated primarily by hand. Fraunhofer IPM has developed a laboratory process for the semi-automatic fabrication of high-temperature modules, which marks the first step towards industrial module production.

The global demand for thermoelectric modules has increased significantly in recent years. The market for high-temperature modules, which can use waste heat at temperatures of far above 250 °C, is showing particular promise. Fraunhofer IPM boasts one of the world's leading research groups for this type of module. Thanks to major advances in research and development, thermoelectric materials are now available for use at these high temperatures and can be produced on a large scale. Examples include half-Heusler compounds, skutterudites, and silicides. Fraunhofer IPM is using these new materials to manufacture thermoelectric modules that can be integrated into both stationary units like combined heat and power plants or mobile systems such as vehicles. Many of the steps needed to produce high-temperature modules are still performed by hand. To date, efforts to automate the fabrication of thermoelectric modules have been limited to modules operating at room temperature, which have been commercially available for decades. Fraunhofer IPM has now become the first to automate the production of new thermoelectric high-temperature modules to a certain extent.

Dexterity and concentration

Thermoelectric modules consist of n- and p-type conducting materials. Known as thermoelectric legs, they are connected thermally in parallel and electrically in series. The waste heat is converted by means of a heat flux that passes through the modules and generates electricity due to the so called Seebeck effect. For this to happen efficiently, the legs are connected to a material with the highest possible level of electrical conductivity. Modules are sandwiched between thin ceramic plates, which form their exterior. The module production process comprises the following main steps: Firstly, cylindrical blanks are lapped to size and cut into legs. These are then joined to the electrodes by means of soldering, brazing or welding.

Dexterity and a high level of concentration are crucial, especially when positioning the legs by hand. Under a microscope, tweezers are used to position up to 80 legs, each with an edge length of around 1 mm, onto the electrodes of each module. N- and p-type legs, which in terms of their

USING »ENERGY HARVESTING« TO BOOST ENERGY EFFICIENCY

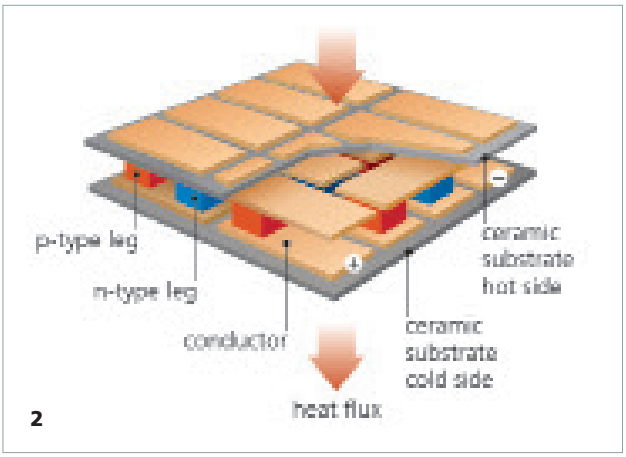
Thermoelectric modules convert heat into electricity. As robust and low-maintenance energy converters, they are ideal for generating electricity from waste heat in combustion engines, power stations and industrial plants. Since most of this energy is currently unexploited, thermoelectric energy harvesting will help to significantly increase energy efficiency in these areas.

appearance are scarcely distinguishable from one another, must be arranged in a checkerboard pattern. It only takes one leg to be positioned incorrectly for the completed module not to function. Positional accuracy of around 0.1 mm is needed for the modules to work. It is therefore vital that each step is performed with the utmost precision. This means that the entire contacting process, including the joining temperature, quantity of solder or braze and processing steps, must be reproducible and carried out precisely.

Automation and measurement techniques

The module fabrication process put into operation by Fraunhofer IPM at the start of 2016 has now automated many of the production steps. An automatic precision saw ensures the legs are manufactured precisely, while a positioning machine is responsible for arranging the legs. An automated joining unit developed at the Institute regulates the brazing process precisely and efficiently. Special measurement techniques are used to monitor various stages of the fabrication process with respect to quality assurance. For example, particular procedures are employed to measure the electrical conductivity and Seebeck coefficient of the blank, inspect the shape of the legs after sawing, and test completed modules for desired electrical properties like internal resistance. The majority of these processes are performed using measurement systems developed by Fraunhofer IPM. This ensures real-time 100 percent control on request.

1 *The positioning robot precisely places the legs on the ceramic plate. A module comprises up to 80 legs. These are made from n- and p-type thermoelectric materials and are arranged in a checkerboard pattern.*



2

2 *Setup of a thermoelectric module.*

By starting up the semi-automated batch production line on a laboratory scale and increasing production capacity to several thousand modules a year, Fraunhofer IPM has taken a significant step towards establishing industrial module production and lowering module prices for innovative high temperature modules.

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