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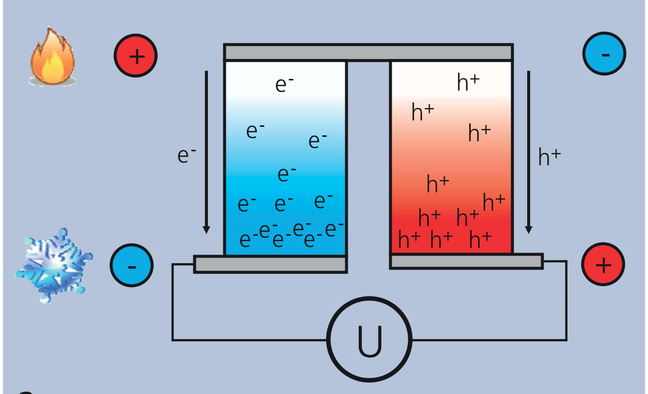
THERMOELECTRIC MODULE OF FLEXIBLE GEOMETRY

THE TASK

The challenge of providing reliable energy to sensor networks will become more important in the future. The digitalization and miniaturization of sensor networks to monitor the condition of components and machinery in combination with the "Internet of Things" and mobile applications lead to an increased demand for autarkic electronics and the associated need for energy supplies.

Energy-autarkic sensor platforms with wireless communication units require operating voltages of only a few 100 mV. This voltage range is suitable for thermoelectric generators, which can contribute substantially to building reliable, durable and autarkic energy supplies. However, for this to happen, the thermoelectric elements need to be cost-effective, efficient and mass producible. Thermoelectrics is based on the Seebeck effect. A temperature gradient within a thermoelectric material leads to diffusion of charge carriers, which results in a usable voltage. The heat flow from warm to cold regions is converted directly into electrical energy.

Schematics of a thermoelectric generator



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Currently thermoelectric modules are fabricated semi-manually. Compared to automated production the process yield is low. Conventional elements use materials (e. g., bismuth, telluride and germanium), which are often toxic, rare or expensive. A conventional element is also rigid and geometrically inflexible. Thermal stresses between the materials limit the maximum size of the elements. The development of flexible thermoelectric modules, which can be manufactured with a high degree of automation would be desirable.

OUR SOLUTION

With dispenser printing it is possible to efficiently produce thermoelectric modules at low costs. The maskless process can be highly automated at high production throughput and offers great flexibility with respect to geometric parameter variations. Dispenser printing works for different materials in paste form (metals, polymers, composites). The pastelike material is squeezed with defined quantity through a fine capillary and deposits onto the two- or three-dimensional substrate.

The process advantages become especially obvious when producing individual thermoelectric modules that fit a given contour. The substrate is first printed with electrical contacts and the thermoelectric material. Then the contour is laser cut. Such cutouts are then stacked, vertically oriented and electrically contacted. The vertical orientation allows for a large number of thermocouples to be packaged. The height of the thermoelectric material and the resulting temperature gradient can be adjusted to the requirements of a given application.

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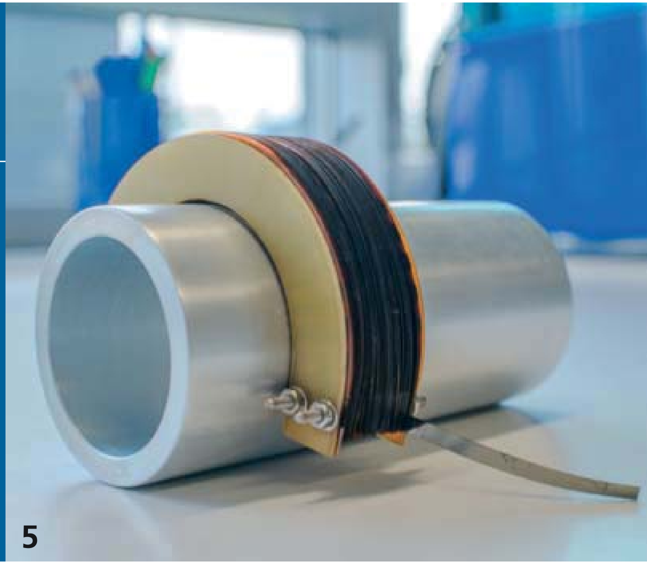

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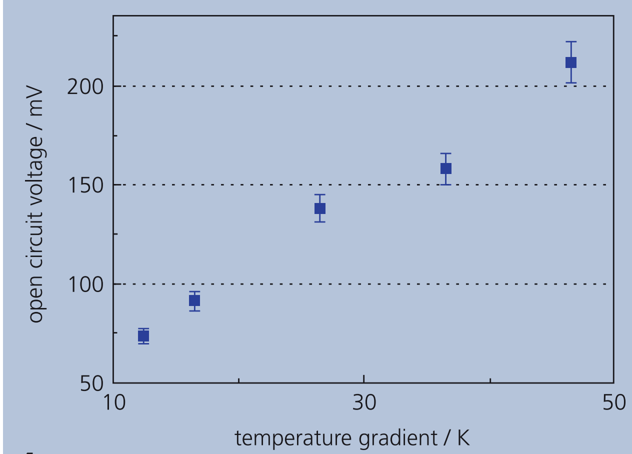
RESULTS

A CAD model is created of the geometry of the heat source so that it can be analyzed for adaptation of the contour of the thermoelectric foil. The model is then used to produce the print images for electrical contacting and the thermoelectric material. The substrate material is often a flexible and temperature resistant polyimide foil.

The electrical contacting of the thermoelectric materials is done with printed silver conduction paths. After drying, the printed silver paste becomes highly conductive and is little prone to cracking when bended.

In a next step, the thermoelectric material is printed onto the carrier foil with the silver contacts. To demonstrate feasibility, only a p-type material (polyethylenedioxythiophene polystyrene sulfonate, PEDOT:PSS) is used as n-type polymers are not yet available commercially. Depending on the application, several layers of PEDOT:PSS are printed and dried to adjust the conduction cross section.

Open circuit voltage of a thermoelectric module as a function of temperature



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The carrier foil is then laser cut to contour. The process yields several small flexible foil pieces. These thermoelectric foils can then be electrically connected, either in series or parallel, to generate the desired voltage or current.

Connected in series, the foils generate a voltage of 125 mV at a temperature gradient of 25 K. The cold side of the module is at room temperature. This voltage is sufficient to supply a commercial microcontroller in a sensor platform.

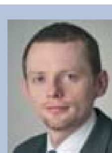
While maintaining the geometry and the manufacturing process, the voltage or power of such generators can be significantly increased when using materials with higher Seebeck coefficients or combinations of p- and n-type materials. Additional progress for such thermoelectric modules is expected from improving the thermal transport from heat source to heat sink.

1 Printed substrate prior to laser cutting

3 Separate generator foil after cutting

5 Thermoelectric module matching the contour of a pipe

CONTACT



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