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MATERIAL DEVELOPMENT FOR PRINTED FLEXIBLE THERMOELECTRIC GENERATORS

THE TASK

The energy efficient utilization of available resources is not just limited to improving technical processes. It is also important to recover waste heat generated at each step. The total amount of waste heat is a substantial energy reservoir. Thermoelectric generators (TEG) can convert such heat to electrical energy and return it to the process. This will improve overall energy efficiency.

A classic TEG consists of two semiconductive materials with electron and hole charge carriers (n- and p-type semiconductors). Such a material combination generates an electric voltage between the warm and the cold side when being exposed to a temperature gradient (Seebeck effect, Fig. 2). Generated Seebeck voltages are on the order of only a few $\mu V\ K^{-1}$. However, if the semiconductors are connected in series, the voltage will add. The large area implementation of TEG requires low cost materials and high volume capable manufacturing technologies. Fraunhofer IWS engineers exploit printing technologies to deposit in-house developed and optimized thermoelectric materials.

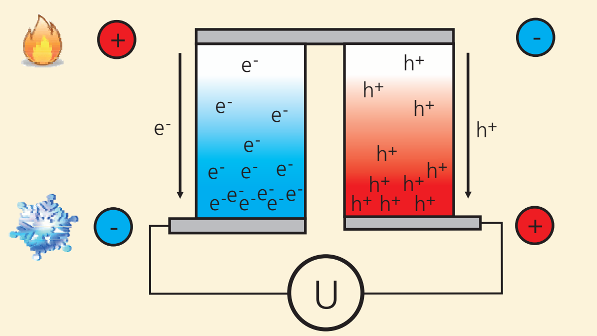
OUR SOLUTION

Electrically conductive polymers are an interesting material class for flexible thermoelectric applications. Polymers can be processed with scalable printing techniques, which are capable of high volume manufacturing of thermoelectric generators.

Dispense printing is the particular technology of choice. The process does not require masking and is flexible with respect to variations of geometric parameters. Many pastes can be processed. The paste is fed through a fine hollow needle and dispensed by scanning the needle over the substrate.

A promising intrinsically conductive polymer for thermoelectric applications is PEDOT:PSS poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate). The Seebeck coefficient of oxidized PEDOT:PSS is about 16 $\mu V\ K^{-1}$. Adding 6 % by weight dimethyl sulfoxide (DMSO) increases the electric conductivity from 8 to 84 $S\ cm^{-1}$ without negatively affecting the Seebeck coefficient.

Schematics of a thermoelectric generator (TEG)



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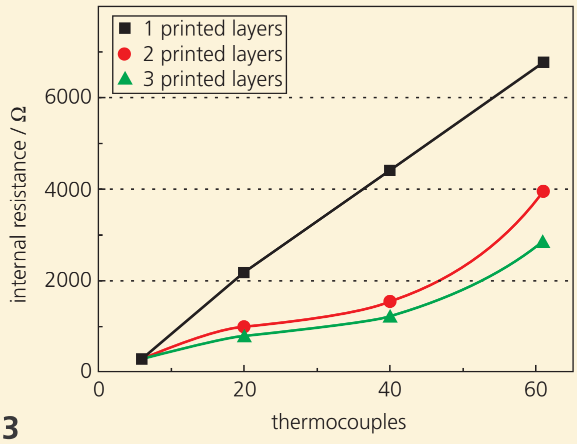
RESULTS

The substrate is a 75 µm thick polyimide foil. This flexible foil is stable at higher temperatures. The interconnecting conductors are made using silver print paste.

Internal resistance of a printed polymer TEG versus the number of thermocouples (silver-polymer)



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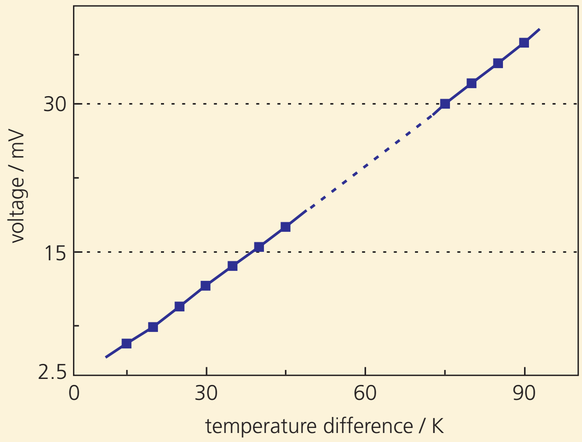
DMSO modified PEDOT:PSS is printed onto polyimide strips that are for example 300 mm long. This corresponds to 60 couples of silver and PEDOT:PSS. The printed structures are 1 mm wide and 10 mm long. The internal resistance of the TEGs can be reduced by printing multilayers of the material PEDOT:PSS (Fig. 3).

After drying and tempering the TEG strip is wound onto an adapter to characterize its performance (Fig. 4). It is placed between a heat source and a cold side. The latter is being held constant at 20 °C. The temperature on the warm side is increased step by step. With increasing temperature the open circuit voltage of the TEG increases linearly. A temperature difference of 90 K generates 37 mV (Fig. 5).

Open circuit voltage of a printed TEG versus temperature difference



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1 Printed TEG strip made from PEDOT:PSS and silver

4 Flexible TEG strip wound onto a testing adapter

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