

# 2D printable flexible based n-type bulk thermoelectric materials and printable flexible high power density TEG

## Background

Thermoelectric generators (TEGs) convert heat flux (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect. This promising energy conversion technology is less bulky and uses no moving parts compared to conventional heat engines. Unfortunately, TEGs are typically more expensive, less efficient and not in a position to compete with other environmentally friendly energy conversion technologies like photovoltaics. Therefore, TEGs are not yet used to a large extent for real-life applications. Only widely known Bi-Te based materials are successfully implemented for TE device applications at ambient temperature. Production of low cost and high outputpower density TE devices using conventional bulk materials is unsatisfactory due to a large amount of material used and complex manufacturing processes. In addition, TEGs made of bulk materials are usually not flexible and hardly integratable into non-flat surfaces of different micro and complex electronic or mechanical systems. On the other hand, conductive polymers might be potential candidates for flexible TE materials due to their good printability, environmental stability, high electrical conductivity and low thermal conductivity. However, they exhibit low TE performance. Nevertheless, efforts are still being made to enhance TE performance of conductive polymers, such as p-type PEDOT and n-type 1,1',2,2'-ethenetetrathiolate(ett)-metal coordination polymers [poly[Ax(M-ett)] through hybridization and functionalization with different inorganic or organic elements and compounds.

## Problem

Even though some organic-based printable p-type TE materials have been reported, there are currently no known sufficiently efficient and environmentally stable printable n-type TE materials for device manufacturing. TEGs made of bulk materials are usually not flexible. If they are printed nevertheless, bulk materials, binders, solvents and additives strongly interfere with the TE transport parameters at grain boundaries, especially the electrical conductivity, resulting in poor TE performance. In summary one can say that state-of-the-art TE materials have either low Seebeck coefficients, poor printability and/or environmental instability.

## Solution

An innovative strategy for producing printable flexible Ag-Se-based n-type thermoelectric materials comprising a binary  $Ag_2Se$  phase, which is based on a moderate temperature post printing sintering procedure to avoid detrimental effects at grain boundaries preserving its high TE performance. Unlike conventional inorganic powder based printed films containing grain boundaries, interruption of carrier transportation through the percolated path of the  $Ag_2Se$  phase is minimized, which results in high advantageous electrical conductivity, and thus in a very good TE performance. In addition, this n-type thermoelectric material can be combined with our recently developed corresponding p-type

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## Entwicklungsstand

TRL3

## Patentsituation

EP 3796404B1 granted

## Referenznummer

19/067TLB

## Service

The Technologie-Lizenz-Büro GmbH is in charge of the exploitation of this technology and assists companies in obtaining a license.

material based on  $\text{Cu}_2\text{Se}$  (see our ref. 21/010TLB) for even more powerful TEG.

### Advantages

- Novel Ag-Se based n-type thermoelectric (TE) materials
- 2D printable
- Flexible
- Environmentally stable
- High power density/high TE performance
- Moderate temperature post printing sintering procedure
- Low-cost manufacturing of high power density 2D printable flexible TEG
- can be combined with our recently developed corresponding p-type material based on  $\text{Cu}_2\text{Se}$  (see our ref. 21/010TLB) for even more powerful TEG

### Fields of application

Printable, flexible thermoelectric (TE) materials particularly for large scale applications. Integratable into non-flat surfaces of different micro and complex electronic or mechanical systems.