

## Electrodeposition of Copper/Indium-Doped N-Type Bismuth Telluride-Based Thermoelectric Nanomaterials

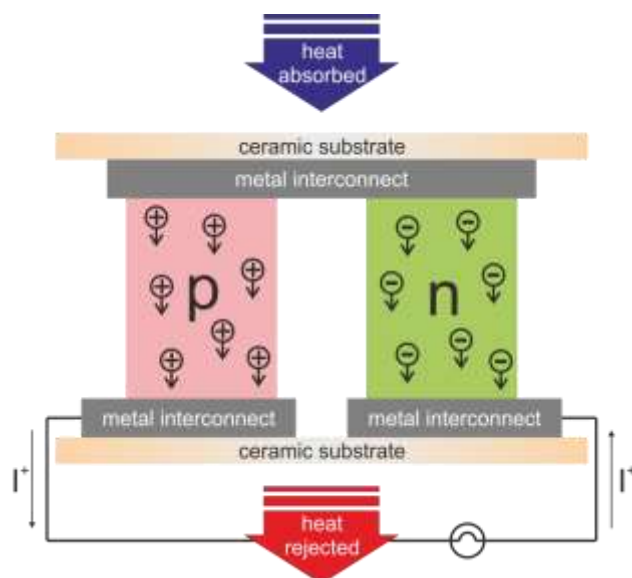
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The work presented focuses on the use of cyclic voltammetry and electrochemical deposition as analytical and fabrication techniques, respectively, to deposit nanostructured thermoelectric materials. Specifically, these materials would be used as the n-type leg (see schematic below) in a thermoelectric device for employment in room temperature medical applications.

### Thermoelectric Devices

Power harvesting from thermoelectric (TE) devices is seen as a highly promising route towards sustainable energy, as electricity can be generated from waste heat. This is, however, contingent on fabricating materials with higher TE efficiencies than currently available, as it cannot always be assumed that large thermal gradients will exist.



Bismuth telluride-based alloys are currently the best commercially available TE materials for applications at room temperatures. It is hoped that increased efficiency of TE devices that operate at room temperature will lead to applications in the healthcare industry, powering miniature, low-cost sensing elements from human body heat.

Theoretical calculations predict that low-dimensional nanostructures of these materials can spectacularly enhance the figure of merit (a measure of the goodness of TE materials) from currently ~1 to higher values of up to 14 [1].

### Electrochemical Fabrication

Whilst a wide range of fabrication techniques exist, such as single crystal growth, thin film technologies (MOVPE deposition, molecular beam epitaxy (MBE) including liquid phase epitaxy) and bulk powder syntheses, for the production of bismuth telluride compounds, these have proven to be quite costly and/or difficult to achieve due to the high temperatures and pressures generally employed in these methods.

Electrochemical deposition provides an attractive low-cost, room temperature and scalable route to the fabrication of high-quality TE materials such as bismuth telluride alloys [1,2].

### Microstructural and Physical Properties

The correlation of microstructural properties with TE properties is still a mandatory challenge in order to achieve further progress in this emerging technology and has surprisingly received very little attention.

This study focuses on a detailed and systematic investigation of the microstructural properties (morphology, chemical composition, crystallinity and grain size) and physical properties (Seebeck coefficient, Hall coefficient, electrical resistivity, Hall mobility and carrier concentration) of electrochemically deposited bismuth telluride-based nanomaterials.

The cyclic voltammetry of each system has been studied well, leading to insights into the nature of the electrochemical processes being employed for deposition of the materials.

Well adherent and high-quality n-type bismuth telluride films with a preferential (1 1 0) orientation, as determined by XRD, and close to stoichiometric composition were obtained by electrodeposition from aqueous electrolytes containing the surfactant sodium lignosulfonate and transport property measurements indicate that these films show promising TE properties as well [3].

The effects of electrodeposition potential, electrolyte composition and Cu/In-doping on microstructural and electrical properties of ternary n-type Bi-Te-Se and Bi-Sb-Te compounds, as well as quaternary Bi-Sb-Te-Se, are under investigation.

Preliminary results show that, for the fabrication of Bi-Te-Se films, the composition is dependent on the deposition potential. The desired composition of Bi<sub>2</sub>Te<sub>2.7</sub>Se<sub>0.3</sub>, which is reported previously to show improved thermoelectric properties [4], has been achieved.

### References

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