Tellurium-Free Thermoelectric Modules by Interface Engineering

Kornelius Nielsch[1] *, Pingjun Ying, Amin Bahrami, Ran He

[1] Leibniz Institute for Solid State and Materials Research Dresden, Germany

* presenting author e-mail: k.nielsch@ifw-dresden.de

Thermoelectric (TE) technology provides solutions for solid-state heat recovery and cooling, with Bi_2Te_3 modules being the only commercially mature option. However, their use is limited due to the scarcity and toxicity of tellurium (Te). The THERMOS project aims to develop efficient, Te-free modules using atomic layer deposition and Zintl materials, targeting a conversion efficiency of 8.5% and a cooling temperature of 65°C, surpassing Bi_2Te_3. This initiative will enable new applications, such as powering off-grid IoT nodes and harvesting energy from low-grade waste heat.

Recent advancements in TE technology have focused on non-toxic, abundant materials like p-type MgAgSb and n-type $Mg_3(Sb,Bi)_2$. Despite their potential, concerns about long-term stability in harsh environments remain. This study investigates the performance degradation of TE modules under various conditions. Elemental mapping analysis reveals degradation mechanisms during cycling in argon, highlighting atomic migrations and complex oxide formation at contact regions. Cycling tests in air show significant degradation, leading to the exploration of protective strategies.

Surface coatings via atomic layer deposition (ALD), particularly with HfO_2, show promise in enhancing module protection. Additionally, re-soldering has been found to restore module performance, underscoring the need for advanced soldering techniques to support magnesium-based TE technology as a sustainable alternative to Bi_2Te_3. These findings highlight the importance of novel contact materials and the potential of ALD to improve module reliability and robustness [1].

Furthermore, we have applied ALD coatings of metal oxides to BiSb and ZnSb powders, significantly enhancing their thermal stability and suppressing Zn whisker formation in ZnSb, which is crucial for device applications.

In conclusion THERMOS has resulted in highly efficient, durable thermoelectric modules from sustainable MgSb-based alloys for heat recovery and solid-state cooling.

References

[1] Ying, P. et al., Advanced Functional Materials **2024**, *34*, 826.

Supported by the Saxon Ministry, SMWK – Sächsisches Staatsministerium für Wissenschaft, Kultur und Tourismus