

# Development of Sb-chalcogenide thin film semi-transparent solar cells: focus on Sb<sub>2</sub>S<sub>3</sub> controlled growth

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## Summary

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*This PhD topic is focused on optimization of optoelectronic properties of Sb<sub>2</sub>S<sub>3</sub> absorber layer by spray solution composition, seed-layer promoted growth of crystallites and post-deposition treatments. Sb<sub>2</sub>S<sub>3</sub> is an emerging inorganic PV material that have drawn much interest in recent years due to its excellent stability, suitable bandgap ( $E_g=1.7$  eV) relatively high absorption coefficient (ca104 cm<sup>-1</sup> at 450 nm), earth abundance, environmentally benign characteristics and low-cost. Due to its unique properties Sb<sub>2</sub>S<sub>3</sub> could be applied in semi-transparent, tandem, and indoor solar cells. This research topic foresees characterisation of material and device properties at home institution and at least one semester at laboratories of the research group collaboration partners (e.g., Liverpool University, or Czech Technical University or University of Verona or Helmholtz Centrum Berlin). We offer an opportunity to be part of the COST action CA21148 - Research and International Networking on Emerging Inorganic Chalcogenides for Photovoltaics, RENEW-PV, <https://renewpv.eu/>*

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| Research field:       | Chemical, materials and energy technology   |
| Supervisors:          | Prof. Dr. Ilona Oja Acik<br>Prof. Dr. Malle Krunks  |
| Availability:         | This position is available.   |
| Offered by:           | School of Engineering<br>Department of Materials and Environmental Technology                 |
| Application deadline: | Applications are accepted between June 01, 2023 00:00 and June 30, 2023 23:59 (Europe/Zurich) |

## Description

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The Laboratory for Thin Film Energy Materials at TalTech was the first to demonstrate semi-transparent Sb<sub>2</sub>S<sub>3</sub> solar cell fabricated by chemical spray method. In the current stage of the development, Sb<sub>2</sub>S<sub>3</sub> thin film solar cells by ultrasonic spray pyrolysis show efficiency of 6.0 % under 1sun. The average visible transparency of structure glass/TCO/TiO<sub>2</sub>/Sb<sub>2</sub>S<sub>3</sub>/HTM is 32% fulfilling the semitransparency requirement of solar windows.

The intrinsic quasi 1D crystal structure of Sb<sub>2</sub>S<sub>3</sub> is known to transfer photogenerated carries along the [hk1] orientation. However, producing Sb<sub>2</sub>S<sub>3</sub> thin films with the controlled [hk1] orientation is challenging.

The key for further increasing the efficiency of the solar cells relays on optimization of the optoelectronic properties of Sb<sub>2</sub>S<sub>3</sub> absorber layer by spray solution composition, seed-layer promoted growth of crystallites and post-deposition treatments. Furthermore, solar cell device structure optimisation is required to reduce interface recombination.

In this PhD thesis, antimony chalcogenide and metal oxide thin films will be fabricated by robust, resource saving, and easily scalable method such as ultrasonic spray pyrolysis. Spray deposition has great potential to become front-line technology for rapid, cost-effective, large-area and high yield mass production of solar cell.

The project will involve synthesis of materials, fabrication of solar cells, characterization of materials and devices.

## Responsibilities and (foreseen) tasks

- Engineering the device quality properties of Sb<sub>2</sub>S<sub>3</sub> thin films deposited by chemical spray pyrolysis method.
- Development and optimization of semi-transparent solar cells and its constituent layers (Sb<sub>2</sub>S<sub>3</sub> absorber layer, electron transport layer, hole transport layer, interface layers) by chemical deposition methods.
- Characterisation of material and device properties at home institution and at least one semester at laboratories of the research group collaboration partners (e.g., Liverpool University, or Check Technical University or University of Verona or Helmholtz Centrum Berlin)
- Analysis of the research data, preparing reports, presentation at conferences (poster, oral talk), write research articles.

- Contribute to the organization and dissemination of research and practitioner workshops where project findings are presented.

### Applicants should fulfil the following requirements:

The successful applicant will hold a Master degree in Physics, Chemistry, Materials Science or a related field. Previous research experience in thin film technologies and material characterization will be an advantage. Excellent team working attitude and communication skills in English (both written and oral) are an essential requirement. Competences in using data analysis and graphing software: Microsoft Office (Word, Excel and PowerPoint), Origin.

The candidate should submit a research plan for the topic, describing the understanding of the current state of the art of Sb<sub>2</sub>S<sub>3</sub> thin films and solar cells development and propose the research activities for the Sb<sub>2</sub>S<sub>3</sub> controlled growth engineering.

### We offer:

- 4-year PhD position in one of the most internationalized and leading PV research groups in Estonia
- The chance to do high-level research in one of the most booming emerging photovoltaic field.
- Opportunities for conference visits, research stays and networking with globally leading universities and research centres in the fields of material science.
- Opportunity to be part of the COST action CA21148 - Research and International Networking on Emerging Inorganic Chalcogenides for Photovoltaics, RENEW-PV, <https://renewpv.eu/>

### About the research group

The main research topic of the Laboratory for Thin Film Energy Materials is the development of metal oxide and sulphide thin films and nanostructured materials for solar cells, electronics and environmental applications by chemical technologies such as spray pyrolysis, chemical bath deposition and sol-gel. The technologies that are developed in the laboratory are simple, inexpensive, and easily transferrable to industrial scale. A new type of ultra-thin absorber based solar cell design and its component layers were developed in the laboratory and secured by several international patents. Over the last 25 years the main topics in the research group has been development of emerging thin film photovoltaic materials such as CuInS<sub>2</sub>, Sb<sub>2</sub>S<sub>3</sub>, Sb<sub>2</sub>Se<sub>3</sub>, Sb<sub>2</sub>(S,Se)<sub>3</sub> and Sb-Bi alloys, and the fabrication of solar cells based on them. The research group has extensive knowledge on development of CdTe thin film solar cells by close spaced sublimation. The laboratory staff is coordinating or being involved in several international and national research projects and are the grant holders of the COST action project RENEW-PV. RENEW-PV is a joint network of more than 200 researchers and industry partners from more than 30 countries worldwide developing emerging inorganic PV materials and devices.

### Additional information

For further information, please contact Prof Ilona Oja Acik [Ilona.oja@taltech.ee](mailto:Ilona.oja@taltech.ee), Prof Malle Krunks [malle.krunks@taltech.ee](mailto:malle.krunks@taltech.ee) or visit <https://taltech.ee/en/laboratory-thin-film-energy-materials>



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