# Development of fully inorganic Sb2S3 thin film solar cells for semi-transparent applications

## Summary

*The ambition of the Laboratory for Thin Film Energy Materials at TalTech is to develop the next generation of thin film photovoltaic technology capable of Internet of Things (IoT) devices and enabling integration into solar windows and related Building Integrated Photovoltaics (BIPV) products. This PhD research topic will explore inorganic hole transport materials (HTMs) – primarily inorganic – for use in Sb-based thin film solar cells. Antimony sulphide (Sb2S3) is an emerging inorganic PV material that has attracted significant interest in recent years due to its excellent stability, suitable bandgap (Eg=1.7 eV), relatively high absorption coefficient (~104 cm-1 at 450 nm), earth abundance, environmentally benign nature and low-cost. Due to these unique properties, Sb#S# holds great promise for applications in semi-transparent, tandem, and indoor solar cells. This research topic foresees material and device characterisation at TalTech and at research group collaboration partners (e.g., Liverpool University, or Czech Technical University or University of Verona or Helmholtz Centrum Berlin). The candidate will also have an opportunity to participate in 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>Merike Kriisa |
| 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, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich) |

## Description

*The research*

We have established a baseline technology platform for Sb-chalcogenide thin film solar cell fabrication using ultrasonic spray pyrolysis (USP) technology and were the first to demonstrate a semi-transparent Sb2S3 solar cell fabricated by USP. In the current stage of the development, Sb2S3 thin film solar cells show efficiency of ca 7.5 % under 1 Sun. The average visible transparency of the structure glass/TCO/TiO2 /Sb#S#/HTM is 32% fulfilling the semitransparency requirement of solar windows. Currently, the organic HTM used – poly(3- hexylthiophene-2,5-diyl or P3HT) – is limited by high cost, low stability, and moisture sensitivity. This highlights the need for more robust alternatives.

In the frame of this research topic, we will investigate and develop alternative HTMs, focusing primarily on inorganic materials, that can be used in Sb-based solar cells. One promising candidate is nickel oxide (NiO), a p-type inorganic metal oxide with a wide band gap (Eg ≈ 3.6–4.0 eV), high optical transmittance (above 90

% in the visible spectrum), excellent chemical stability, and favourable energy level alignment with Sb2S3 absorbers. Its p-type conductivity (due to nickel vacancies) facilitates efficient hole transport and electron blocking. NiO also supports various synthesis techniques and has shown impressive performance in related devices, including perovskite solar cells (PCEs of 7.6%–16.5%) and Sb2S3 solar cells (PCEs of 2.5–3.0%).

The project will involve identification of suitable precursors and fabrication methods for alternative HTMs, synthesis of materials, fabrication of thin films and solar cells, characterization of materials and devices.

*Responsibilities and (foreseen) tasks*

- Identification of suitable inorganic HTMs and fabrication methods
- Developing the HTM fabrication protocol and engineering the device quality properties of Sb2S3 thin films deposited by chemical spray pyrolysis method.
- Fabrication and optimization of solar cells and its constituent layers, focusing mainly on hole transport layer using chemical deposition methods.
- Characterisation of material and device properties at home institution and at research group collaboration partners (COST action CA21148, RENEW-PV partners)

- Analysis of the experimental data, preparing reports, oral and/or poster presentations at conferences, publishing research articles.

*Applicants should fulfil the following requirements:*

Required qualifications:

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- Master's degree in Chemistry, Materials Science, Physics, or a related field.
- Good command of written and spoken English.
- Strong teamwork and communication skills.

Preferred qualifications:

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- Previous experience with thin film technologies or materials characterisation.
- Familiarity with data analysis and plotting software (e.g., Microsoft Office, Origin).

Application requirement:

Applicants are expected to submit a short research plan, demonstrating an understanding of the state of the art in Sb#S# thin film solar cells and outlining proposed research activities for the development of non- organic HTMs.

*We offer:*

- A 4-year fully funded PhD position in one of Estonia's leading photovoltaic research groups.
- Participation in cutting-edge research in a rapidly growing field of emerging photovoltaics.
- Opportunities to attend conferences and undertake research visits to partner institutions.
- Access to international collaboration and mobility through the COST Action 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 CuInS2, Sb2S3, Sb2Se3, Sb2(S,Se)3 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:

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To get more information or to apply online, visit https://taltech.glowbase.com/positions/1000 or scan the the code on the left with your smartphone.