# Low cost solution processing of kesterite solar cells from binary chalcogenide starting precursors

## Dr Jake Bowers – Loughborough University

**Aims**: The aims of the project are to develop a solution deposition method for fabrication of CZTS thin film solar cells. The student will use a novel solvent chemistry developed at Loughborough, which is able to dissolve binary chalcogenide materials without the need of the explosive and toxic solvent hydrazine. Using this method, it is possible to dissolve the constituent binary chalcogenide precursor materials (Cu2S, SnSe and ZnS) in solution, deposit by spin coating, and anneal to create phase pure kesterite material for PV applications. The work will continue that already currently in its early stages of development at Loughborough in low cost solution processed thin film photovoltaics.

**Background**: Solar energy conversion based on thin film photovoltaics has matured significantly over the last decade after years of intensive research and development. In particular, CdTe and Cu(In,Ga)Se­2­ based technologies have been successfully developed and exploited by companies such as First Solar Inc (USA), and Solar Frontier (Japan) who are currently producing high performance modules at large scale. A significant factor behind the successful development of these technologies is that the materials are deposited using vacuum processes from high purity starting materials. As such, it is possible to deposit PV materials with high efficiency and performance, due to the careful process control achieved with vacuum processing.

Whilst these methods produce high quality PV material, there is a significant price to pay. Vacuum deposition techniques are inherently expensive processes due to the fact that they require high initial capex costs. Also, the use of the rare elements tellurium, indium and gallium increase the production costs even further of CdTe and CIGS technologies, respectively. As a result, the cost of the produced electricity is expensive and the person who ultimately suffers is the final electricity consumer. This is one of the primary reasons why electricity production from photovoltaics is not as ubiquitous as it could be.

A possible solution to this problem is to develop low cost alternatives, using cheaper atmospheric deposition methods such as ink jet printing and spray methods combined with cheap and abundant starting precursors. A promising class of materials which have exhibited both high efficiency and low materials cost is the kesterite Cu­2­(Zn,Sn)Se­4­ (CZTS) which has been most successfully deposited using a solution processing method by dissolving the constituent binary chalcogenides (Cu­­2­S, SnSe, and ZnS) in hydrazine, followed by spin coating and annealing. The method is surprisingly simple and has produced some of the highest efficiency CZTS devices to date, and is successful only because of the unique ability of hydrazine to dissolve chalcogenides effectively. This means that unwanted impurities such as carbon, oxygen and halides can be avoided from the solution mixture which would otherwise have been included in the final film composition. However, whilst hydrazine is necessary for the process to work, it makes the technique a difficult one to commercialise because of the highly toxic and explosive nature of the solvent.

Recently, we have developed an alternative safer solvent system to hydrazine which is still able to dissolve binary chalcogenide precursors. We have already demonstrated its ability to dissolve Cu­2­S and In­2­Se­3­ in solution, and spin coat and anneal films with a desirable chalcopyrite phase for PV applications [1]. Preliminary results show that it is possible to dissolve a variety of other chalcogenides suitable for solution processing of PV materials. This project will aim to develop this method to deposit CZTS solar cells from solution, using this solvent which is much more safe and benign alternative.

**References**

[1] P. Arnou, C. S. Cooper, A. V. Malkov, J. W. Bowers, and J. M. Walls, “Solution-processed CuIn(S,Se)2 absorber layers for application in thin film solar cells,” *Thin Solid Films*, pp. 0–3, Oct. 2014.