An Atmospheric Pressure Vapor Deposition Process for the Development of Thin–Film Solar Cells

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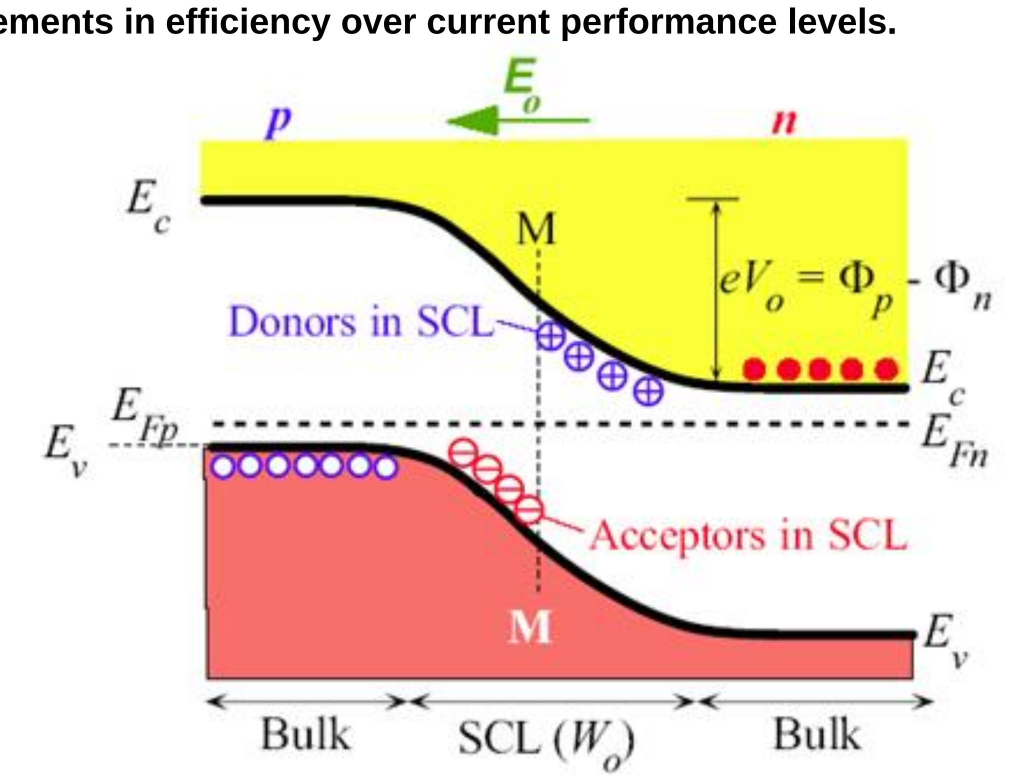
Abstract

This project focuses on a fundamental investigation into the impact of stoichiometric variations on the doping of II-IV compounds such as cadmium telluride (CdTe), deposited in polycrystalline form. The main experimental tool is a vapor deposition apparatus, which will be used to deposit CdTe films under various growth conditions (Cd/Te ratio; the films will also be extrinsically doped with impurities for p and n-type conductivity). Hall Effect studies will be performed to measure mobilities and net doping concentration. In addition, impurity profiling will quantify the impact of dopants on the efficiency of solar cells made with this material; photoluminescence measurements will also be used to study the optical properties of the films. Ultimately, these investigations will reveal optimal aspects that will increase the efficiency of solar cells to near 20%. This will lead to the widespread usage of thin–film photovoltaic cells for electricity generation due to their inexpensive manufacturing costs and flexibility of being developed on various substrates.

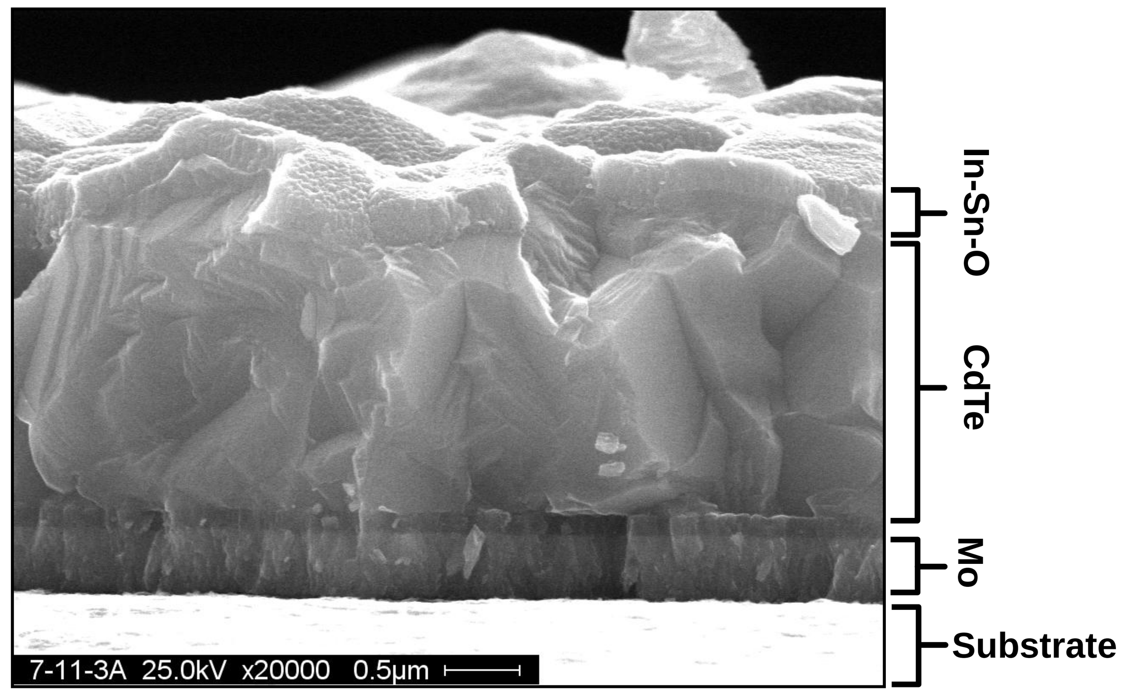
Purpose

The main objectives of this project are:

- Investigate and control the doping levels and transport properties of II-VI thin–film polycrystalline solar cells through use of an Elemental Vapor Transport at Atmospheric Pressure (EVTAP) apparatus
- Explore variations in doping and co-doping and assess which levels are more conducive to improve performance in the thin–film cell
- Fabricate single and multi junction photovoltaic cells and demonstrate improvements in efficiency over current performance levels.



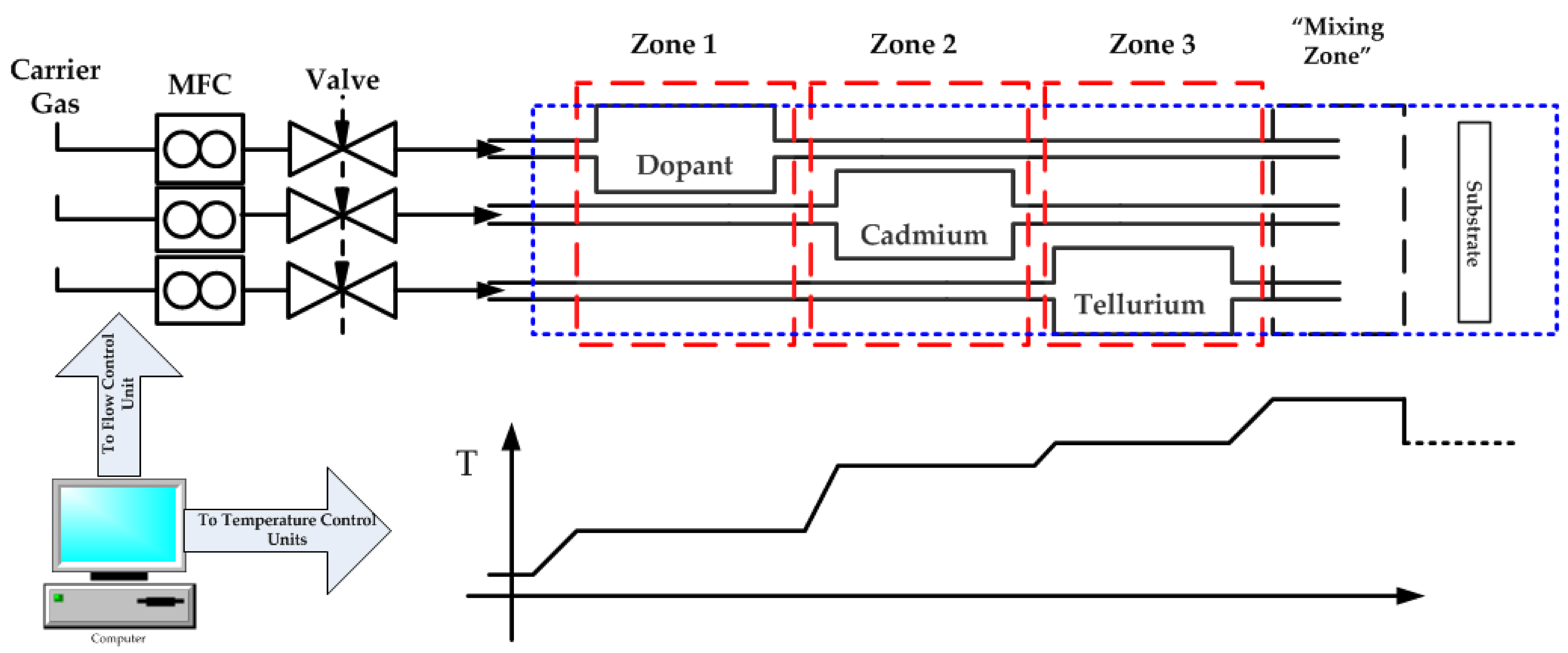
P-N Junction Diagram depicting the establishment of a voltage in the PV Cell [1].



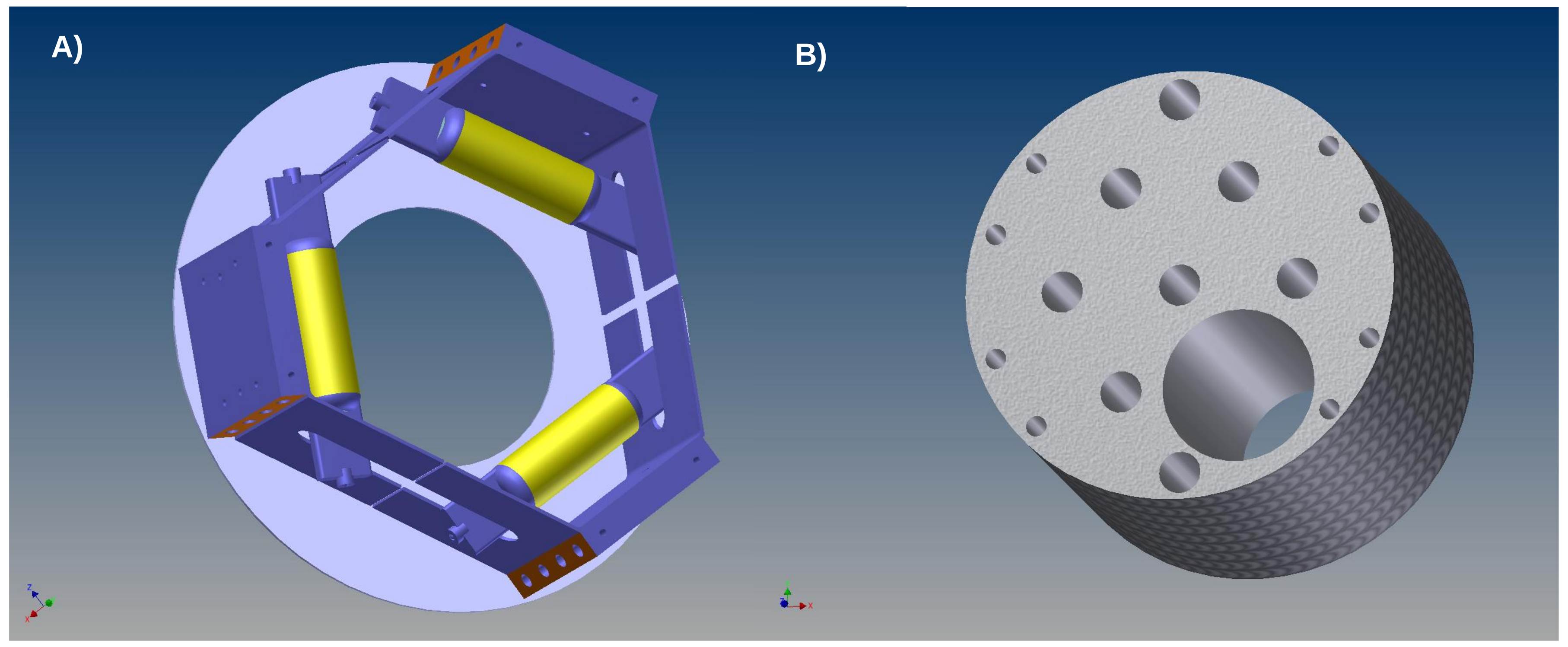
SEM image of one type of a CdTe Thin-Film PV cell. Layers are deposited on stainless steel substrate. *Image courtesy of C.S. Ferekides.*

Experimental Design

- The EVTAP system utilizes a multi-zone configuration to allow precise mixing of each semiconductor material and dopant
- Each zone will house a different element to be deposited on a substrate in the final combination zone
- The system is designed for minimal temperature cross-talk and fast heating
- Each element's vapors will be transferred to the deposition zone and there be deposited on the substrate which will be held at a high temperature
- By use of independent zones for co-doping, the intent is that a more effective dopant incorporation will be accomplished



Schematic of proposed EVTAP Assembly, highlighting the temperature gradient along the length of the apparatus. *Image courtesy of C.S. Ferekides.*



Three-Dimensional Models of A) one of the heating elements that will encapsulate the each zone, embedded in the graphite column passing through the center of the apparatus, as displayed by the cross sectional image B). *Images courtesy of M. Ferraz.*

Proposed Milestones

The tasks listed below will be pursued following construction of the EVTAP deposition system:

1. Controlled co-doping through deposition of group II-VI compounds (such as CdTe, CdSe, and ZnTe) onto various substrates
2. Investigate stoichiometric effects as a function of temperature and pressure
3. Applying results to design a lab experiment for students of the Electronic Materials class. The lab will consist of measuring doping concentrations of substrates using the Hall Effect measurement

Accompanying Educational Modules

It is beneficial to incorporate the Hall Effect system to measure the mobilities and free carrier concentration of PV materials being study under this project. This system is applicable in industry for sensor manufacturing. Therefore, an educational module will be developed in conjunction with the Solar Cell Development.

The purpose of this experiment is to educate students about:

- The history and background of the Hall Effect
- How to induce the Hall Effect
- How to connect it with different components in a circuit
- Practical field applications

This is a secondary educational experiment inside of the Solar Cell Development that will be offered to USF electrical engineering students.

Work Cited

[1] S.O. Kasap, *Principles of Electronic Materials and Devices,* 3rd Ed. New York: McGraw Hill, 2005.

Acknowledgements

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