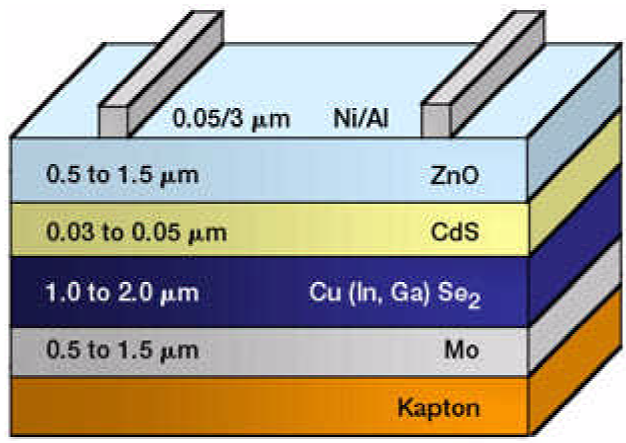
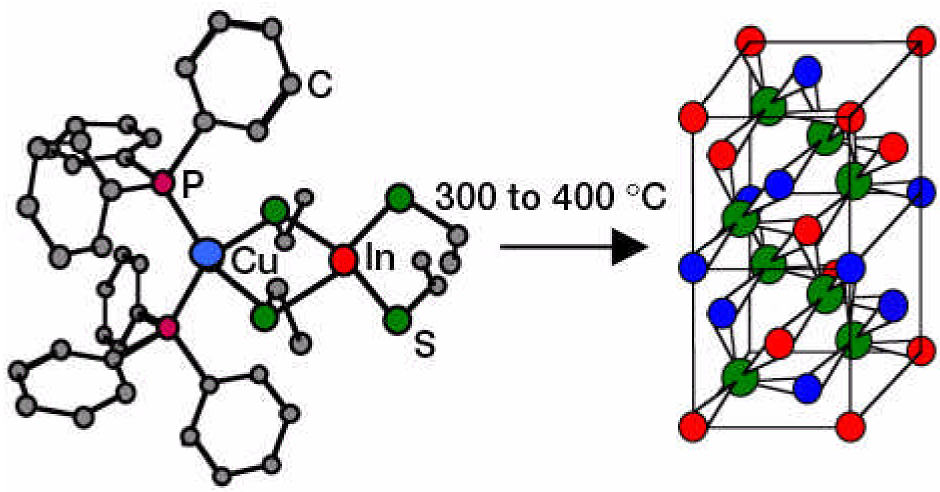
Chemical Fabrication Used to Produce Thin-Film Materials for High Power-to-Weight-Ratio Space Photovoltaic Arrays

The key to achieving high specific power (watts per kilogram) space solar arrays is the development of a high-efficiency, thin-film solar cell that can be fabricated directly on a flexible, lightweight, space-qualified durable substrate such as Kapton (DuPont) or other polyimide or suitable polymer film. Cell efficiencies approaching 20 percent at AM0 (air mass zero) are required. Current thin-film cell fabrication approaches are limited by either (1) the ultimate efficiency that can be achieved with the device material and structure or (2) the requirement for high-temperature deposition processes that are incompatible with all presently known flexible polyimide or other polymer substrate materials. Cell fabrication processes must be developed that will produce high-efficiency cells at temperatures below 400 °C, and preferably below 300 °C to minimize the problems associated with the difference between the coefficients of thermal expansion of the substrate and thin-film solar cell and/or the decomposition of the substrate.



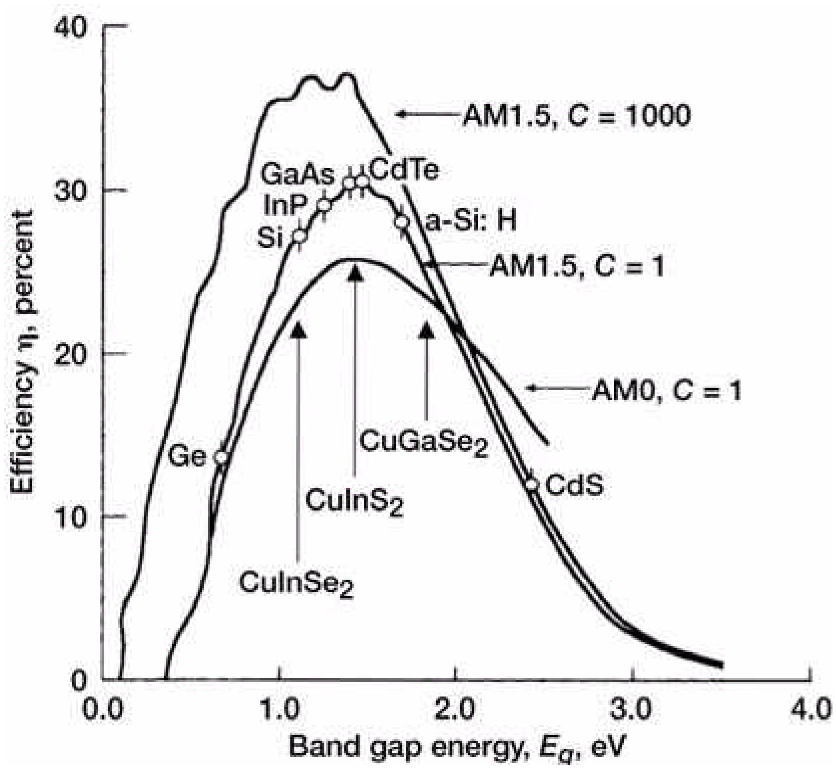
Thin-film solar cell deposited on Kapton substrate.

A chemically based approach at the NASA Glenn Research Center at Lewis Field is enabling the development of such a process: deposition of thin-film solar cell materials via a chemical spray process (using advanced single-source precursors) or electrochemical deposition directly onto molybdenum-coated Kapton or other suitable substrates (see the preceding figure). A single-source precursor containing all the required atoms (copper, indium, and sulfur, or copper, indium, gallium, and selenium, see the next figure) in chemical coordination will enable the use of low deposition temperatures that are compatible with the substrate of choice. Electrochemical deposition enables the precise stoichiometry control required to produce materials with fine-tuned bandgaps.



Decomposition of single-source precursor to produce $CuInS_2$.

Work in collaboration with Professor William Buhro and Jennifer Hollingsworth at Washington University (St. Louis, Missouri) (ref. 1) has resulted in low-temperature chemical spray vapor deposition to produce $CuInS_2$ thin films from an optimized single-source precursor. A combination of low-temperature electrochemical deposition and chemical bath deposition was used to produce $ZnO/CdS/CuInSe_2$ thin-film photovoltaic solar cells on lightweight flexible plastic substrates. This work was performed at Glenn with onsite research faculty Professor Ryne Raffaelle (Rochester Institute of Technology) and NASA Glenn Research Associates Dr. Jerry Harris and Dr. David Hehemann (Kent State University) (ref. 2). One potential device configuration to achieve an efficiency at AM0 of 20 percent or better is based on a copper indium diselenide/copper indium disulfide/copper gallium diselenide ($CuInSe_2/CuInS_2/CuGaSe_2$) three-junction multiple-bandgap structure. The bandgaps of these three materials are shown in the final figure in relation to the optimal efficiencies to be realized as a function of wavelength for the solar spectrum in space (AM0) and on the surface of Earth (AM1.5).



Predicted efficiency versus bandgap for thin-film photovoltaic materials for solar spectra in space (AM0) and on the surface of the Earth (AM1.5) at 300 K.

Find out more about this research http://powerweb.grc.nasa.gov/pvsee/programs/

References

1. Hollingsworth, J.A.; Hepp, A.F.; and Buhro, W.E.: Spray CVD of Copper Indium Sulfide Films: Control of Microstructure and Crystallographic Orientation. Chem. Vapor Deposition, vol. 3, no. 3, 1999, pp. 105–108.

2. Raffaelle, R.P., et al.: Electrodeposited Cds on CIS pn Junctions. Solar Energy Materials and Solar Cells, vol. 57, 1999, pp. 167–178.

Glenn contact: Dr. Aloysius F. Hepp, (216) 433–3835, Aloysius.F.Hepp@grc.nasa.gov

Authors: Dr. Aloysius F. Hepp, Dr. George C. Rybicki, Professor Ryne P. Raffaelle, Dr. Jerry D. Harris, Dr. David G. Hehemann, William Junek**,** Professor Joseph Gorse**,** Tracy L. Thompson, Jennifer A. Hollingsworth, and Professor William E. Buhro

Headquarters program office: OSS

Programs/Projects: CETDP, SSP