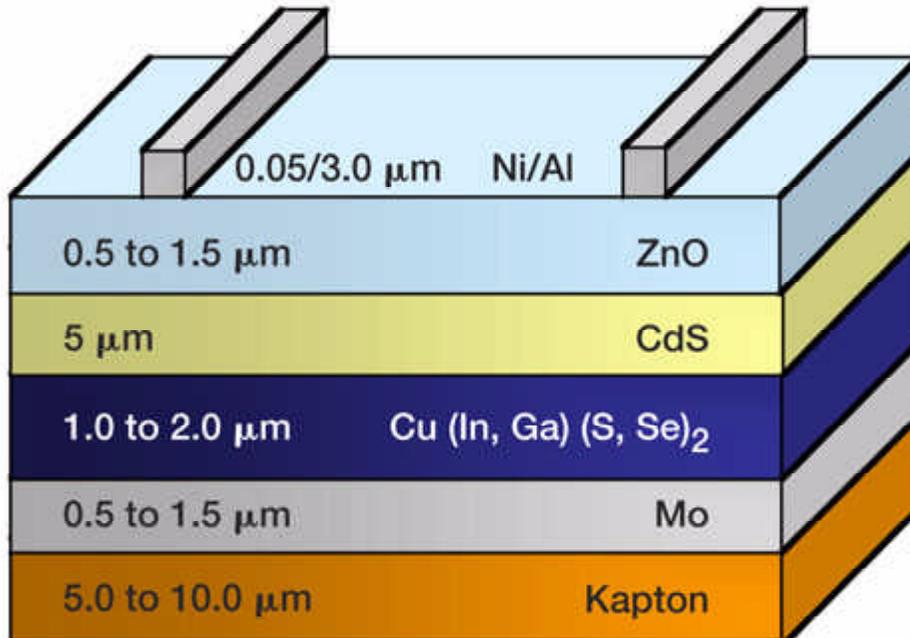


Atmospheric-Pressure-Spray, Chemical-Vapor-Deposited Thin-Film Materials Being Developed for High Power-to-Weight-Ratio Space Photovoltaic Applications

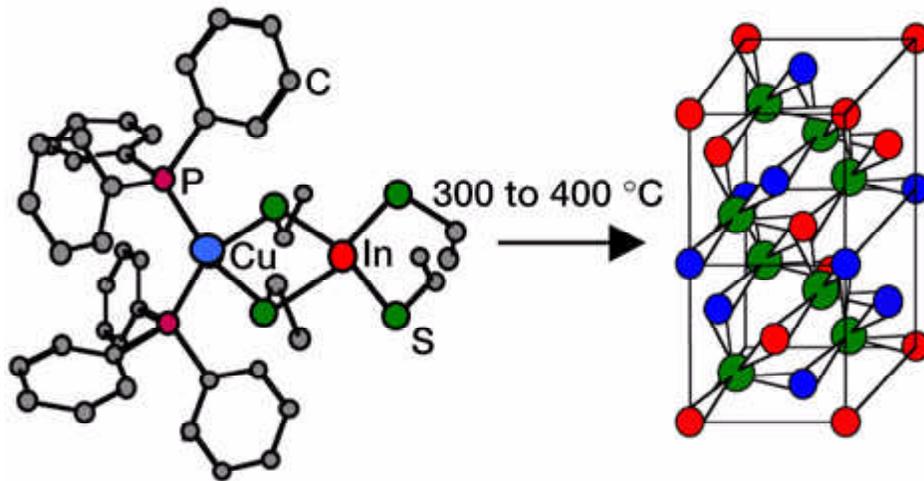
The key to achieving high specific power (watts per kilogram) space photovoltaic arrays is the development of high-efficiency thin-film solar cells that are fabricated on lightweight, space-qualified substrates such as Kapton (DuPont) or another polymer film. Cell efficiencies of 20 percent air mass zero (AM0) are required. One of the major obstacles to developing lightweight, flexible, thin-film solar cells is the unavailability of lightweight substrate or superstrate materials that are compatible with current deposition techniques. There are two solutions for working around this problem: (1) develop new substrate or superstrate materials that are compatible with current deposition techniques, or (2) develop new deposition techniques that are compatible with existing materials. The NASA Glenn Research Center has been focusing on the latter approach and has been developing a deposition technique for depositing thin-film absorbers at temperatures below 400 °C.



Thin-film solar cell deposited on Kapton substrate.

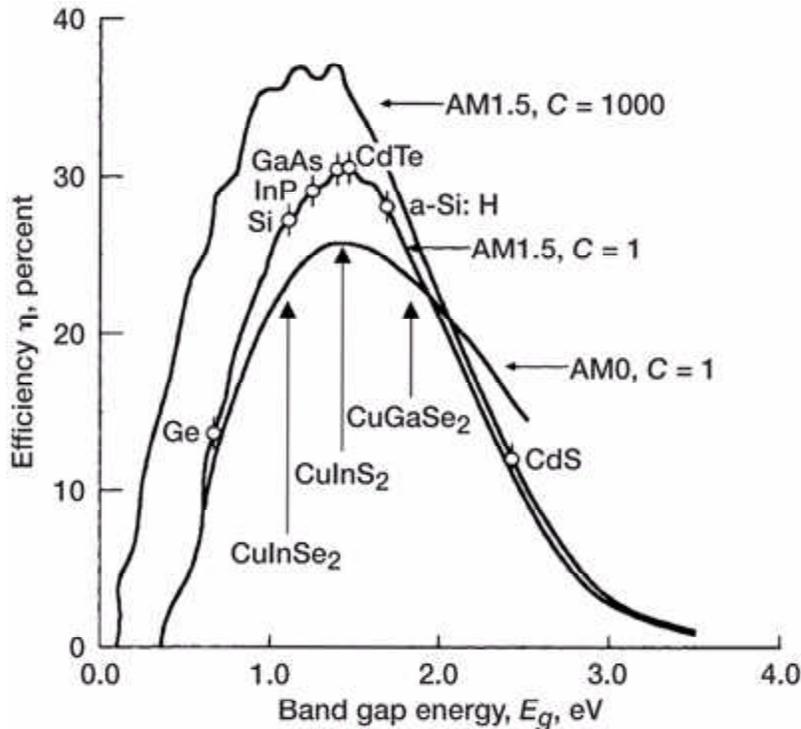
Schematic showing five layers and electrodes of solar cell. Electrodes: 0.05/3.0 μm Ni/Al; top layer: 0.5 to 1.5 μm ZnO; second layer: 5 μm CdS; third layer: 1.0 to 2.0 μm Cu (In, Ga) (S, Se)₂; fourth layer: 0.5 to 1.5 μm Mo; fifth layer: 5.0 to 10.0 μm Kapton.

A chemically based approach is enabling the development of such a process by employing single-source molecular precursors and atmospheric-pressure-spray chemical vapor deposition. Thin films of CuInS_2 can be deposited on substrates at temperatures as low as $300\text{ }^\circ\text{C}$ (see the preceding figure) (ref. 1). Single-source precursors are molecules that contain all the required atoms (copper, indium, and sulfur for CuInS_2 ; or copper, indium, gallium, and selenium for $\text{CuIn}_{1-x}\text{Ga}_x\text{Se}_2$) in the correct ratio to yield the desired material when they decompose (see the following figure). The first liquid precursors for the preparation of CuInS_2 films were recently synthesized and utilized (ref. 2). Liquid precursors offer the advantage of even lower decomposition and deposition temperatures.



Decomposition of single-source precursor to yield CuInS_2 .

One potential configuration to achieve an efficiency at AM0 of 20 percent is a copper indium disulfide/copper indium diselenide/copper gallium diselenide ($\text{CuInS}_2/\text{CuInSe}_2/\text{CuGaSe}_2$) triple-junction multiple-bandgap structure. The bandgaps for these materials are shown in the preceding graph 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 the solar spectrum in space (AM0) and on the surface of the Earth (AM1.5) at 300 K.

Graph plotting data for Ge, CuInSe₂, CuInS₂, CuGaSe₂, Si, InP, GaAs, CdTe, a-Si: H, and CdS, along with the locations of AM1.5, C = 1000; AM1.5, C = 1; and AM0, C = 1.

References

1. Harris, J.D., et al.: Using Single Source Precursors and Spray Chemical Vapor Deposition to Grow Thin-Film CuInS₂. IEEE Photovoltaic Specialists Conference, 2000, pp. 563-566.
2. Banger, K.K., et al.: Synthesis and Characterization of the First Liquid Single-Source Precursors for the Deposition of Ternary Chalcopyrite (CuInS₂) Thin Film Materials. Chem. Mater., vol. 13, 2001, pp. 3827-3829.

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