Cost-Effective CIGS Film Boosts Solar Cell Performance

The Pitch

Compared with traditional silicon photovoltaic (PV) manufacturing, thin-film PV uses roughly 1% of the active (and costly) PV material to convert the sun's energy into electricity. Copper-indium-gallium selenide (CIGS) with high conversion efficiencies has long been the most promising thin-film material. The company HelioVolt has patented a process that prints high-quality CIGS thin films. Called FASST (field-assisted simultaneous synthesis and transfer), it is a rapid manufacturing process that can be scaled up effectively to meet the needs of the $36 billion photovoltaic market.

Observations drawn from the HelioVolt work on device-quality CIGS show large, columnar grains and an overall copper deficiency compared to the structure of the conventional α-phase copper indium di-selenide ($CuInSe_2$). Confirmed by tests conducted with the National Renewable Energy Laboratory (NREL), the intra-absorber junction (IAJ) model shows that the different charges of CIGS elements cause the molecules in the material to spontaneously arrange themselves into a percolation network, α so-called nanoscale expressway for electricity.

The IAJ model shows that compositions lie in the equilibrium of a two-phase domain, $\alpha + \beta$, and form a nanoscale *p-n* junction network or nanodiode network (percolation network). The *n*-type networks act as preferential electron pathways while the *p*-type networks act as preferential hole pathways. Positive and negative charges travel to the contacts in physically separate paths, reducing recombination and improving efficiency. By designing the FASST process around these findings, HelioVolt is able to significantly reduce the cost of thin-film CIGS devices and to control the quality of high-throughput manufacturing. High-quality, low-cost CIGS thin films deliver electricity that is cost competitive with other conventional fossil-fuel–based sources and open the photovoltaic market to regions with less solar irradiation or more diffuse light conditions.

The Technology

FASST is a two-stage reactive transfer printing method involving (1) the deposition of two separate precursors, and (2) the chemical reaction between the precursor films to form CIGS, as shown in Figure 1. In the first stage, two Cu-In-Ga-Se–based precursor layers forming the chemical basis of CIGS are deposited onto a substrate and a print plate. The use of two separate precursors provides the benefits of an independently optimized composition, structure, deposition method, and processing conditions for each; eliminates pre-reaction prior to the second-stage FASST; and facilitates optimized CIGS formation in the second stage. Furthermore, precursors can be deposited at a low substrate temperature, saving energy and costs.

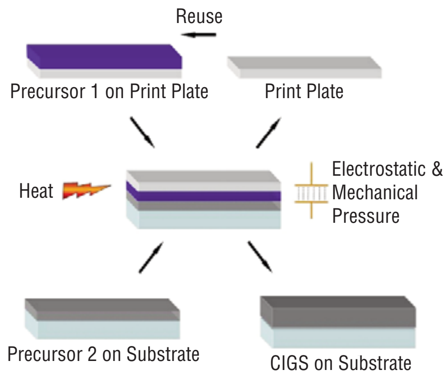

Figure 1. Schematic of the FASST® process. CIGS stands for copper indium gallium selenide.

In the second stage, these precursors are brought into intimate contact and rapidly reacted under heat and pressure in the presence of an applied electrostatic field. The method utilizes physical mechanisms characteristic of rapid thermal processing (RTP) used in semiconductor manufacturing and anodic wafer bonding (AWB), effectively creating a sealed micro-reactor that ensures high material utilization, direct control of reaction pressure, and low thermal budget. By pulse heating the film through the print plate, the overall thermal budget is significantly reduced, allowing the use of low-cost, less thermally stable substrate materials.

Sufficient mechanical pressure can substantially prevent the loss of volatile Se vapor from the reaction zone, achieving highly efficient incorporation of Se into the composition layer and ensuring overall device efficiency. The use of an electrical bias between the print plate and substrate creates an attractive force between them that ensures intimate contact between the precursor films on an atomic scale, and can be used in conjunction with mechanical pressure to control the total pressure in the reaction zone. Furthermore, the electrostatic field helps control the ionic constituent transport during synthesis.

The FASST process produces high-quality CIGS films with large columnar grains and a chalcopyrite crystal structure with (220/204) preferred orientation, which helps junction formation and improves solar cell performance. Solar cells of over 14% efficiency have been fabricated. The FASST process synthesizes CIGS in five minutes from the two precursors compared to several hours for competitive processes. This reaction time is expected to be decreased further, eventually reaching a few seconds. The rapid processing time for CIGS formation significantly increases manufacturing throughput, maximizing the utilization of capital equipment. The unique processing approach results in a lower thermal budget compared to co-evaporation and two-step selenization, processes common in CIGS manufacturing.

The ability to tailor the two precursors independently allows for the use of unconventional, non-vacuum deposition techniques such as ultrasonic/pneumatic atomization spraying, inkjet printing, direct writing, screen printing, and slot die extrusion coating. These atmospheric-pressure–based deposition tools offer great flexibility and open new windows for materials processing, as well as a viable means of introducing nanoparticle technology, metal organic chemistry, and novel reaction paths to produce CIGS. In contrast to vacuum deposition equipment, these materials can be deposited in air at temperatures below 200°C.

Opportunities

HelioVolt is seeking proposals from potential partners for joint development agreements to co-develop application-specific solar systems, including systems for utility, commercial, residential, and building-integrated photovoltaics.

Source: Louay Eldada, HelioVolt Corporation, Austin, TX 78744, USA; 512-767-6060; and e-mail leldada@heliovolt.com.

TECHNOLOGY ADVANCES seeks materials developments on the threshold of commercialization. Send suggestions to Renée G. Ford, Renford Communications, renford@comcast.net.

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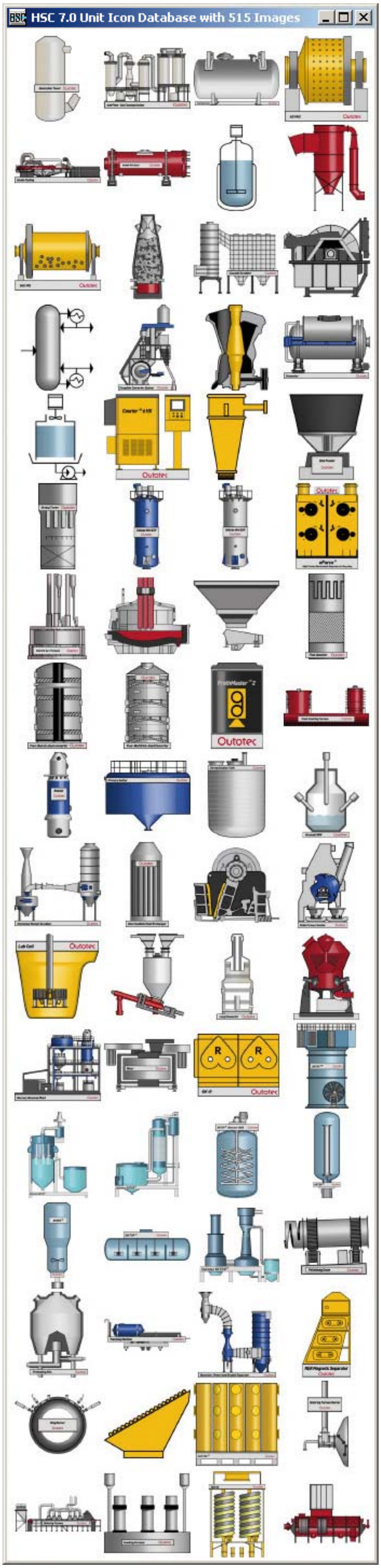

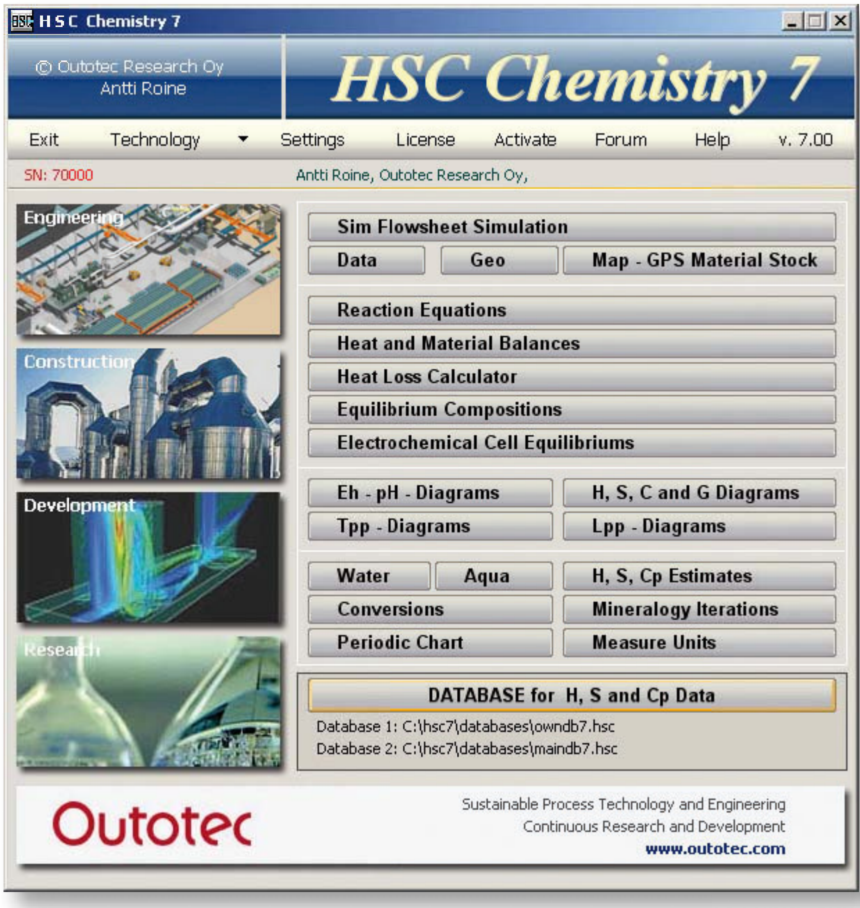

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