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THIN-FILM PHOTOVOLTAICS

Buffer against degradation

Cheap, efficient, and stable thin photovoltaics that use abundant and non-toxic materials can deliver widespread renewable energy. New results using Earth-abundant and potentially cheap ZnO/Sb_2Se_3 solar cells indicate promising levels of stability.

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Following years of research and development, photovoltaic (PV) technologies today are becoming increasingly competitive with conventional forms of electrical power generation. About 93% of solar cells manufactured today are silicon-based. Even though they are built on relatively expensive silicon wafers, silicon solar cells enjoy dominance because they were able to capitalize on the progress of established silicon microelectronics technology, and today they offer the best blend of cost and performance. However, silicon still has limitations, chiefly the need for structurally high-quality silicon substrates and poor optical absorption requiring active device material tens of micrometres thick. To overcome this, there has been sustained interest in developing micron-thick PV materials that can be deposited on cheap glass substrates and could provide higher performance at a lower cost. These so-called thin-film technologies, such as CdTe and $Cu_xIn_{1-x}GaSe_2$ (CIGS), account for less than ~7% of the market because of their limited efficiencies compared to silicon-based PV, as well as issues with toxicity (in the case of Cd) and elemental scarcity (for In). Consequently, there continues to be interest in identifying abundant and non-toxic materials for thin-film solar cells that will be efficient, cheap, and rugged in terms of field performance. Now writing in *Nature Energy*, Jiang Tang and colleagues from the Huazhong University of Science and Technology and other institutions in China report[1] progress in a relatively less-studied material, Sb_2Se_3, that has so far exhibited severe shortcomings in efficiency and stability. Through the use of a new layer in the structure of the device, the researchers have shown that they can dramatically improve the stability of Sb_2Se_3 solar cells.

As shown in Fig. 1, a thin-film solar cell is built around a semiconducting thin-film absorber material, matched to a second thin-film (called a buffer) to form (typically) a p–n junction. Sb_2Se_3 as an absorber has many attractive properties:

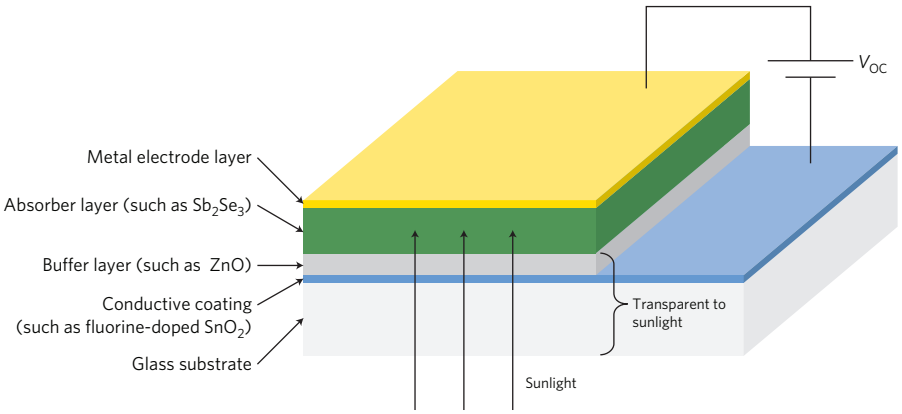

Figure 1 | Typical architecture of a thin-film solar cell. A thin-film solar cell is built around a thin-film absorber material, whose role is to efficiently absorb light and create electron–hole pairs. The absorber layer is matched to a buffer layer, usually a semiconductor. This creates an electrical field that separates the electrons and holes spatially. The separated electrons and holes are then conducted away by electrical contacts, one of which is transparent to let the sunlight in. V_{OC} is the open circuit voltage.

it has a band gap (1.17 eV) that allows the absorption of a significant portion of the solar spectrum, a high optical absorption coefficient, and a reasonable carrier mobility. It can also be evaporated congruently so that the stoichiometry of the deposited film is the same as that of the evaporated source material. This makes the deposition process simple and economical. Usually, the buffer layer in Sb_2Se_3 solar cells is made of CdS (refs 2,3). Now, Tang and colleagues have replaced the buffer layer with ZnO, demonstrating that they were not only able to eliminate a toxic component (Cd), but that the stability of the devices was dramatically improved by avoiding the diffusion of Cd into the absorber layer. Testing for 1,100 hours, at 85 °C and under 85% relative humidity — extreme operating conditions typically used in microelectronics as a test for durability — resulted in minimal degradation of the solar cell (<2% drop in efficiency, to be compared to a ~10% drop in 100 hours with the CdS buffer). This improvement brings these materials to levels close to what might be expected in a commercial product in terms of device stability, an equally important, though often less glamorous companion to another metric — the solar cell efficiency.

The reduced toxicity and improved stability shown by Tang and colleagues are significant milestones, but they come with a couple of caveats. First, the device sizes shown (~0.04 cm^2) are small and while they are acceptable at the initial stages of research, device dimensions typically need to be at least 0.5 to 1 cm^2 in size to begin to allay scalability concerns. Second, the efficiencies of Sb_2Se_3 solar cells still remain low — the researchers report an efficiency of 6%, a marginal improvement over earlier work. This is to be compared with record efficiencies of ~22% achieved in thin-film solar cells using other absorber materials such as CdTe, CIGS, and metal halide perovskites[4]. It is also important to note that stability at lower efficiencies may not guarantee stability at higher efficiencies. Finally, while the Sb_2Se_3 devices exhibit decent photocurrent densities, corresponding to ~70% of the theoretical limit at this band gap and indicating that the material may be relatively free of charge carrier traps, the open circuit voltage is only about 0.35 V, which is roughly half

of that of a good silicon solar cell with a similar band gap. This may indicate that substantial energy loss mechanisms are at play during charge carrier transport across electrical junctions in the device. It may not be a fundamental barrier, but points to a major problem that needs to be methodically tackled.

The past decade has seen the resurgence or emergence of new Earth-abundant materials for PV solar cells such as $Cu_2ZnSnSe_4$ (CZTS)[5] or the metal halide perovskites[6] with promising results. However, they have remained a few steps short of true viability: CZTS is ultimately limited by power conversion efficiencies, and the perovskites continue to be plagued by stability problems. The challenges for thin-film technologies are significant since they need to meet simultaneous requirements of high efficiency, low cost, material availability, stability, and non-toxicity, at cost and performance target levels that have to constantly re-adjust to ever-improving silicon PV cells. In addition, the solar technology investment community remains wary of new approaches, following the high-profile and expensive burnouts (around 2010–2012) of start-ups such as Nanosolar and Solyndra, who tried to develop ink-printed and cylindrical form factor solar panels, respectively[7]. These approaches — in hindsight — appear rushed and unrealistic. 'Incremental' is often a bad word in academic engineering research, but this is the flavour of activity needed for developing the next thin-film solar cell. It is worthwhile to note that both instances of successful thin-film solar technologies that have wide deployment today — CdTe and $CuInGaSe_2$ — have resulted from steady efforts over years, sustained by patient business and funding strategies. For PV technologies to be deployed globally at large scales, they need to move from the world of conventional semiconductor processing (that led to silicon PV) to the realm of cheap, large-scale construction sheet goods in terms of cost, robustness, and ease of installation. Thin-film solar cells are our best bet for accomplishing this: unlike crystalline silicon, they are fine-grained, polycrystalline, and potentially adaptable to a variety of substrates and form factors. It is the reason work in this field continues to be important. The work by Tang and colleagues on the enhanced stability of ZnO/Sb_2Se_3 solar cells suggests that we should begin to take a closer look at Sb_2Se_3 and related compounds for PV. ❐

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