Area 2: Thin-Film Compound Semiconductor PV

CIGS SOLAR CELLS WITH ABOVE 22% EFFICIENCY: CHARACTERISTICS AND HIGHLIGHTS

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It was once prophesized that 20% efficiency simply isn't possible for thin-film solar cells based on Cu(In,Ga)$(S,Se)_2$ (CIGS). However, this milestone was achieved in 2007 and in the nine years since several groups employing different variations of the CIGS technology have achieved over 22% efficiency; the current record is now at 22.6% [1, 2]. This contribution will provide a technological overview, discuss its status at both the R&D and industrial level, and introduce the recent developments which have enabled such high efficiencies. Various concepts as well as insights into new developments with the potential to advance to 25% efficiency will also be presented.

A central feature of the CIGS solar cell is the CIGS absorber layer itself, including its surface which is defining for the heterojunction formation. There are two major approaches to the formation of the CIGS layer: the two-step process and the co-evaporation process. Both approaches have their advantages and disadvantages and both have resulted in solar cells with efficiencies exceeding 22% [1, 2]. Furthermore, the thin-film nature of the technology means that alternative substrates may be employed: sturdy glass for a robust module, polyimide or metal foil for flexible, lightweight applications.

Recent advances in alkali-based surface treatments, known collectively as post-deposition treatments (PDT), are key processes to enable efficiencies significantly over 20% in various laboratories and with various CIGS technologies. The PDT treatment has been shown to significantly increase the cell's open-circuit voltage by improving the junction quality. Likewise, the photocurrent density is improved since PDT-CIGS allows the thickness of the CdS buffer layer to be reduced. Investigations into both phenomena indicate a homogenizing of the CIGS surface at a sub-µm scale, which is also likely why PDT is levelling the playing field for different approaches to CIGS growth. This process can be seamlessly integrated into an in-line multi-stage coevaporation CIGS coating system. Successful implementation of the PDT process in the commercial production of CIGS modules is expected to result in an absolute gain of about 1 % efficiency and correspondingly reduced kWh/Wp costs.

As a research institute focussed on industrially relevant clean energy technologies of the future, we are further developing the potential for flexible CIGS modules with an all-in-one coating plant. Furthermore, even higher efficiencies will eventually require conversion of a wider range of the solar spectrum. All-thin-film tandem solar cells based on perowskite and CIGS can be highly efficient, cheap and even lightweight and flexible. A brief outlook on current activities and achievements will conclude the presentation.

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[1] http://spectrum.ieee.org/static/interactive-record-breaking-pv-cells
[2] P. Jackson, R. Wuerz, D. Hariskos, E. Lotter, W. Witte, M. Powalla, "Effects of heavy alkali elements in Cu(In,Ga)Se_2 solar cells with efficiencies up to 22.6%", Physica Status Solidi RRL 10, No. 8, 583-586 (2016)