Chalcopyrite-based nanostructures: new prospects for highly efficient photovoltaic devices

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Cu-containing, chalcopyrite-based solar cells currently lead the energy conversion efficiency ranking of photovoltaic devices based on thin-film technology. With record figures above 20% for 0.5 cm^2 small-area devices [1] and 15.7% for commercial 1 m^2 modules [2], thin-film photovoltaics is approaching the typical performing ratios of polycrystalline silicon. Not only in terms of efficiency, but also industrial production capacity, thin film photovoltaics is becoming a key player in the development of solar electricity generation [3].

The progress achieved in the performance of chalcopyrite-based photovoltaic devices, by far the most promising approach among all thin-film technologies, has largely been a consequence of phenomenological rather than a fundamental understanding of some of their physical properties. Although a number of important questions remain unanswered, it is already clear that Cu-containing chalcopyrites have unique properties not observed in other semiconducting materials. Such properties are often counterintuitive and challenge our common understanding of semiconductor physics, raising, amongst others, the following questions: how can grain boundaries, ubiquitous in thin films of microcrystalline material, be harmless (if not beneficial) to the electronic transport? Why is it that we can build an efficient electronic device out of a piece of semiconductor even when we are unable to extrinsically control its doping level? Why, ultimately, are the highest efficiencies systematically recorded in devices made from microcrystalline-based material, and not mono-crystalline counterparts? And finally, how can we explain why good solar cells have absorbers with off-stoichiometric compositions?

In this presentation, we will first briefly address some of these intriguing questions and discuss some recent results of research on such topics, highlighting the key role played by material characterization at the nanoscopic level in the search of convincing answers. We will then discuss growth, characterization and design of nanostructures based on Cu-containing chalcopyrites, not only as a means to implement large-scale, thin-film production, but additionally to open new possibilities for the realization of advanced photovoltaic devices beyond conventional architectures. Finally, the current status of research on nano-crystalline chalcopyrites will be reviewed, addressing the fundamental points for their utilization in highly efficient devices.

References

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