Mechanochemistry for photovoltaics and green energy

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New industrial and technological solutions for green energy and optoelectronics are needed to bypass the state of the art in methodology and performances, demanding an extra-effort from researchers in field of material science for the synthesis, characterization and prototyping of more performant materials and device solutions.
In this framework, we show how mechanochemistry (MC) can be smartly applied to this field, specifically through the high energy ball milling method. This simple and cheap technique allows to directly control materials' reactivity and to synthetize inorganic powders from a solid-state reaction both in stable and metastable phases: particularly, MC allows to exploit a non-equilibrium thermodynamic regime, keeping the process around room temperature and ambient pressure, and avoiding the use of toxic solvents. Moreover, thanks to MC, it is possible to obtain large amounts of products while minimising by-products and costs.
We present an overview on different semiconducting materials innovatively synthetized at IMEM-CNR via high-energy ball milling and their ground-breaking properties, together with a simple process to obtain targets from these products [1], which could be exploited through physical vacuum techniques.
Specifically, we focus on Cu(In,Ga)(S,Se) (CIGSSe) chalcogenides, a class of compounds notoriously used as efficient absorbers ($\alpha > 10^5$) for stand-alone thin film solar cells application. Through MC it is possible to obtain pure phases freely varying the cationic (In/Ga) and anionic (S/Se) ratio of the solid solution, allowing to tune the optical bandgap from 1.02 eV ($CuInSe_2$) to 2.5 eV ($CuGaS_2$). The products are then morphologically refined with a lower energy ball milling process (carried out with the same apparatus) to produce a stable suspension that could be used as a photovoltaic varnish to be deposited by a low-cost spin coating method. This process results in a deep modification of the chalcogenides' optical properties, providing an astonishing semi-transparency (>90%) suitable for tandem application on standard Silicon based solar cells technology.
In parallel with these, we present the first results of the ferroelectric-photovoltaic SbSI synthesis, refinement and preliminary characterization. This pure MC product was used to produce a mechano-target, which was exploited as the source material for the Low-Temperature Pulsed Electron Deposition (LT-PED) of a semi-transparent thin film.

References

[1] Delmonte, D., et al. "An affordable method to produce CuInS2 'mechano-targets' for film deposition." Semiconductor Science and Technology 35.4 (2020): 045026.