

Functional Thin Films for Solar Energy Systems

This technology applies advanced thin-film deposition methods, originally developed for fusion materials research, to the fabrication of high-performance coatings for solar energy devices. Developed through collaboration between CIEMAT's Laboratory for Fusion Technology (LNF) and the Solar Energy Division, the technology leverages magnetron sputtering to produce functional semiconductor and ceramic films with tailored optical, electronic, and mechanical properties. These coatings enable improved light absorption, durability, and efficiency in photovoltaic systems, bridging fusion plasma expertise with renewable energy innovation.

■ Description of the technology

The technology relies on reactive magnetron sputtering, a vacuum-based deposition process that allows atomic-level control over film composition and thickness. Using this approach, thin layers of eco-friendly materials such as copper nitride (Cu_3N) and silicon carbide (SiC) are fabricated on glass or silicon substrates. These materials exhibit tunable optical band gaps, high chemical stability, and strong mechanical adhesion, making them ideal for solar absorbers and optoelectronic applications.

The films developed at CIEMAT demonstrate excellent surface uniformity, dense morphology, and stable nanomechanical performance, with hardness values above 4 GPa and elastic moduli up to 100 GPa. Optical analyses reveal direct band gaps between 2.0 and 2.4 eV and high absorption coefficients, confirming their suitability as absorber layers in photovoltaic devices. In addition, Cu_3N films show reversible hydrogen uptake and release at moderate temperatures, opening further opportunities for hybrid solar-hydrogen systems. The sputtering process enables fine adjustment of key parameters (substrate temperature, working pressure, and plasma composition), allowing the production of defect-tolerant, high-purity coatings compatible with standard industrial processes.

■ Innovation and advantages of the offer

The innovation of this technology lies in the application of fusion-developed magnetron sputtering know-how to the fabrication of functional thin films with tightly controlled optical, mechanical, and structural properties. The deposition techniques were originally established to meet the stringent requirements of fusion materials research, where coating uniformity, adhesion, reproducibility, and stability under extreme conditions are critical.

Compared to conventional thin-film fabrication methods, magnetron sputtering enables superior control over film thickness, composition, and microstructure, resulting in coatings with high uniformity, strong substrate adhesion, and stable performance under thermal and environmental cycling. In addition, the versatility of the sputtering platform allows the same technological base to be adapted to a wide range of functional materials and application requirements across different energy and optoelectronic sectors.

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■ Non-fusion Applications

The technology is directly applicable to several energy and materials sectors requiring thin, stable, and functional coatings:

- **Photovoltaics:** absorber and buffer layers for next-generation solar cells.
- **Optoelectronics:** coatings for photodetectors, optical sensors, and transparent electronics.
- **Hydrogen technologies:** Cu_3N -based films for reversible hydrogen storage and catalytic applications.
- **Protective coatings:** hard, chemically resistant thin films for energy conversion devices and electronic substrates.

■ EUROfusion Heritage

Developed within CIEMAT's fusion materials research and extended through collaboration with the LNF project and the Solar Energy Division, this technology represents a successful case of intra-institutional knowledge transfer. It demonstrates how expertise in sputtering and plasma materials processing from fusion research can directly benefit renewable energy innovation, strengthening the link between fusion science and sustainable industrial applications.