Pulsed laser ablation processes in photovoltaics

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Laser ablation has been developed as a promising technique for photovoltaics (PV) to enhance solar cells' performance and efficiency. Laser ablation is employed for surface texturing and patterning of PVs. For example, it can be used for selective ablation of passivated emitters, anti-reflective coating in inorganic-based solar cells or monolithic interconnections in organic solar cells. In this research, we present laser ablation methods for organic and inorganic PVs and address the challenges of these processes.

In inorganic solar cell manufacturing, establishing metal contacts with silicon is crucial for completing the electric circuit, requiring the selective removal of insulating layers (e.g. SiN_x)[1]. Pulsed lasers offer a fast, stable, cost-effective, and reliable method for this task. However, concerns about laser-induced damage arise if the SiN_x coating does not fully absorb the laser light, potentially causing partial ablation and damage to the underlying emitter, a challenge intensified on textured surfaces. Femtosecond lasers induce nonlinear effects like two-photon absorption, where molecules or atoms absorb two photons simultaneously, leading to an energetically excited state. Utilizing green light at 520 nm also implies UV absorption at half the wavelength (260 nm), with UV intensity increasing quadratically with green light intensity. This phenomenon allows for processing transparent media near the surface without harming underlying layers, provided optimal laser parameters are chosen to minimize thermal damage.

Selective laser micromachining is utilized in organic or hybrid solar cells for monolithic interconnection [2]. Thermal diffusion in the irradiated material is significant for long pulse lasers (ns or continuous wave), leading to a large melting zone extending beyond the irradiation zone. In contrast, ultra-short pulse lasers (ps and fs) vaporize material in the irradiation zone before significant heat can be passed on to its surroundings, resulting in clean and high-resolution processing. Three layers (bottom electrode, absorber layer insulation, and front contact) must be individually ablated for monolithic interconnection by laser ablation. Picosecond and femtosecond pulsed laser systems (pulse length 10 ps, wavelength 532 nm, and 200 fs, 520 nm) are available for these processes, ensuring low electrical resistance in the electrical contacts while preserving the solar cell's vulnerable layer structure.

Acknowledgements: The research presented here is funded by Solar Era Net project COMET(**FFG FO999897446**).

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