Femtosecond Laser Nanostructuring of ITO for Improved Light Harvesting in Optoelectronic Devices

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Transparent conductive oxides, such as indium tin oxide (ITO), are essential for various optoelectronic devices including solar cells, LEDs and touchscreens that rely on both transparency and electrical conductivity. Despite widespread use, ITO's performance remains suboptimal. This project investigates femtosecond laser nanostructuring to enhance ITO's optical properties while maintaining conductivity. In this project, 60 samples were fabricated with varying laser powers (30–265 mW) and scan speeds (0.5–40 mm/s) to identify optimal processing parameters. Nanostructured arrays were created to increase surface area. Optical, electrical and morphological properties were systematically characterized to identify optimal parameters. The optimized nanostructured ITO demonstrated a significant increase in light transmittance compared to conventional ITO, while maintaining nearly identical electrical resistance. In addition, the study identified an exceptionally broad range of effective laser processing parameters (namely an average power range of 30-50 mW combined with scan speeds of 20-40 mm/s) that notably maintained excellent and almost identical ITO performance, demonstrating a remarkable processing tolerance. This optimization could be ultimately used to enhance the performance of perovskite solar cells fabricated using the nanostructured ITO. This work highlights the potential of femtosecond laser nanostructuring to enhance ITO performance without compromising its electrical conductivity, offering a pathway to more efficient solar cells and other optoelectronic devices. The scalability, precision and parameter tolerance of this technique make it industrially viable, paving the way for next-generation TCOs with superior performance.

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