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From Ion Tracks to Nanoscale Holes in Oxide Semiconductors: Swift Heavy Ion Engineering of BiVO4 for Solar Water Splitting

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Swift heavy ion (SHI) irradiation with 150 MeV Xe ions (5 × 109 - 5 × 1011 ions cm-2) was used to tune the defect landscape and morphology of hydrothermally grown BiVO4 (BVO) thin films, aiming to enhance their photoelectrochemical (PEC) performance for the oxygen evolution reaction (OER). Irradiation induces residual stress, partial amorphization, and bismuth-rich hillocks over oxygen-depleted ion tracks. At the highest fluence, overlapping tracks and excessive defect accumulation cause irreversible performance loss. In contrast, lower fluences (5 × 109 and 1 × 1010 ions cm-2) generate controlled defects that initially trap charges but subsequently boost activity, increasing photocurrent density by 58.6% and 25.2%, respectively. Post-PEC analysis reveals evolution of latent ion tracks into nanoscale holes (up to 30 nm in diameter, 200 nm deep), with the 1 × 1010 ions cm-2 sample displaying the most uniform features, indicative of an optimal defect–stress balance enabling localized restructuring. These results demonstrate SHI irradiation as a precise nanoscale morpho-structural engineering tool, with the controlled creation of holes in oxide semiconductors offering pathways for cocatalyst or plasmonic integration to further enhance PEC efficiency.

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