WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

PH.D. DISSERTATION

ENTITLED

"CONTROLLED SYNTHESIS OF NANOSTRUCTURED TWO-DIMENSIONAL TIN DISULFIDE AND ITS APPLICATIONS IN CATALYSIS AND OPTOEELECTRONICS"

BY

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Abstract:
Tin disulfide (SnS_2) is a two-dimensional (2D) material with exciting properties and high prospects for low-cost solutions to catalytic and optoelectronic applications. In this work, vertical nanoflakes of SnS_2 have been synthesized using custom-designed close space sublimation (CSS) system and investigated for two distinct applications: photoelectrochemical (PEC) water oxidation and metal-semiconductor-metal (MSM) photodetector. For PEC water oxidation, vertical SnS_2 nanoflakes grown directly on transparent conductive substrates have been used as photoanodes, which produce record photocurrents of 4.5 mA cm^{-2} for oxidation of a sulfite hole scavenger and 2.6 mA cm^{-2} for water oxidation without any hole scavenger, both at 1.23 V_{RHE} in neutral electrolyte under simulated AM1.5G sunlight, and stable photocurrents for iodide oxidation in acidic electrolyte. This remarkable performance has been attributed to three main factors: (1) high intrinsic carrier mobility of 330 $cm^2\,V^{-1}\,s^{-1}$ and long photoexcited carrier lifetime of 1.3 ns in the nanoflakes, (2) the nanoflake height that balances the competing requirements of light absorption and charge transport, and (3) the unique stepped morphology of these nanoflakes that improves photocurrent by exposing multiple edge sites in every nanoflake. In another application, these SnS_2 nanoflakes have been used to enhance the performance of lead sulfide quantum dot (PbS QDs) photodetectors by providing a high-mobility channel for photoexcited charges from PbS QDs, which results in 2 orders of magnitude enhancement in responsivity and fast response time. The physical models and experimental findings presented in this dissertation can help engineer more cost-effective solutions for PEC water splitting and optoelectronics based on 2D metal dichalcogenides.

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https://wpi.zoom.us/j/318708790

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