# Controlled Growth of Tellurium Network Structures for Multi-Spectral Photodetector Applications

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**Abstract:**

Recently, tellurium (Te) has gained significant interest for its unique helical atomic chain structure bonded by van der Waals (vdW) forces. It exhibits thickness-dependent electronic properties similarly to two-dimensional (2D) materials, along with strong spin–orbital coupling from its chiral structure and enhanced environmental stability. As a p-type semiconductor, Te has a narrow band gap (1.2 to 0.3 eV), large responsivity, high detectivity, high on/off ratios, and high carrier mobility, making it a promising material for short-wavelength infrared (SWIR) photodetection. Although a convenient physical vapor deposition (PVD) has been widely applied as a tailored growth technique for the Te growth, the critical parameters controlling the synthesis of 2D and 1D Te structures remain unclear. Herein, this research focuses on understanding the growth mechanism of Te nano- and microstructures. Key parameters, such as pressure, temperature, and growth time, have been systematically explored to study their effects on growth evolution. Various Te structures, including microspheres, microrods, microplates, nanowires, etc., have been synthesized at different growth zones. This study makes it possible to realize controlled growth of different Te structures and a research focus is centered on a unique Te network structure of microrods (Te-Net). This innovative structure is the first of its kind to be reported, as previous reports have mostly been focused on individual micro- or nanostructure. The network structure enables low-cost device fabrication without sophisticated lithography.

The Te-Net based photodetectors demonstrate excellent responsivity (R) and detectivity (D*) under different illumination conditions, with typical values as high as R = 0.43 A/W and D* =3.98 × $10^7$ Jones at 405 nm. At 532 nm and 808 nm, the device exhibits responsivity of 8.6 × $10^{-3}$ A/W and 7.3 × $10^{-3}$ A/W, and detectivity of 9.6 × $10^5$ Jones and 7.4 × $10^5$ Jones, respectively. We are investigating the photoresponse mechanisms including direct carrier photogeneration and local heating for further performance improvement. One important phenomenon we discovered is that the devices are extremely sensitive to the dark environment with the room lights off. No significant visible/near-infrared light was detected from the dark environment using a commercial spectrometer and no existing theory explains this phenomenon. Therefore, future research will focus on investigating the source of the light signals and the mechanism of this extreme sensitivity. We are looking into the device performance under illumination of other light sources, especially those in the SWIR to mid-wavelength infrared ranges. Additionally, further structure characterization and optical measurement (e.g. Raman, X-ray diffraction, ellipsometry, etc.) will

be performed on the Te-Net to reveal their composition, crystal structure, band structure, defects, and other optical properties. A clear structure-property relation can then be established for the Te-Net structures in multi-spectral photodetection, paving a solid pathway to realize their high-efficiency applications in environmental monitoring, imaging, and optical sensing.