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Copper Nitride films and their hybrid nanostructure with Oxide for UV Light Sensing

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Introduction

The microstructure of Cu_3N nanocrystals displays a uniform crystalline morphology, owing to the high ionization rate during deposition by HiPIMS. Phase structure analysis confirms the presence of Cu_3N thin film with an anti-ReO_3 structure. Cu_3N exhibits impressive absorbance in the ultraviolet (UV) range, significantly impacting the photodetection. Then, varying substrate temperatures influence Cu_3N film crystallinity, showcasing optimized conditions for high-performance UV photodetectors. Nanorods have a large surface-to-volume ratio that raises the number of surface trap states and improves incident light trapping by multiple reflections. The deposition of p-type Cu_3N film using HiPIMS over n-type ZnO NRs forming p-n junction augment the properties of both materials together. The incident light gets absorbed and provides pathways for carrier collection. Provides efficient usage of materials compared to thin film. Also, ameliorates charge transport and collection. This makes novel ZnO/Cu_3N core-shell NR heterostructures based self-powered UVPDs a potential candidate for future advanced optoelectronic devices such as IoTs.

Experiments and Results

Single Layer Cu_3N

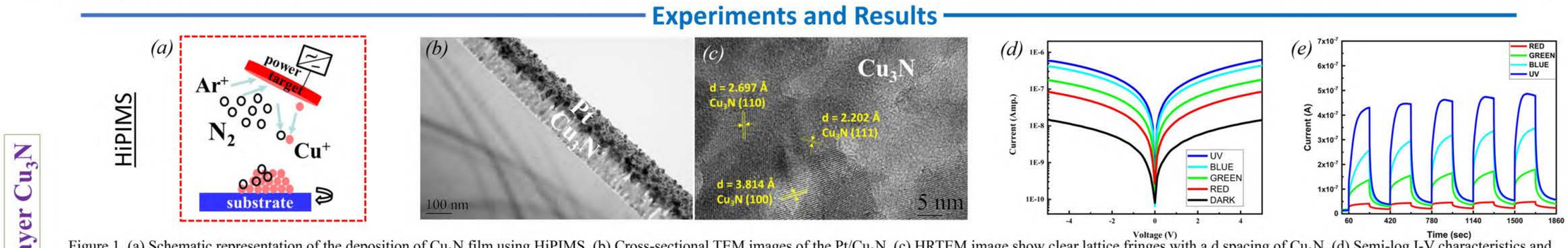

Figure 1. (a) Schematic representation of the deposition of Cu_3N film using HiPIMS. (b) Cross-sectional TEM images of the Pt/Cu_3N, (c) HRTEM image show clear lattice fringes with a d spacing of Cu_3N. (d) Semi-log I-V characteristics and (e) Real-time I-T characteristics of ITO/Cu_3N/ITO device in dark and in the presence of UV: 365 nm, Blue: 456 nm, Green: 532 nm, and Red: 632 nm lights.

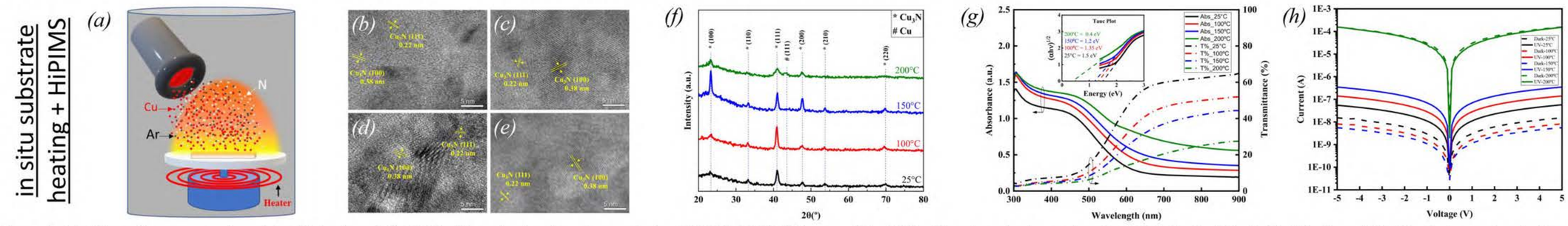

Figure 2. (a) Schematic representation of the fabrication of Cu_3N thin film using in-situ substrate during HiPIMS. HRTEM image of Cu_3N thin films deposited at various T_s (b) 25 ◦C, (c) 100 ◦C, (d) 150 ◦C, and (e) 200 ◦C shows clear lattice fringes with the d spacing. (f) XRD patterns (g) Absorbance and transmittance of Cu_3N thin films deposited at different substrate temperatures. Inset shows the corresponding Tauc Plot for the indirect optical band gap (Eg) of Cu_3N thin films. (h) I-V measurements in dark and under UV (365 nm) light illumination on Cu_3N thin films UV photodetector deposited at different substrate temperatures.

Hybrid structure

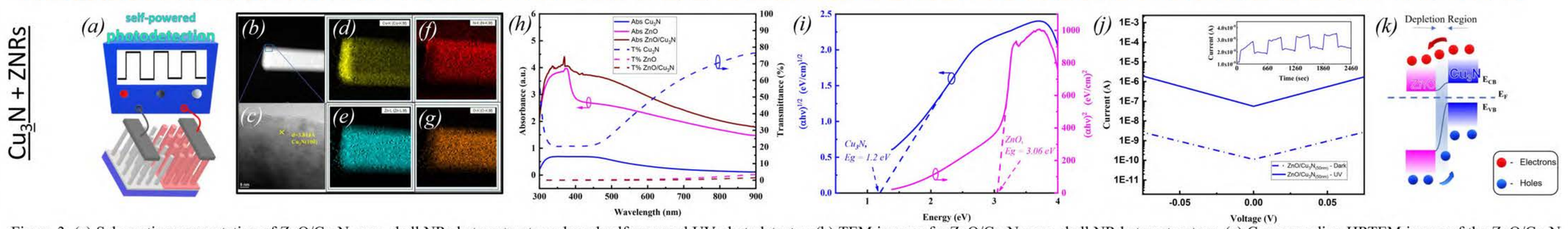

Figure 3. (a) Schematic representation of ZnO/Cu_3N core–shell NRs heterostructures based self-powered UV photodetector. (b) TEM image of a ZnO/Cu_3N core–shell NR heterostructure. (c) Corresponding HRTEM image of the ZnO/Cu_3N captured close to the top face of the ZnO NR. Corresponding EDS–STEM elemental maps of the (d) Cu, (e) Zn, (f) N, and (g) O elements, respectively. (h) Absorbance and transmittance of Cu_3N thin films deposited using HiPIMS, ZnO NR array grown by hydrothermal method and ZnO/Cu_3N core–shell NR heterostructures. (i) Tauc Plot for the indirect and direct optical band gap (Eg) of Cu_3N thin films and ZnO NR array. (j) I-V measurements for self-powered UV photodetection by ZnO/Cu_3N core–-shell NR heterostructures in dark and under UV (365 nm) light illuminance @ 0V with the inset of real-time photocurrent response of self-powered ZnO/Cu_3N core–shell NR heterostructure based UV photodetectors. (k) Schematic representation of the energy band diagram of ZnO/Cu_3N.

Summary

Reactive HiPIMS deposition technique used to achieve smooth and uniform Cu_3N films. Single layer Cu_3N photodetector demonstrated significant broadband photodetection with high sensitivity, fast response, and long-term stability under UV light illumination. In situ substrate heating exhibited improved stoichiometry and optical properties resulting in enhanced UV photodetection. ZnO/Cu_3N core-shell heterostructure resulted in high-performance and advanced self-powered UV photodetectors due to formation of p-n junction and high surface-to-volume ratio. Cu_3N thin films and their hybrid nanostructures hold promise for optoelectronic properties and sensing applications.

Publications

1. **Shikha Sakalley**, Adhimoorthy Saravanan, Wei-Chun Cheng, Sheng-Chi Chen, et al. "Cu_3N thin film synthesized by selective in situ substrate heating during high power impulse magnetron sputtering for augmenting UV photodetection. " Sensors and Actuators A: Physical 350 (2023) 114137.
2. **Shikha Sakalley**, Adhimoorthy Saravanan, Wei-Chun Cheng, Sheng-Chi Chen, et al. "High Performance Self-Powered UV Photodetection by ZnO/Cu_3N Core-Shell Nanorod Heterostructures via pn Junction Formation." Journal of Alloys and Compounds 936 (2023): 168157.
3. **Shikha Sakalley**, Adhimoorthy Saravanan, Wei-Chun Cheng, Sheng-Chi Chen, et al. "High power impulse magnetron sputtering growth processes for copper nitride thin film and its highly enhanced UV-visible photodetection properties." Journal of Alloys and Compounds 896 (2022): 162924.

Autobiography

My academic journey is highly multi-disciplinary. I did my Bachelor of Engineering in the Department of Electronics and Communication, CDGI, Indore, India. In the meantime, I also interned in the SMART lab @ IIT Indore, India. Then, I got an opportunity to pursue a Master of Science in the Department of Materials Engineering from Ming Chi University of Technology, Taiwan. Finally, I joined the Department of Mechanical Engineering as a PhD student at the National Taiwan University of Science and Technology, Taiwan. Awarded with the NTUST Outstanding Youth Award for 2022 and the Certificate of Excellence for excellent performance in the College of Engineering of TAIWAN TECH.