Tellurium Nanostructures via New Liquid-Phase Exfoliation Method

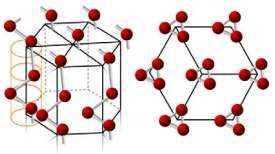
Krishna Didugu[1], Ahmed Adel A. Abdelazeez[2], Haitao Zhang[3]

[1]Department of Chemistry and Biochemistry, USC, [2]Chemistry and NanoScale Program, UNC Charlotte, [3]Department of Mechanical Engineering and Engineering Science, UNC Charlotte

CHARLOTTE

Introduction

Tellurium (Te) is a promising material for electrooptical applications due to its narrow band gap (0.3 eV to 1.2 eV), high responsivity (6650 A W^{-1}), high photodetecivity (1.15×10^{10} Jones) and on/off rations in the order of 10^6. Its helical chain structure, held together by weak van der Waals forces, makes it an ideal material for liquid-phase exfoliation (LPE).



Te crystal structure

Objectives

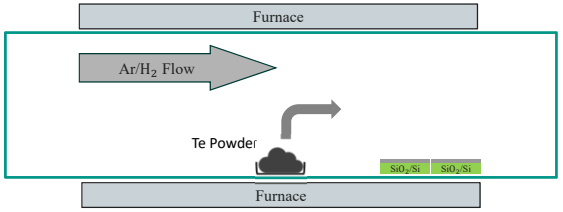
Conventional methods for synthesizing Te nanocrystal lack precise control over crystal morphology. This project explored a novel LPE method for the controlled synthesis of 1D Te nanocrystals

Methods

LPE was conducted using as received Te powder (60 mesh) and physical vapor deposition (PVD) grown Te crystals.

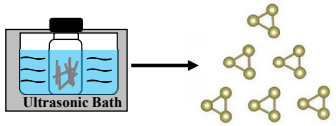
PVD Growth Parameters:

- Source: 80 mg of 200 mesh Te powder
- H_2/Ar: 5 sccm and 20 sccm
- Growth pressure: 100 Torr
- Growth temperature: 500 °C
- Growth time: 30 min



Schematic Diagram of PVD system

LPE through ultrasonication induces sheer forces that can break the week van der Waals forces between the helical chains. Cosolvent mixtures of isopropyl alcohol (IPA) and deionized water (DIW) are used to promote stable dispersion and match surface energy with Te.



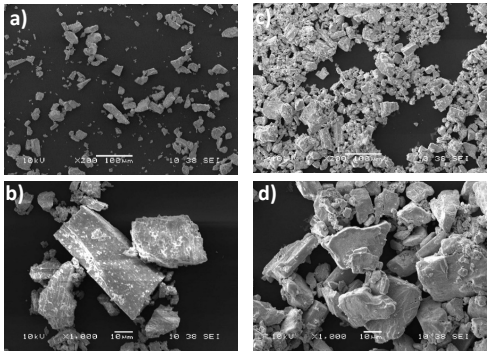
LPE of Tellurium Crystals

LPE Procedures:

- Exfoliation of as-received Te powder (60 mesh):
  - ~50 mg of Te powder added to 10 mL cosolvent of IPA and DIW in a 20 mL glass vial (1:1 cosolvent ratio)
  - Sonication time: 4 hours
- Post-Sonication PVD grown crystals:
  - ~4 mg of Te crystals added to 2 mL cosolvent of IPA and DIW in a 6 mL glass vial (1:1 cosolvent ratio)
  - Sonication time: 3 hours

Results

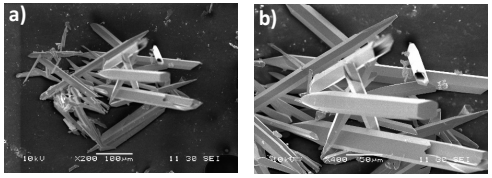
As-received Te Powder (60 mesh):



SEM images of as-received Te powder before and after sonication

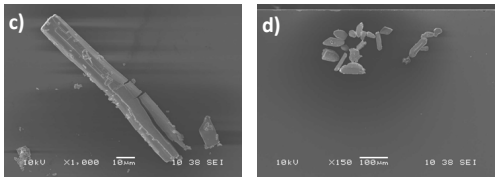
- Pre-Sonication:
  - Crystals Size: 10-85 µm
  - Morphology: particles
- Post-Sonication
  - Crystals Size: 10-65 µm
  - Morphology: particles
  - No 1D nanostructures

PVD-Grown Te Crystals:



SEM images of PVD-grown Te crystals

- Pre-Sonication:
  - Crystals Size: 100-500 µm
  - Morphology: 1D microrods and microtubes
  - Small amount



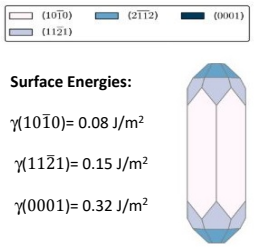
SEM images of PVD-grown Te crystals post-sonication

- Post-Sonication:
  - Crystals Size: 50-100 µm
  - Few clusters present on substrate
  - Few 1D nanostructures showing both transverse and longitudinal cracking

Discussion and Conclusion

Exfoliation was ineffective under current conditions:

- Small difference between vdW and covalent bonds for Te crystals
- Sonication strength is not adjustable using ultrasonic bath
- Small amount (~4 mg) of Te crystals due to low yield of PVD growth



Te surface energies along various planes

Future Work

- Using probe sonication with adjustable power to optimize exfoliation strength
- Using different cosolvent ratios to enhance the longitudinal exfoliation
- Improving PVD growth yield of large size Te crystals by using different growth conditions

Acknowledgments

- Financial support: NanoSURE REU program funded through NSF Award (DMR-2150172).
- Advising: Dr. Haitao Zhang (advisor), Ahmed Adel A. Abdelazeez (PhD student), and Aidan Restelli (PhD student)

References if needed

(1)Amani, et al., *ACS Nano* 2018, *12* (7), 7253–7263. https://doi.org/10.1021/acsnano.8b03424.

(2)Shangguan, et al., *ACS Applied Materials & Interfaces* 2023, *15* (32), 38707–38715. https://doi.org/10.1021/acsami.3c08118.

(3)Teeter, J, et al., . *Advanced Materials* 2024. https://doi.org/10.1002/adma.202409898.