**Objective**
- To create an efficient high temperature thermoelectric material.
- The Samarium sulfides were once explored as promising high temperature thermoelectric materials due to:
  - a) High melting points of 1750°C for Sm2S3 and 1074°C for SmS.
  - b) Natively semiconducting.
  - c) A ZT of 0.9 at 1000K for SmS3.
  - d) Relative abundance compared to bismuth, selenium, and tellurium.
- e) Good electrical conductivities.
- The thermoelectric properties of the samarium sulfides were explored before the nanostructuring impact on efficiency was demonstrated.
- We here present the first nanostructured samarium sulfides.

**Thermoelectric Effect**
- When two metals or semiconductors (n type and p type) are placed in contact with one another, a voltage develops in response to a temperature difference.
- Currently, efficiency is too low for useful power generation and use is largely limited to heating and cooling.
- Recently, it has been demonstrated that nanostructured materials show a drastic improvement in thermoelectric efficiency.
- The ideal is a dimensionless figure of merit (ZT) of 3.0 which would provide a 20% efficiency with a 500 K temperature difference.

**State of the art of bulk thermoelectric materials**

**Thermoelectric Effect**
- Currently, efficiency is too low for useful power generation and use is largely limited to heating and cooling.

**Methods**
- A 1 meter long 1” diameter quartz tube was loaded with the sulfur 14 cm to the right of the center of furnace 1.
- The SmCl3·6H2O and the SiN coated silicon substrate were loaded 13.5 and 12 cm to the left of the center of furnace 2 respectively.
- The furnaces were programmed according to the temperature profile shown.
- The H2 gas was disabled when furnace 2 reached 100°C, and was not re-enabled until 875°C was reached.

**Proposed Mechanism**
- Maximum wire growth occurs when the sulfur is continuously heated.
- Sulfur readily sublimes around 67°C under these pressures.
- The samarium only later (600+ °C) sublimes into the sulfur rich system.
- On a surface, sulfur clusters may serve the liquid droplet collecting role for vapor liquid solid type wire growth.
- As Sm content increases, the first stable solid phase that drops out of “alloy” is SmS2 (arrow).

**Optical Characterization**
- UV-VIS Absorption Spectroscopy
- Fluorescence Spectroscopy
- Tauc plots and absorption (inset) of Sm2S3 wires in water suspension.
- Excitation (a.u.) vs. 800 nm
- Fluorescence spectra by excitation and emission. The emission spectrum’s intense peak at double the excitation wavelength (300 nm) has been removed for clarity.

**Electron Microscopy Characterization**
- Under these conditions, Sm2S3 wires consistently grow as highly anisotropic (up to 1000x aspect ratio) wires.
- Individual wires have diameters of c.a. 20 nm and seem largely consistent.
- Wires are never found individually, but instead stick together into wire bundles.
- Cross sectional SEM images reveal very thick but short bundles near the substrate base while the longer bundles all remain thick.

**Conclusion**
- A VLS based mechanism and the optimal conditions for wire growth has been proposed for the growth of crystalline Sm2S3 nanowires.
- SAED patterns indicate a [010] growth direction.
- Likewise, the characteristic 2.0 Å spacing is only present when viewing perpendicular to the y-axis of alpha phase SmS2.
- Multi-facets strongly suggest a screw dislocation is present as shown below.
- Uncertain if the screw dislocation required for growth or anomalous to the extra long single wire.

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