Negative Differential Resistance in micro-patterned nanocrystals

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Ag_2Se nanoparticle patterned into hollow micro rod in presence of ethanol which exhibits bistable conductance switching via negative differential resistance.

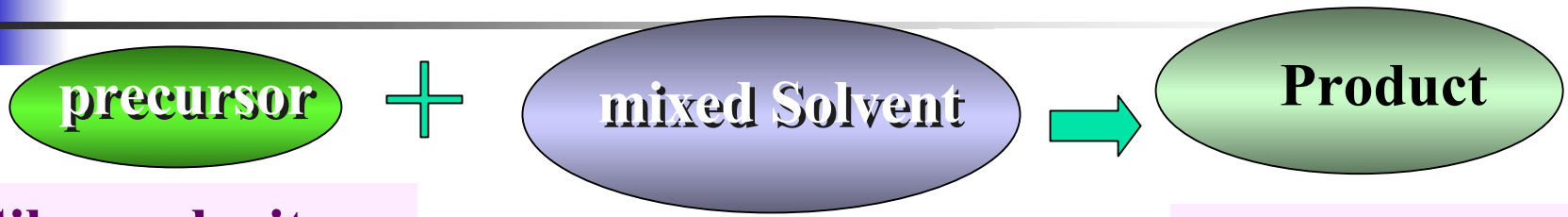
Applications of Ag_2Se:

- Infrared sensors,
- Photolithographic layers,
- Electrochemical storage cells
- Electrochemical potential memory devices
- Magnetic field sensing

Goal of our work

- Construction of special orientation and arrangement of nanostructure to realize the technological importance of nanomaterials
- We synthesised Ag_2Se nanocrystals by reducing Ag_2SeO_3 by DMF and found that these nanocrystals self-assembled in microrods in presence of Ethanol.
- We investigate the conduction phenomena through these rods and found that conduction along the width shows NDR.

Our Synthesis Scheme



Silver selenite Ag_2SeO_3

Dimethyl formamide & Ethanol

Silver selenide Ag_2Se microbundle

Common Synthesis strategies:

Heating the mixtures of the elemental silver and selenium
Using toxic H_2Se as the Se source
High energy ball mill
Solvothermal using elemental silver & selenium in EDA (ethelenedi-amine)

Synthesis of Ag_2Se Micro Bundle

Selenium dioxide(SeO_2) dissolved in sodium hydroxide(NaOH) solution → Sodium Selenite (Na_2SeO_3)

Silvernitrate ($AgNo_3$) solution + **Sodium selenite solution** → **silver selenite (Ag_2SeO_3)**

silver selenite (Ag_2SeO_3) + DMF & Ethanol → (Autoclave, High T & P) → Silver Selenide (Ag_2Se)

Possible reaction scheme:

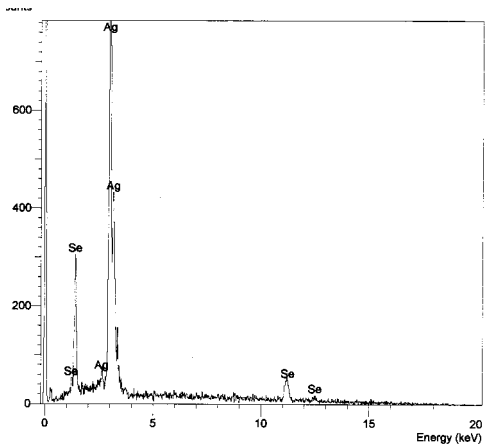
$$Ag_2SeO_3 + 3HCON(CH_3)_2 \longrightarrow Ag_2Se(N.C) + 3(CH_3)_2NH + 3CO_2$$

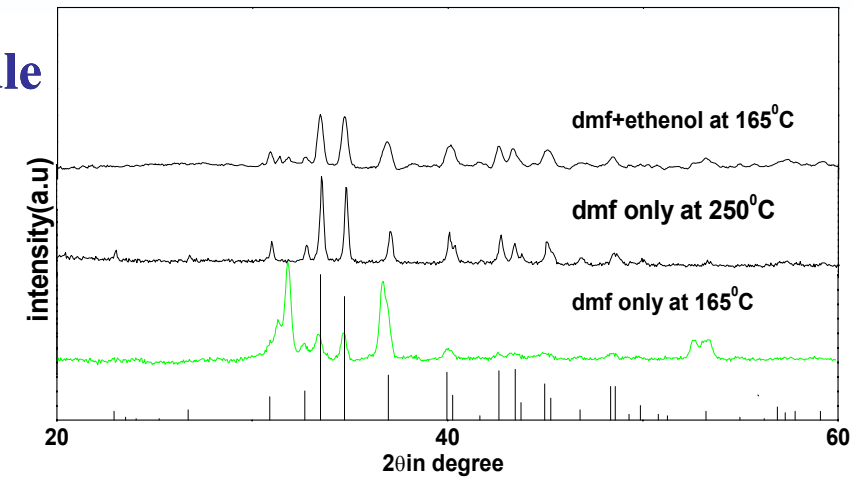
$$Ag_2Se(N.C) + Et\text{-}(OH) \longrightarrow Ag_2Se \text{ (Micro Bundle)}$$

Formations of microbundle

Dried silver selenite(.5gm) was added into a teflon lined stainless steel autoclave (capacity 50 ml) filled with mixture of 12.5 ml DMF and 12.5 ml ethanol, the whole stirred for about 10 minutes. The autoclave was then kept for 24 hours in a furnace prefixed at 165^0C.

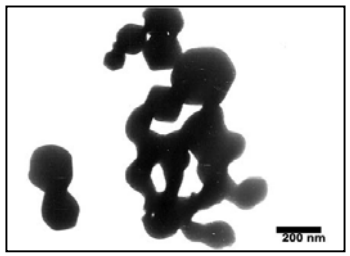
EDX spectrum of Ag_2Se microbundle



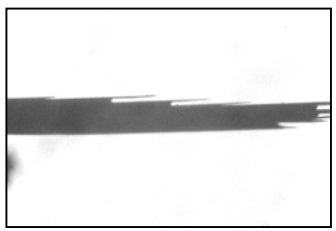


XRD Spectrum of Ag_2Se microbundle & nanocrystals

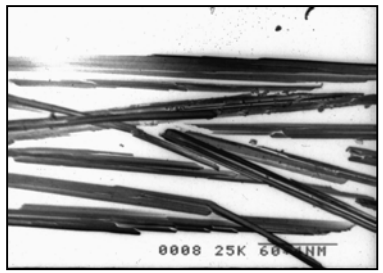
Micrograph of the samples

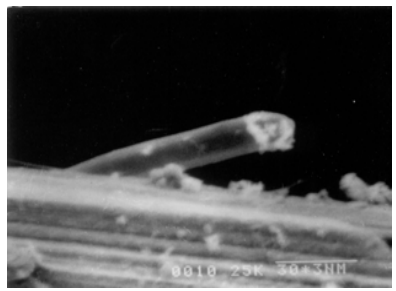


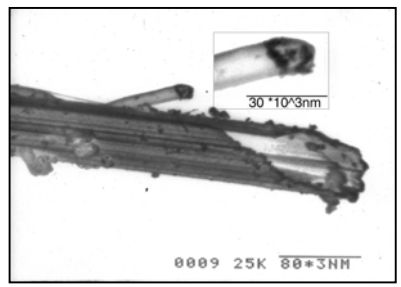
TEM of nanocrystals

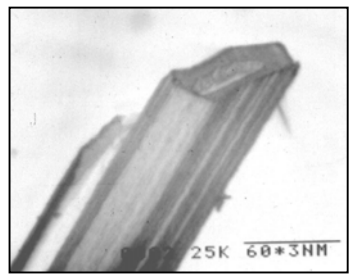


Optical micrograph of microrods









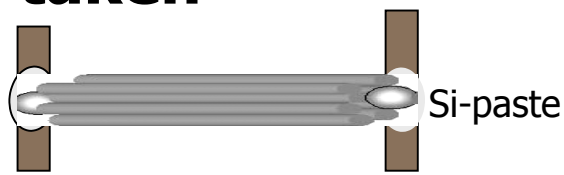
SEM of microords

Electrical characterizations

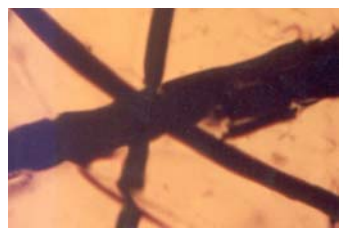
Current Voltage (I-V) characteristics have been taken by Yokogawa 7651 and picoammeter with PC via General Purpose Bus. Each I-V scan has been taken with a step of 0.01V for 1sec in the range –2V to +2V.

Current-Voltage Characteristics was taken

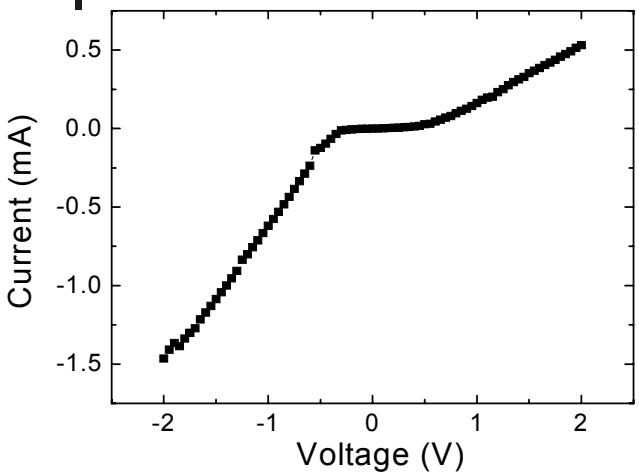
- *Along the length of the micro-bundle*

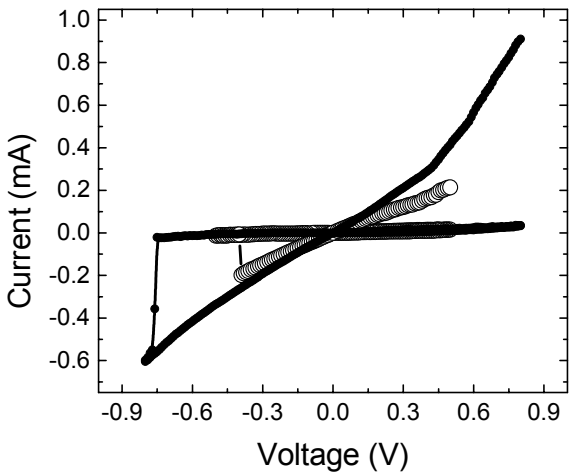


- *Along the width of the micro-bundle*



Electrical conduction along the length

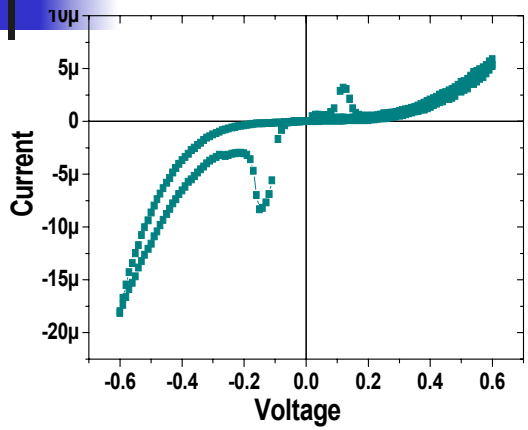


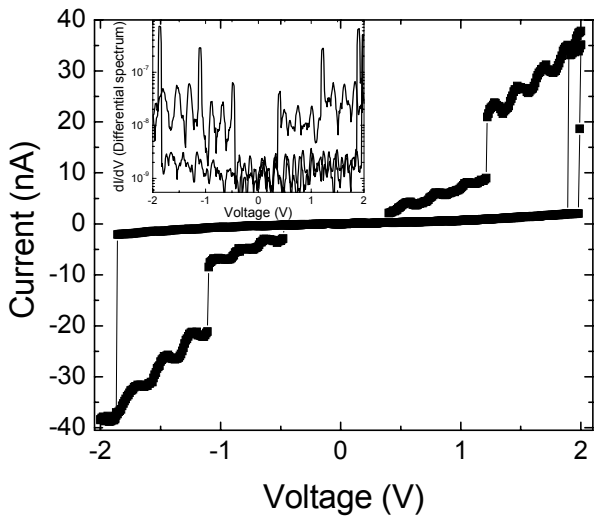


- Conduction occurs through ordered crystalline structure.
- Ohmic behavior beyond the cut-off region.
- Dynamic impedance at both side of bias differs due to asymetric difect state distribution

In the lower temperature the channel behaves as a charging capacitor and bistable conductance switching is observed. Memory is erased only when bias is removed The critical switching voltage depended on the maximum of the voltage scan but not the bistable conductivity i.e magnitude of currents in the high and low conducting states were of the same order.

Current conduction along the width





sharp peaks homogeneously positioned at both sides of the bias direction The peaks are induced by corresponding positive and negative voltages during the initial scancross tunneling of the carriers during forward and reverse bias was controlled by accumulated charge on the needle

This I-V spectra for few ideal symmetric rod

reversible conductance switching observed between high and low conducting state in the room temperature

The rod is in OFF state for the voltage scan from 0 to +V or 0 to -V. Its becomes ON at $+V_{max}$ or $-V_{max}$ and again OFFed at 0 V.

Conclusion and future plan:

Ag_2Se nano particle generated by reducting action of DMF self assembled in to patterned microrod in the presence of ethanol

Current-Voltage Characteristics along the width of the microrod exhibites Negative differential resistance due to defect structure but reversible conductance switching for symmetrical rod.

Cross section of the rod can be used for multichannel conduction.

Elongated nanorod from microstructure could be easy mean to use it as a nano electrode. It might have an application in molecular electronics.