NANOWIRES NANOINTERFACES and NANO CORE – SHELL STRUCTURES

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ACKNOWLEDGMENT :

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INSA, DST, CSIR

SYNTHESIS OF NANOWIRES

TEMPLATES USED:

- **SILICATE GLASS STRUCTURE**

2. POLYMERIC FILM

3. NANO PORES WITHIN A GEL

4. CRYSTAL CHANNEL

GROWTH OF SILVER NANOWIRES IN NANO CHANNELS OF FLUORPHLOGOPITE MICA ($KMg_3AlSi_3O_{10}F_2$)

GLASS COMPOSITION (TYPICAL) :

42 SiO_2 15 B_2O_3 9Al_2O_3 8 MgO 20 K_2O 6KF

⇓

HEAT TREATMENT AT 1168 K FOR 2 HRS

⇓

ION EXCHANGED IN $AgNO_3$ AT 573 K FOR 24 HRS

⇓

ELECTRODEPOSITION WITH 10 VOLTS AT 370 K

(SILVER PASTE ELECTRODES)

GLASS CERAMICS WITH FLUORPHLOGOPITE MICA

SEM

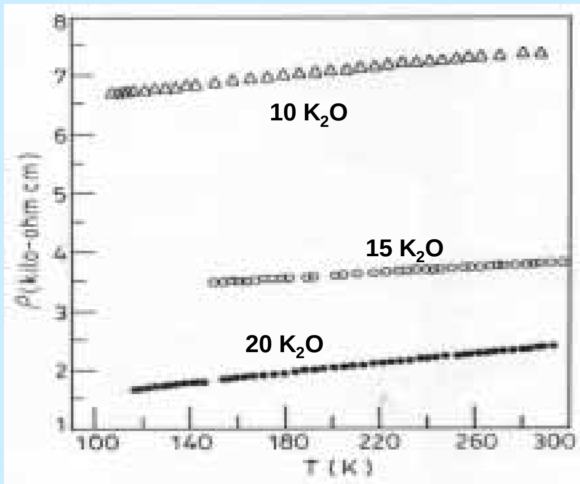
NANOWIRES IN GLASS CERAMICS CONTAINING FLUORPHLOGOPITE MICA

GROWTH OF SILVER NANO PARTICLES IN GLASS CERAMICS CONTAINING FLUORPHLOGOPITE MICA

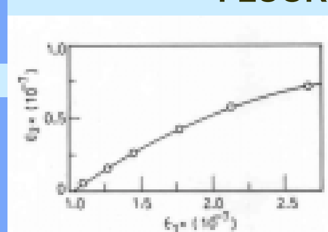
GLASS COMPOSITION

47 SiO_2 15 B_2O_3 12Al_2O_3 10 MgO 10 K_2O 6KF

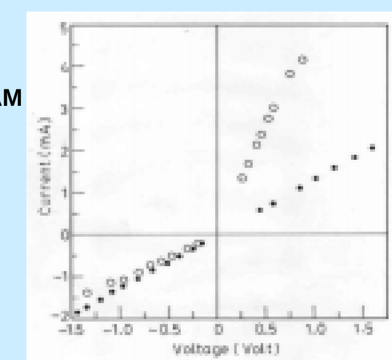
SILVER NANOWIRES IN GLASS CERAMICS CONTAINING FLUORPHLOGOPITE MICA

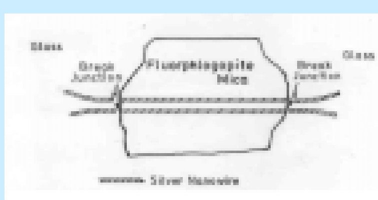


SILVER NANOWIRES IN GLASS CERAMICSCONTAINING FLUORPHLOGOPITE MICA



COLE-COLE DIAGRAM





SCHEMATIC OF BREAK JUNCTIONS

MUKHERJEE AND CHAKRAVORTY J. Mater. Res., 17 3127 (2002)

SILVER NANOWIRES IN MICA CHANNELS– ULTRA HIGH DIELECTRIC PERMITTIVITY

SPACE CHARGE POLARIZATION MODEL FAILS TO EXPLAIN HIGH _

MECHANISM IS ELECTRONIC

INTERRUPTED STRAND MODEL (RICE & BERNASCONI, 1972, PRL)

$$\varepsilon \cong 1/2(q_S l_0)^2$$

$\mathbf{l_0}$: STRAND LENGTH ; $\mathbf{l_0}$ = 1287 nm

$\mathbf{q_s}$: FERMI THOMAS SCREENING WAVE VECTOR OF CONDUCTION ELECTRONS

$\mathbf{q_s}$ ~ a^{-1} FOR METALLIC DENSITIES; FOR _ ~ 10^7 AND a = 0.28 nm

IN AGREEMENT WITH MICA CRYSTALLITE DIMENSIONS

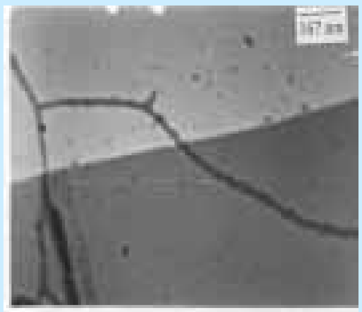
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

GLASS COMPOSITION : 30 Li_2O 12 CaO 3 Al_2O3 55 SiO_2

ION EXCHANGED IN $AgNO_3$ AT 573 K FOR 11 HRS

ELECTRODEPOSITION AT 600 K, 5 and 10 VOLTS FOR 10 HRS

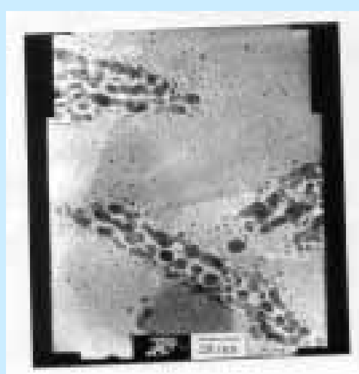
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES



TEM

OF SILVER NANO ARRAYS

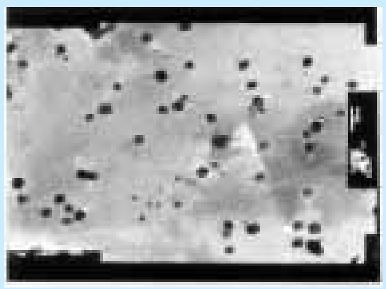
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES



TEM OF NANO ARRAYS OF SILVER IN SILICATE GLASS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

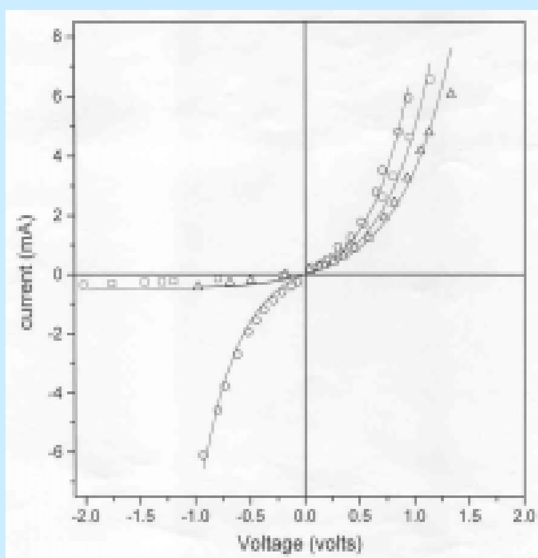
TEM OF SILICA GEL GLASS WITH COPPER NANO ARRAYS



COMPOSITION : **$30Cu(NO_3)_2$ $70SiO_2$**

ELETRODEPOSITION VOLTAGE : 5 VOLTS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES



△ **191 K**

□ **161 K**

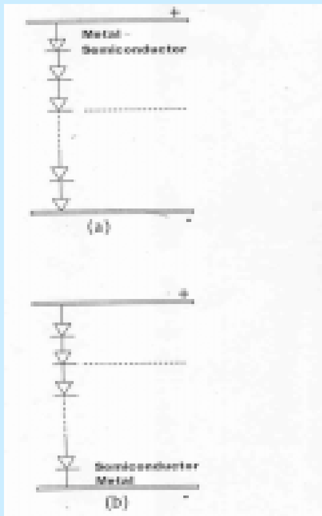
○ **138 K**

GLASS COMPOSITION

$30Li_2O$ $12CaO$ $3Al_2O_3$ $55SiO_2$

ELECTRO DEPOSITION VOLTAGE : 5 VOLTS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

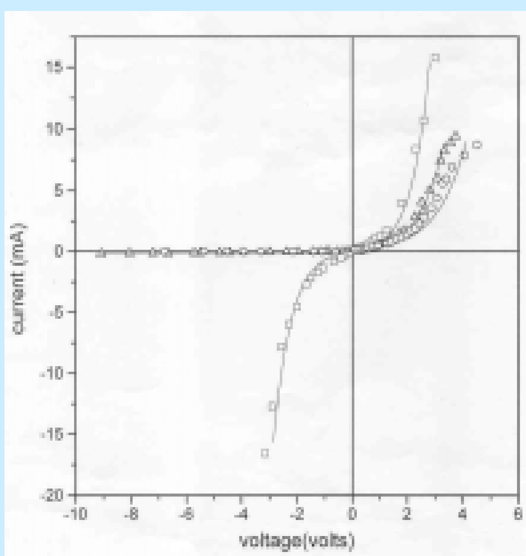


DIODE LIKE BEHAVIOUR

SCHEMATIC REPRESENTATION OF
METAL SEMICONDUCTOR
NANO JUNCTION ARRAYS

SYMMETRICAL NON LINEAR V - I

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES



△ **208 K**

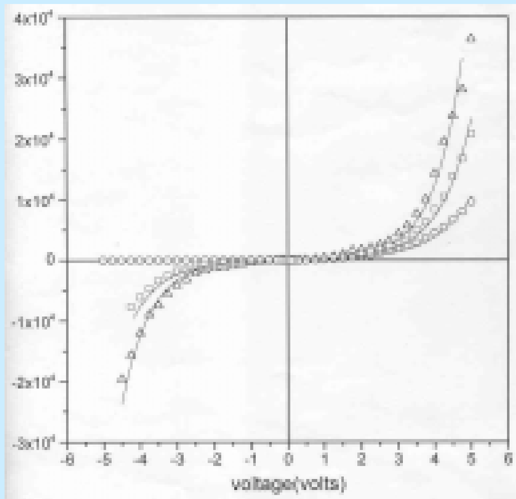
○ **167 K**

□ **125 K**

30 LI_2O 12CaO $3Al_2O_3$ $55SiO_2$

ELECTRODEPOSITION
AT 10 VOLTS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES



○ 275 K

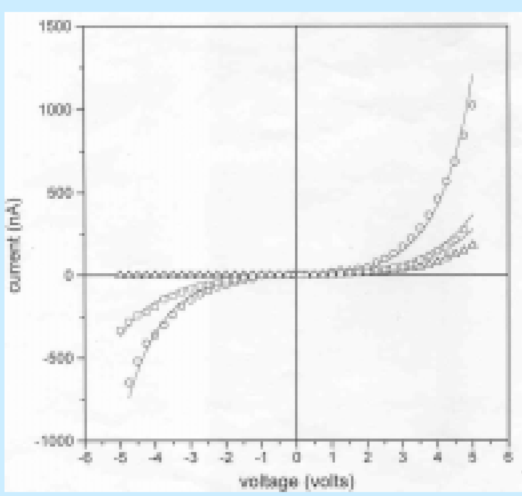
□ 238 K

△ 213 K

$30Cu(NO_3)_2 . 70SiO_2$ GEL

ELETRODEPOSITION
AT 5 VOLTS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES



△ 285 K

□ 265 K

○ 208 K

$30Cu(NO_3)_2 . 70SiO_2$ GEL

ELETRODEPOSITION
AT 10 VOLTS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

DATA FITTED TO $$I = I_0\left[\exp\left(\frac{eV}{nkT}\right) - 1\right]$$

COMPOSITION	ELECTRO DEPOSITION VOLTAGE	I_0 (Amp)	n
1	5	0.5×10^{-3}	30
1	10	0.2×10^{-3}	60
2	5	0.7×10^{-7}	42
2	10	0.07×10^{-7}	55

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

ELECTRODEPOSITION VOLTAGE 5 VOLTS

TEM OF A NANO INTERFACE BETWEEN TWO COPPER PARTICLES

CORE SHELL STRUCTURE

OXIDE COATED SILVER NANOPARTICLES

GEL COMPOSITION : 20 $AgNO_3$ 80 SiO_2

↓

ELETRODEPOSITION WITH 20 VOLTS

↓

HEAT TREATMENT AT 478 TO 653 K FOR _ HR.

↓

GEL POWDER MIXED WITH TETRA HYDRO FURAN

↓

MIXED WITH SOLUTION OF POLYSTYRENE WITH THF

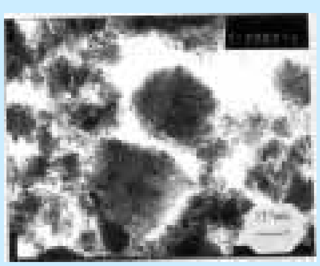
↓

CORNING 7059 GLASS SLIDE DIPCOATED WITH ABOVE SOLUTION

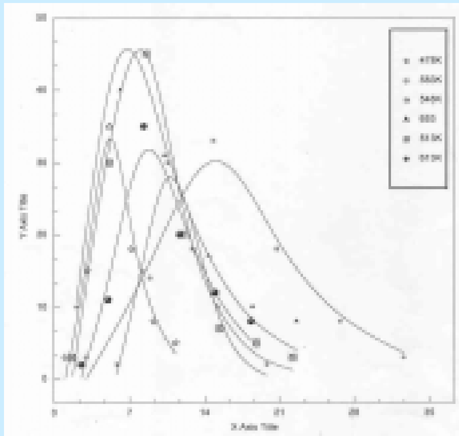
↓

THICKNESS OF FILM 4 µm

OXIDE COATED SILVER NANOPARTICLES



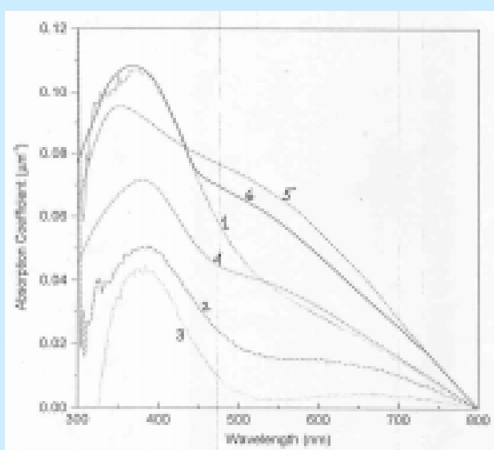
OXIDE COATED SILVER NANOPARTICLES



HISTOGRAM OF PARTICLES

FITTED BY LOG NORMAL DISTRIBUTION FUNCTION

OXIDE COATED SILVER NANOPARTICLES



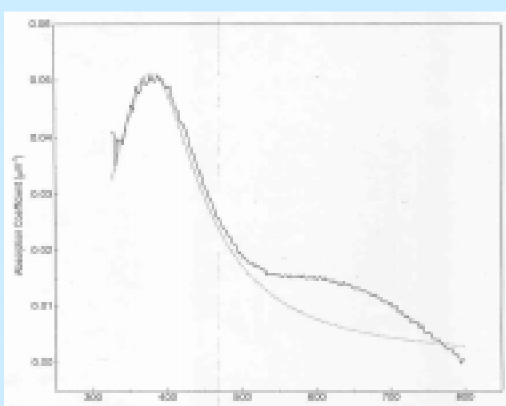
OXIDE COATED SILVER NANOPARTICLES

$$\bar{\varepsilon} = \frac{2f\,\varepsilon_m \varepsilon_h - 2f\varepsilon_h^2 + \varepsilon_m \varepsilon_h + 2\varepsilon_h^2}{\varepsilon_m + 2\varepsilon_h - f\varepsilon_m + f\varepsilon_h}$$

MAXWELL GARNET MODEL

$$\mu = \frac{\omega}{c}\frac{\overline{\varepsilon_2}}{\sqrt{\overline{\varepsilon_1}}} \qquad \varepsilon_m = 1 - \frac{\omega_p^2}{\omega^2 - i\omega\sigma/\varepsilon_0}$$

OXIDE COATED SILVER NANOPARTICLES



EXTRACTED VALUES OF _ FOR ALL SPECIMENS ARE BELOW 2.8 X 10^4 $ohm^{-1}m^{-1}$- MOTT'S MINIMUM METALIC CONDUVTIVITY

$$\sigma_{\min} = \left(\frac{e^2}{3h\pi^2}\right) k_f$$

OXIDE COATED SILVER NANOPARTICLES

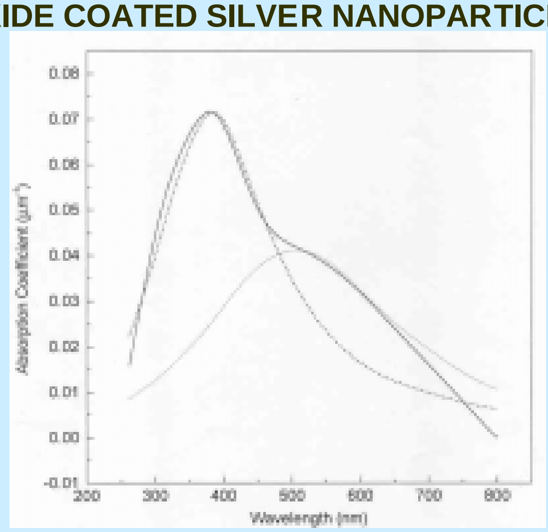
POLARIZABILITY FOR PARTICLE WITH CORE-SHELL STRUCTURE

$$\alpha = \sum_j \frac{n_j r_j^3}{\sum n_j r_j^3} \left[\frac{(\varepsilon_s - \varepsilon_h)(\varepsilon_{mj} + 2\varepsilon_s) + \left(1 - \frac{t_j}{r_j}\right)^3 (\varepsilon_{mj} - \varepsilon_s)(\varepsilon_h + 2\varepsilon_s)}{(\varepsilon_{mj} + 2\varepsilon_s)(2\varepsilon_h + \varepsilon_s) + 2\left(1 - \frac{t_j}{r_j}\right)(\varepsilon_s - \varepsilon_h)(\varepsilon_{mj} - \varepsilon_s)} \right] r_j^3$$

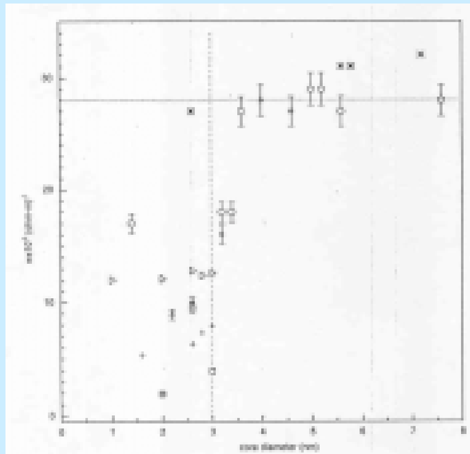
$$\varepsilon_{mj} = \left(1 - \frac{\omega_p^2}{\omega^2}\right) + i \left(\frac{\omega_p^2}{\omega^3}\right)\left(\frac{\sigma_{mj}}{\varepsilon_0} + \frac{V_F}{r_j - t_j}\right)$$

$$\varepsilon = \frac{1 + 2N\alpha}{1 - N\alpha}$$

OXIDE COATED SILVER NANOPARTICLES



OXIDE COATED SILVER NANOPARTICLES



CHATTERJEE et. al.
PHYS. REV. B 66, 085421 (2002)

CORE SHELL STRUCTURES

SILVER NANOSHELLS ON SILVER OXIDE PARTICLES

$AgNO_3$ in Distilled Water ***(a)***
NaOH in Distilled Water ***(b)***

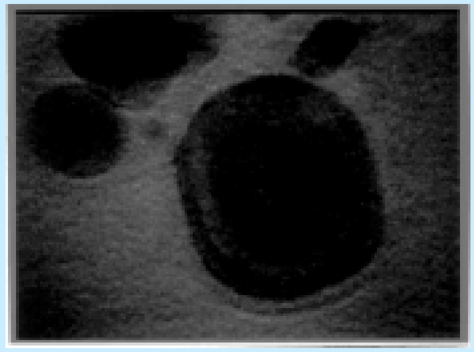
Drops of ***(b)*** added to ***(a)***

↓

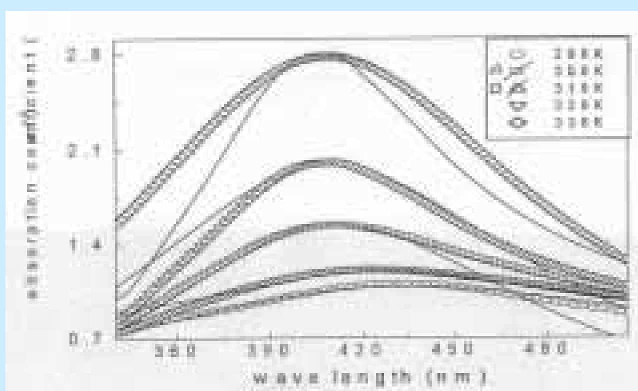
Ag_2O Nanoparticles (21.3 nm)

↓

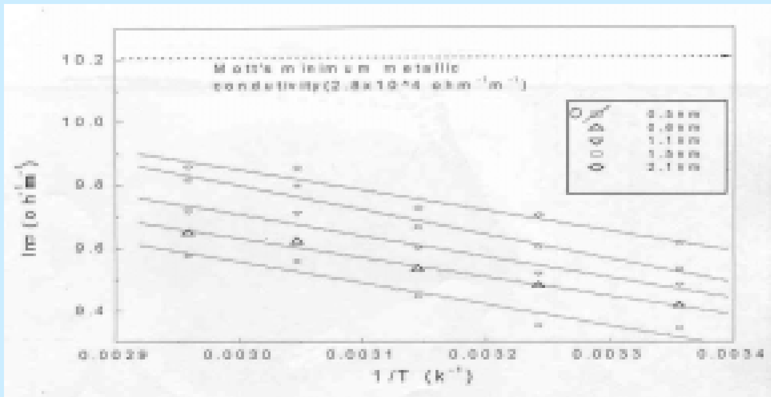
Heat Treatment at 500 – 543 K



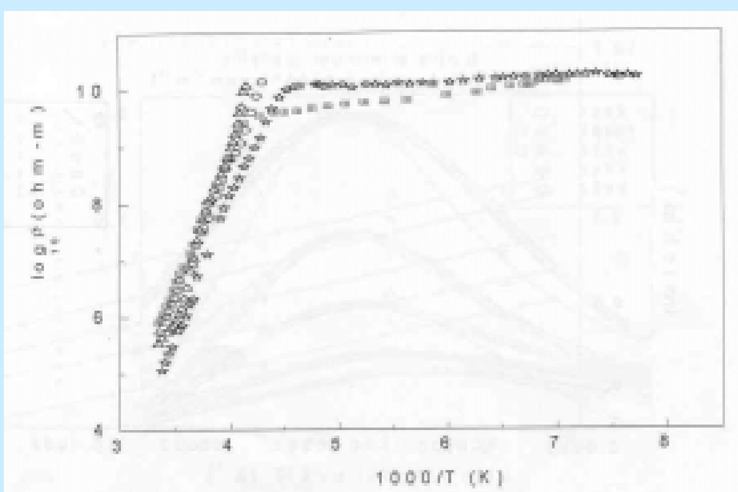
TEM for Ag_2O heat treated at 523 K / 10 Min.s



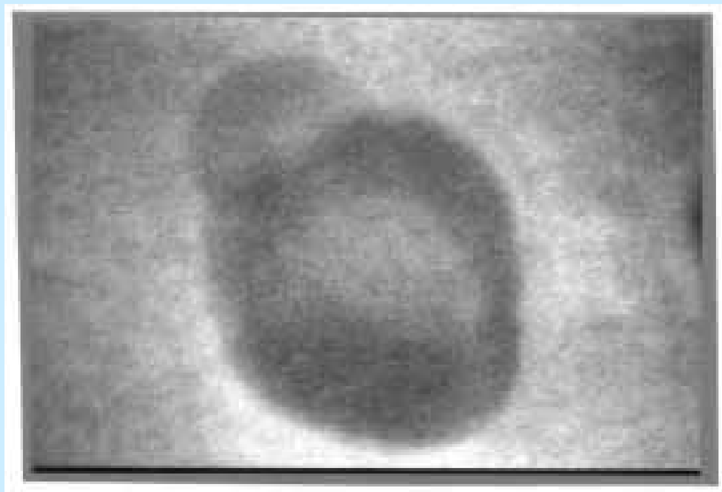
Optical Absorption for Ag_2O – Ag Core-shell
(523K / 10Min.s)



Extracted Electrical Conductivity from Optical Absorption Data Vs. T^{-1}

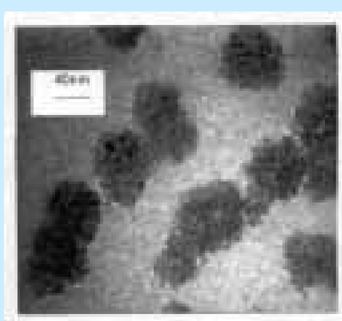


Experimental Resistivity Vs. T^{-1} for Ag_2O – Ag Core-shell

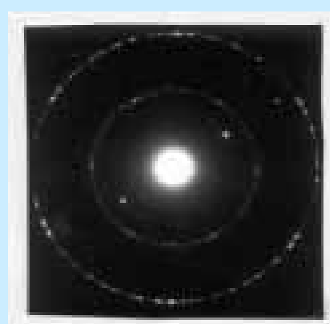


TEM for Ag2O – Ag Core-shell (543K / 10 Min.s)

Copper Nanoshells on Copper Oxide Nanoparticles



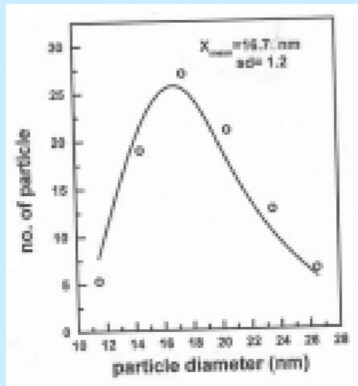
(a)

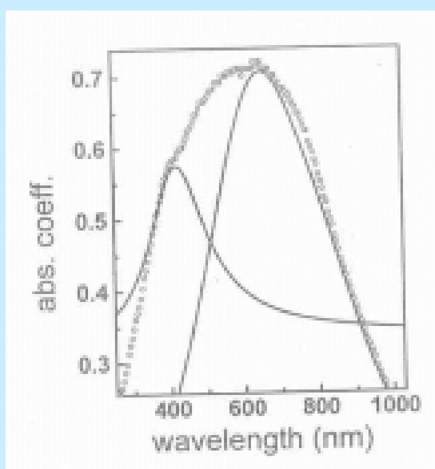


(b)

a) TEM of Copper Oxide Particles
b) Electron Diffraction from (a)

Histogram of CuO Particle Sizes

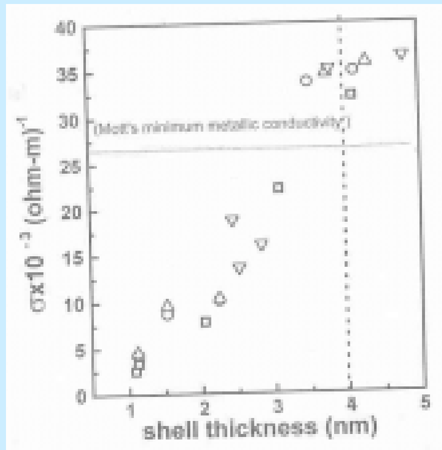




——— Theoretical

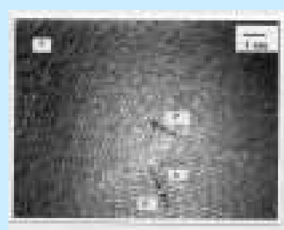
○○ ○ ○○ Experimental

Optical Absorption for CuO–Cu
(Reduction at 373 K/15 Min)

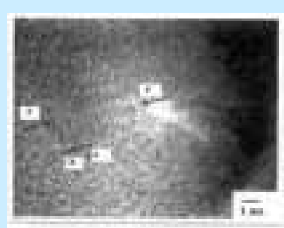


Summary of extracted parameters

373 K / 15 Min

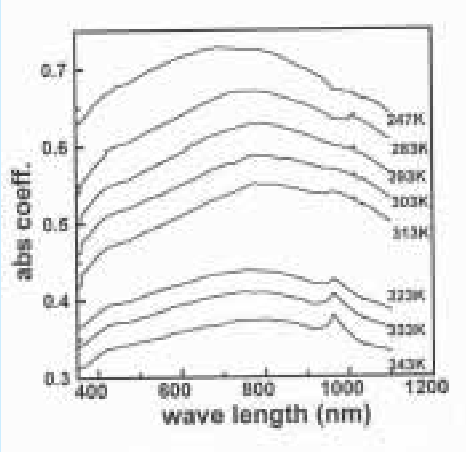


373 K / 60 Min

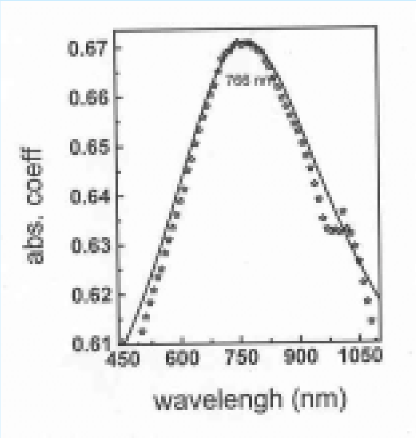


373 K / 45 Min

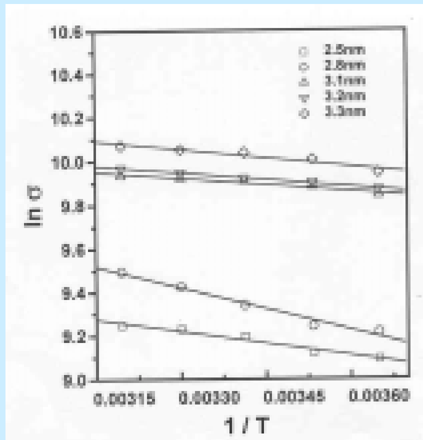
TEM of CuO – Cu Core-shell



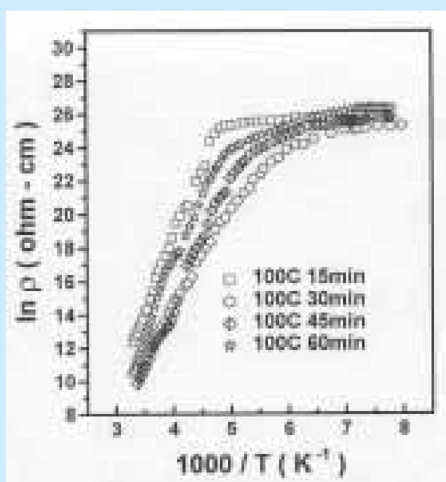
Optical Absorption at Different T
Reduction Treatment at 373 K / 15 Min



Typical Theoretical Fit of Optical Absorption for 283 K



Electrical Conductivity extracted from Optical Data Vs. T^{-1}



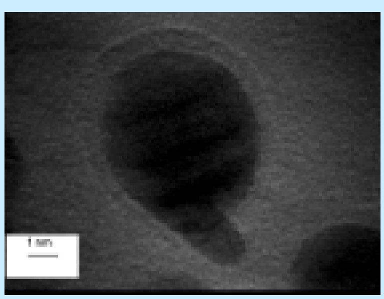
Resistivity Vs. T^{-1} for CuO – Cu Shell structure

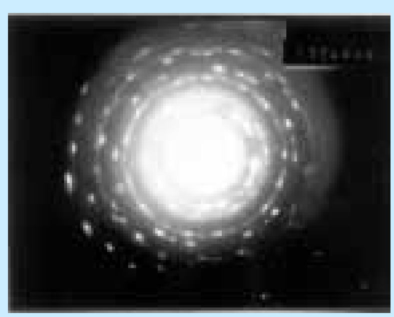
Last but one

COPPER CORE COPPER OXIDE SHELL – INTERFACIAL AMORPHOUS PHASE

- GEL TARGET COMPOSITION 60 CuO 40 SiO_2
  PRECURSORS $CuCl_2$,, $2H_2O$, TEOS, ETHYL ALCOHOL
- GEL REDUCED AT 923K/ 30MIN
- HEATED AT 723-1123K/ 30MIN
- POWDER COMPACTED 5 TONS/CM^2

SPECIMEN REDUCED AT923K / 30MIN + OXIDIZED AT 823K / 30MIN

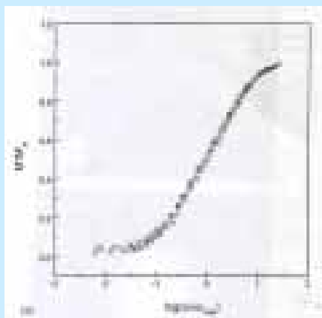




NORMALIZED PLOTS OF M` AND M``

SPECIMEN REDUCED AT 923K / 30 MIN + OXIDIZED AT 723K / 30 MIN

KWW FUNCTION : $F(t) = \exp(-t/\tau_R)^{\beta}$



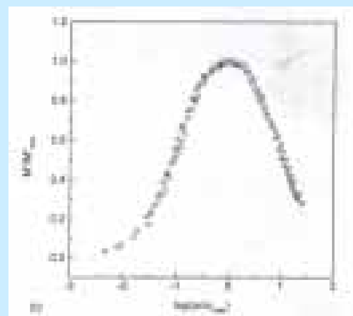
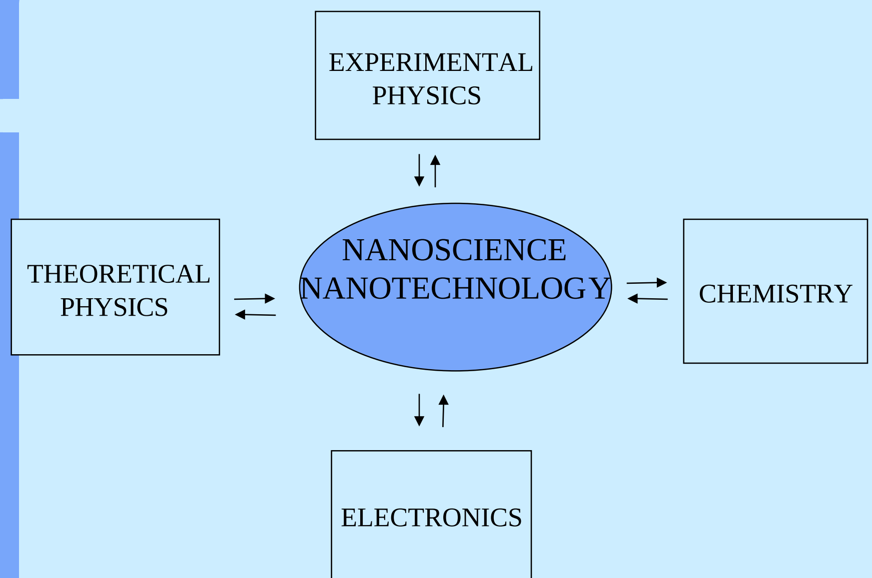


TABLE III. Summary of β values extracted in the case of different samples.

Specimen	β
Reference	0.67
Reduction at 923 K/ $\frac{1}{2}$ h + oxidation at 723 K/ $\frac{1}{2}$ h	0.46
Reduction at 923 K/ $\frac{1}{2}$ h + oxidation at 823 K/ $\frac{1}{2}$ h	0.48
Reduction at 923 K/ $\frac{1}{2}$ h + oxidation at 1023 K/ $\frac{1}{2}$ h	0.47
Reduction at 923 K/ $\frac{1}{2}$ h + oxidation at 1123 K/ $\frac{1}{2}$ h	0.48

EDUCATIONAL BACKGROUND



THANK YOU