SOLAR SELECTIVE ABSORBER FUNCTIONALITY OF CARBON NANOPARTICLES EMBEDDED IN SiO_2, ZnO and NiO MATRICES

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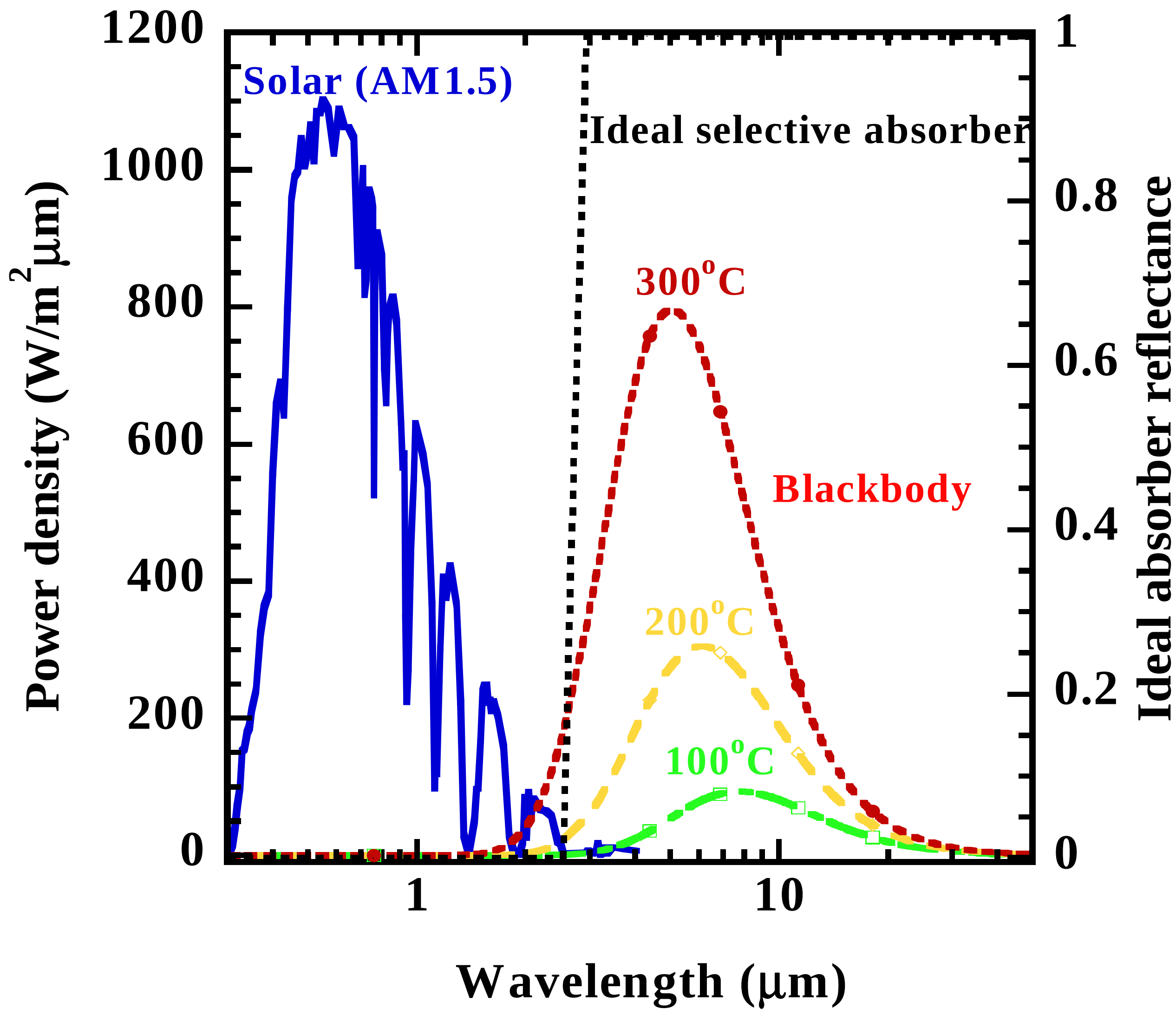
Concept and motivation



Electromagnetic wave propagation

- Interaction of light with matter.
- Complex refractive index.

$$E_m = E_0 \, exp(-k\omega x / c) \, exp[i(\omega t - n\omega x / c)]$$

- Magnetic field is not altered in optical and IR.

- Logarithmic reduction in intensity for a film thickness d is $ln\,(I/I_0) = -\alpha d = -4\pi k d/\lambda$.

Tailoring materials

- Factor kd/λ determines the efficiency of a solar absorber surface.
- Proper combination of k and d.
- Homogeneous films – can only vary d.
- Composite films – change k! Practically constant for most materials used.
- Can also tune n by changing porosity.

Tailoring materials

- Therefore can only tune *d* to place the crossover at an appropriate wavelength.

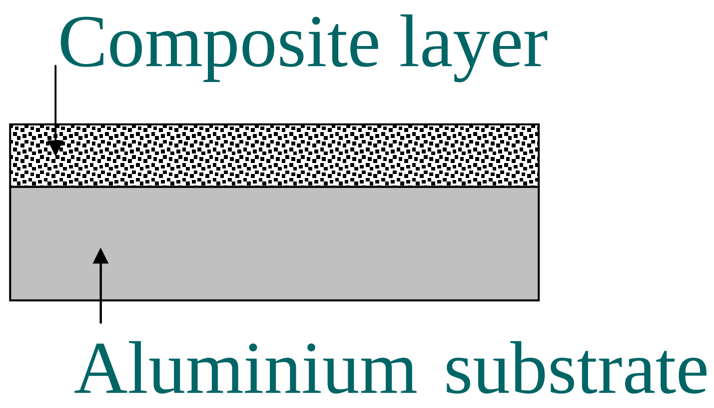
- Reflectance and efficiency of absorber surface depends on *k* and *d*.

- Near-normal reflectance of bulk material is:

$$R = \left|\frac{1-N}{1+N}\right|^2$$

Device structure

- Many designs are possible.
- A tandem device: a composite layer deposited on a metallic substrate.



Effective medium approximations

$$\varepsilon = N^2$$

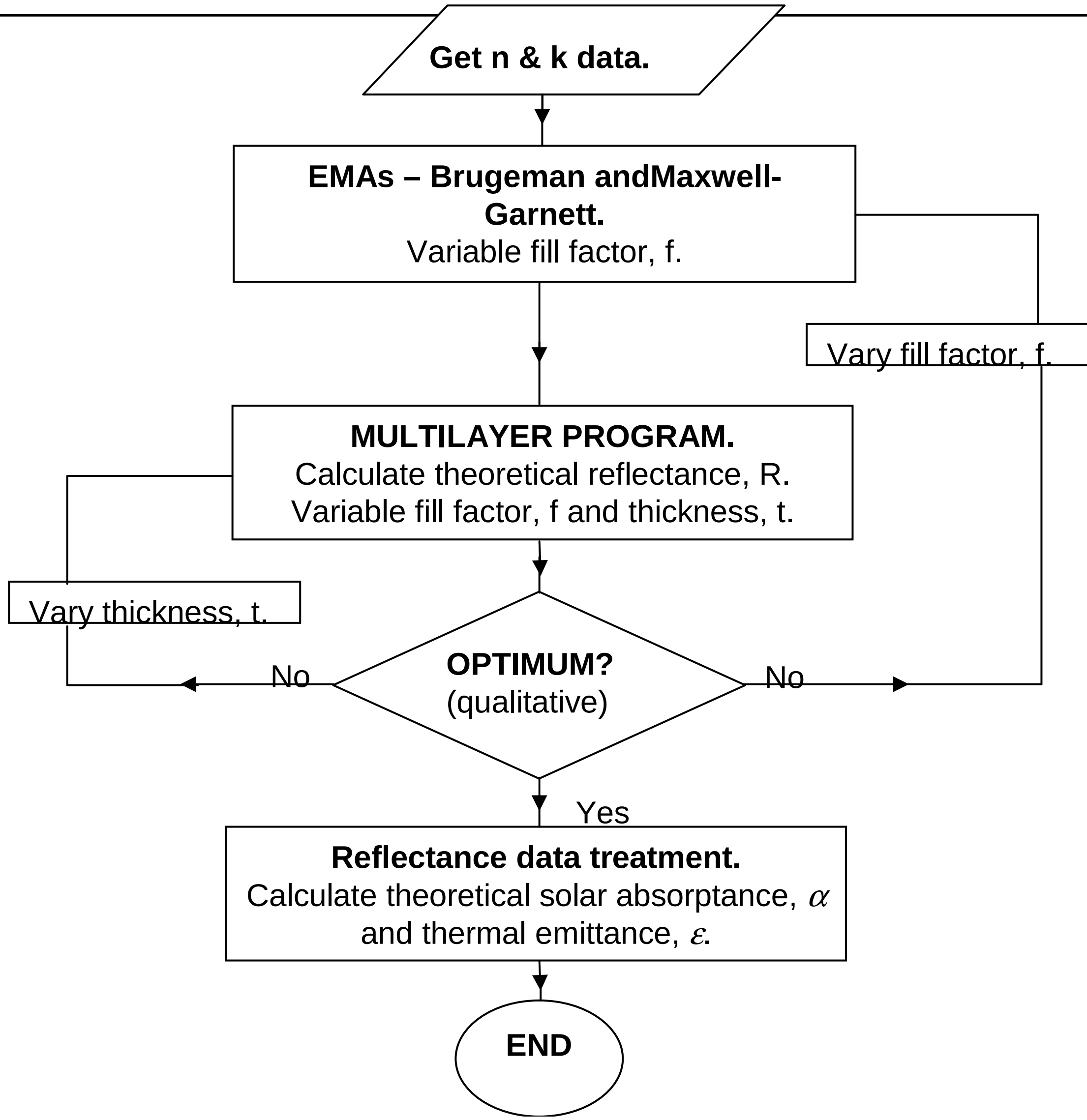
- Bruggeman:

$$f_a \frac{\varepsilon_a - \varepsilon_{Br}}{\varepsilon_a + 2\varepsilon_{Br}} + (1 - f_a)\frac{\varepsilon_b - \varepsilon_{Br}}{\varepsilon_b + 2\varepsilon_{Br}} = 0$$

- Maxwell-Garnett:

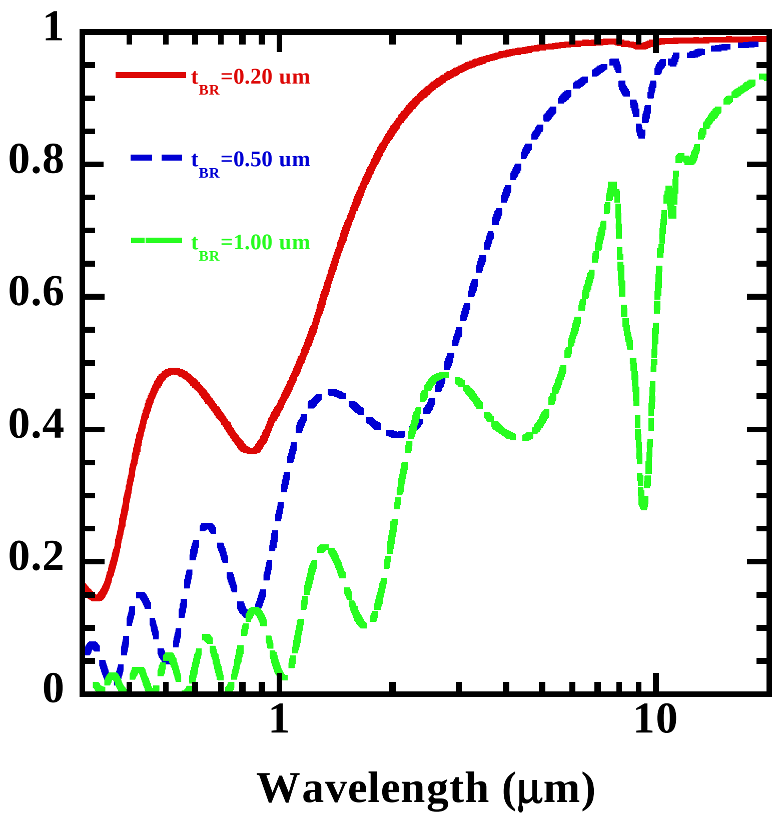
$$\varepsilon_{MG} = \varepsilon_b \frac{\varepsilon_a + 2\varepsilon_b + 2 f_a (\varepsilon_a - \varepsilon_b)}{\varepsilon_a + 2\varepsilon_b - 2 f_a (\varepsilon_a - \varepsilon_b)}$$

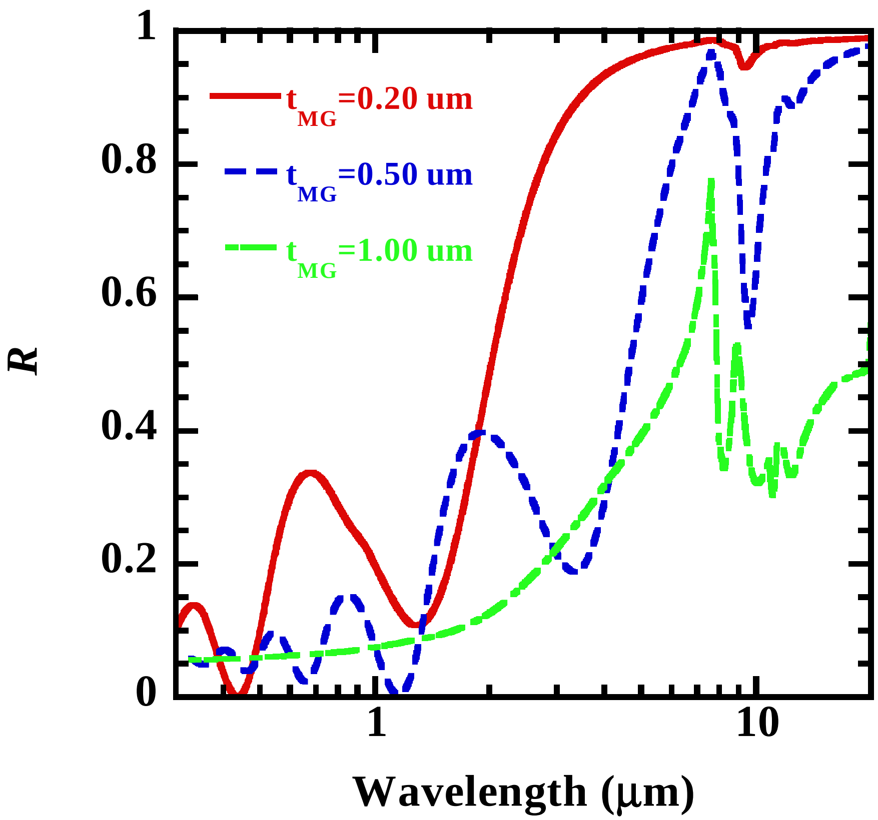
Theoretical optimisation



Theoretical reflectance

- Bruggeman
- Maxwell-Garnett



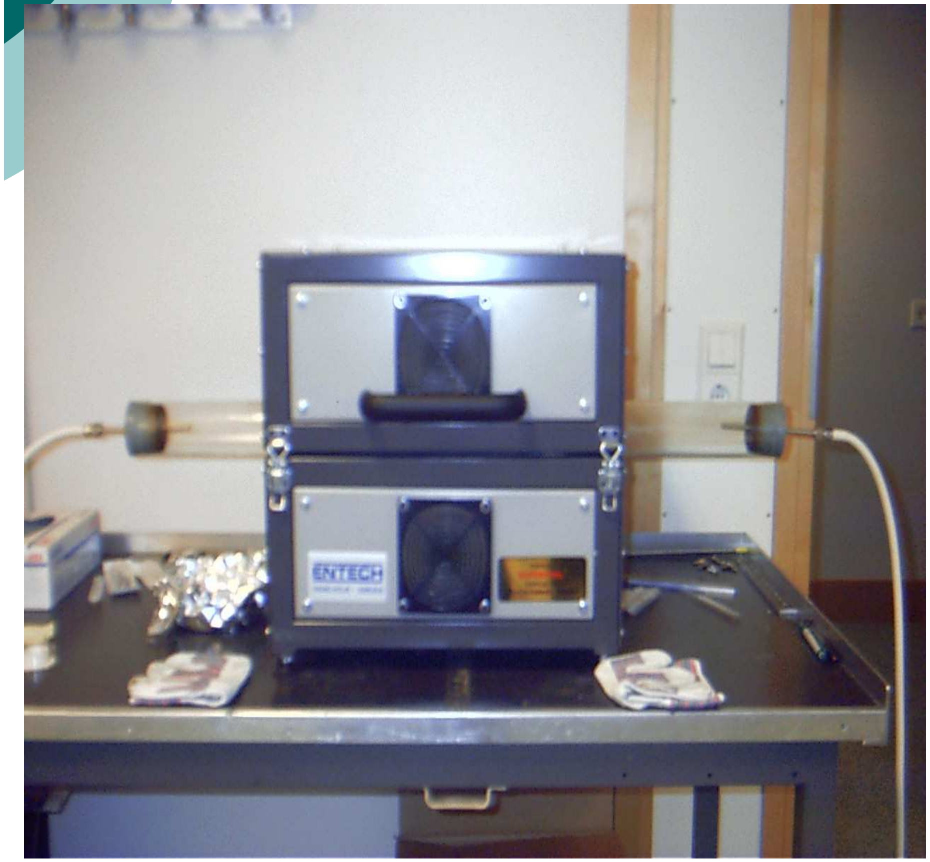


Experimental procedure

- Sol production
- Tube furnace


Experimental procedure

- Carbonization



- Filtration of nitrogen gas

Optical characterisation

- Varian Cary 500
- UV-VIS-NIR

- Bomem DA8
- NIR-IR

Non-optical characterisation

- SEM: Philips XL30

  Surface mophology

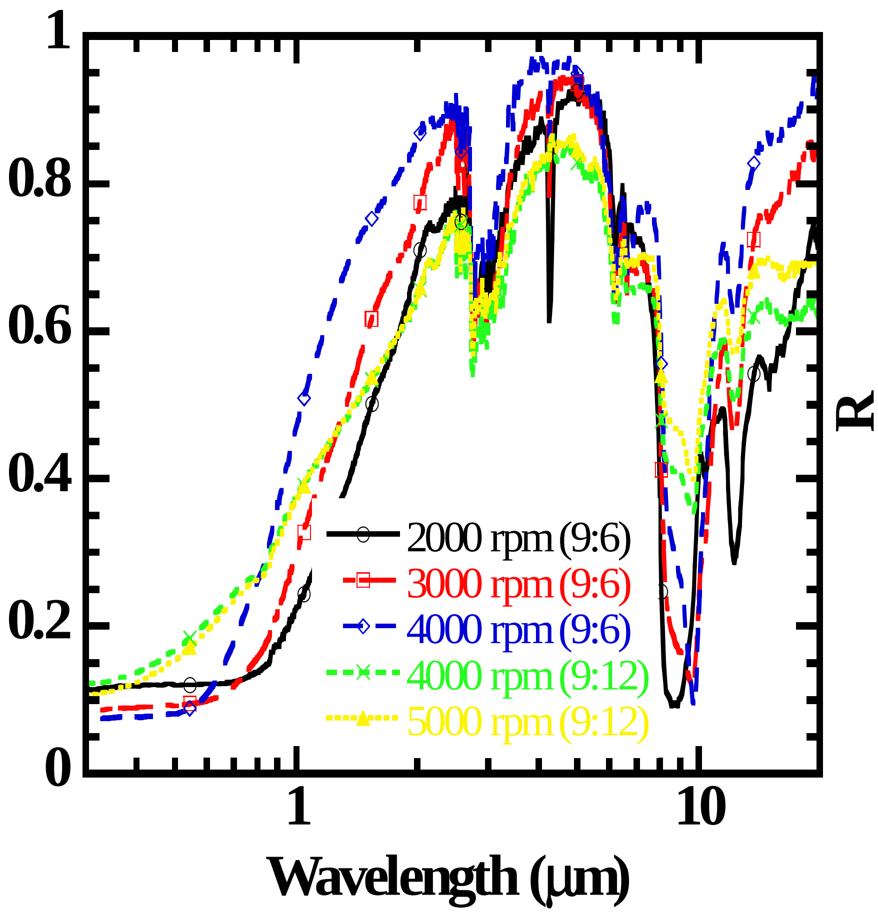
- XRD: Philips PW1840 Diffractometer

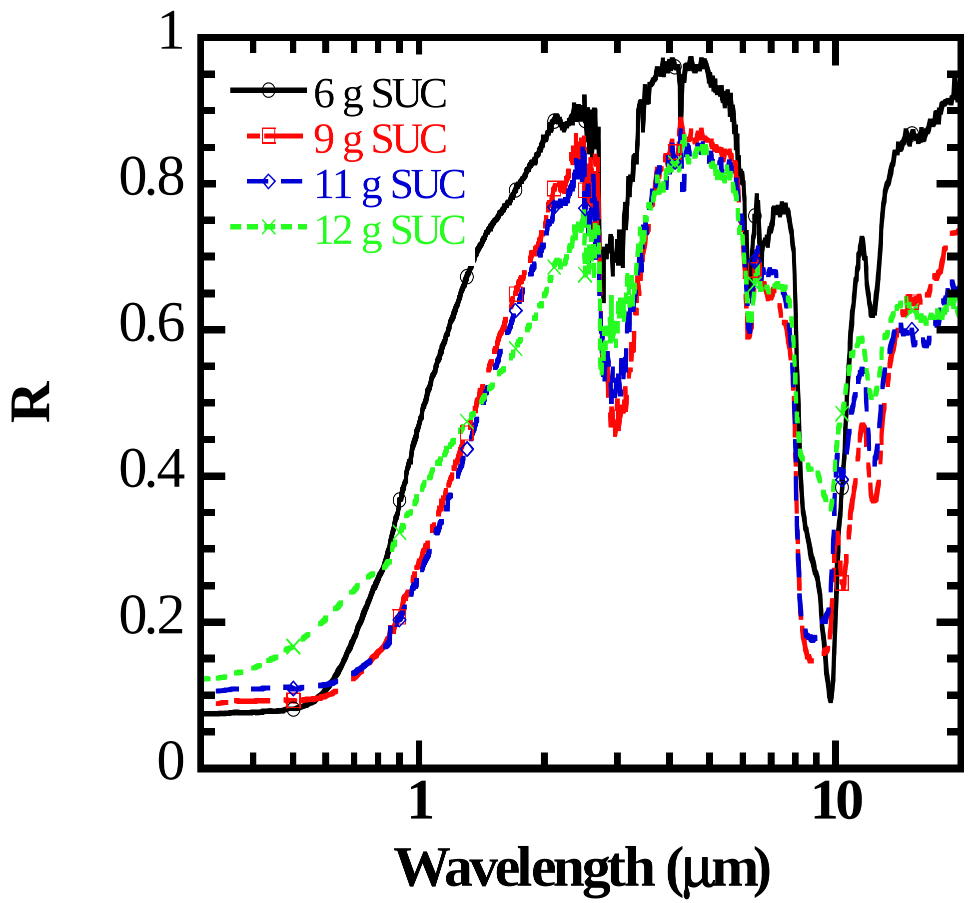
  Cu K_{α}, 35 keV, 30 mA

  Crystal structure

Experimental results: SiO_2 samples

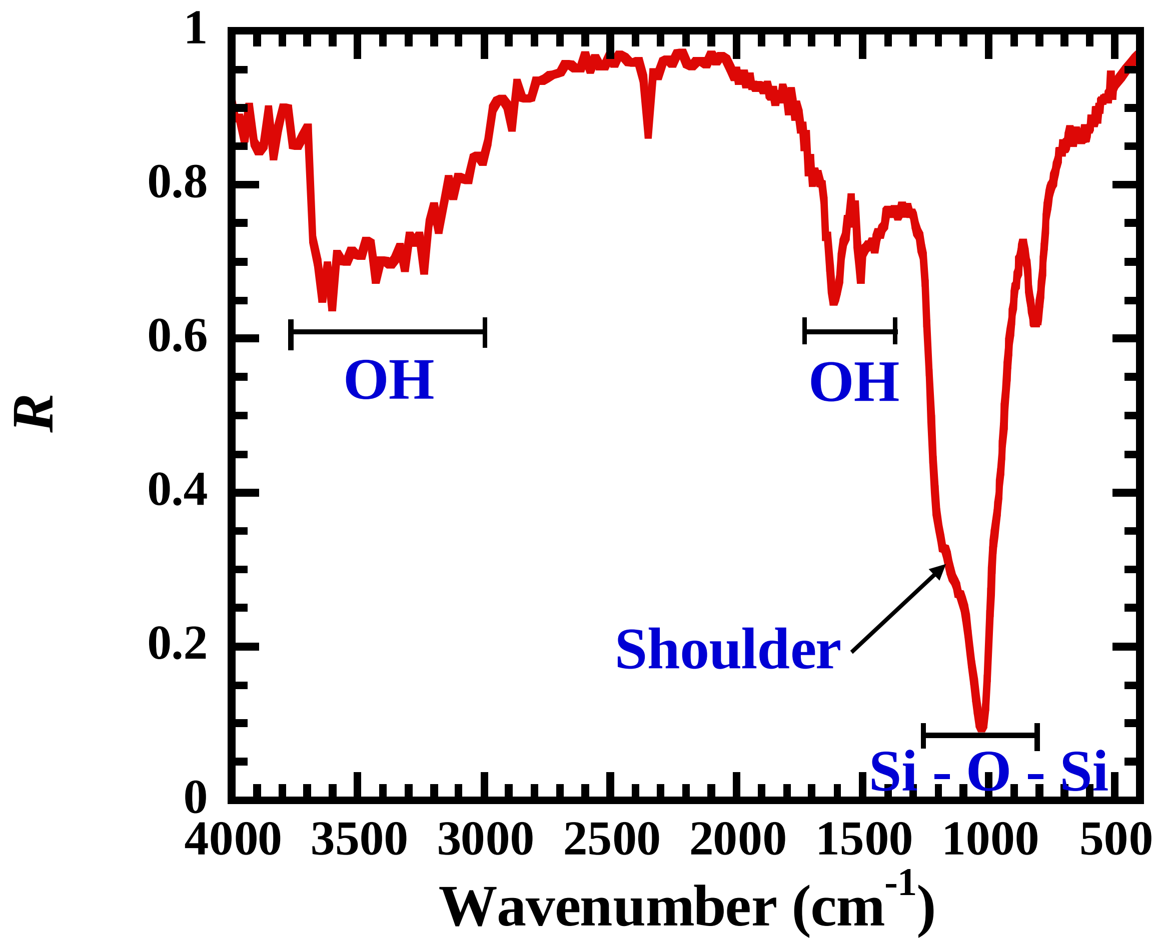
- Spin-coating speed
- Carbon precursor





Experimental results: IR spectrum

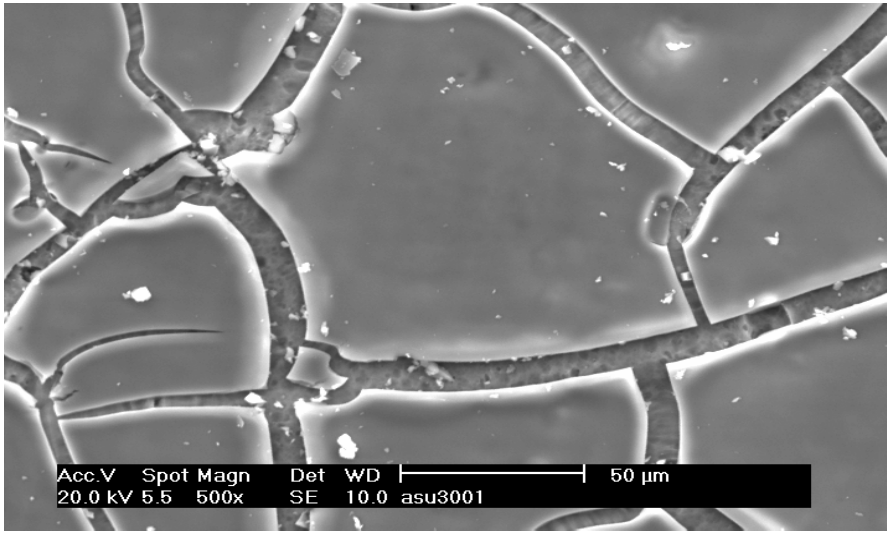
- FTIR reflectance spectrum

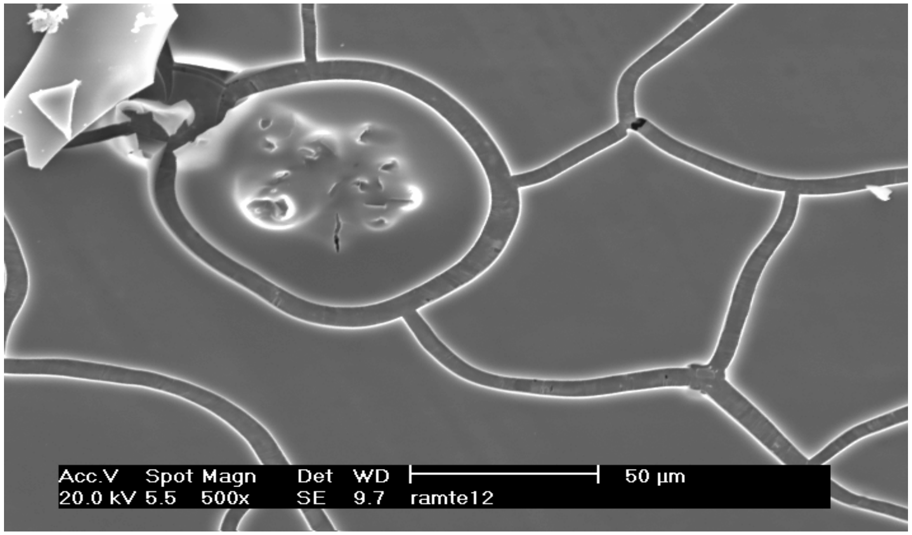


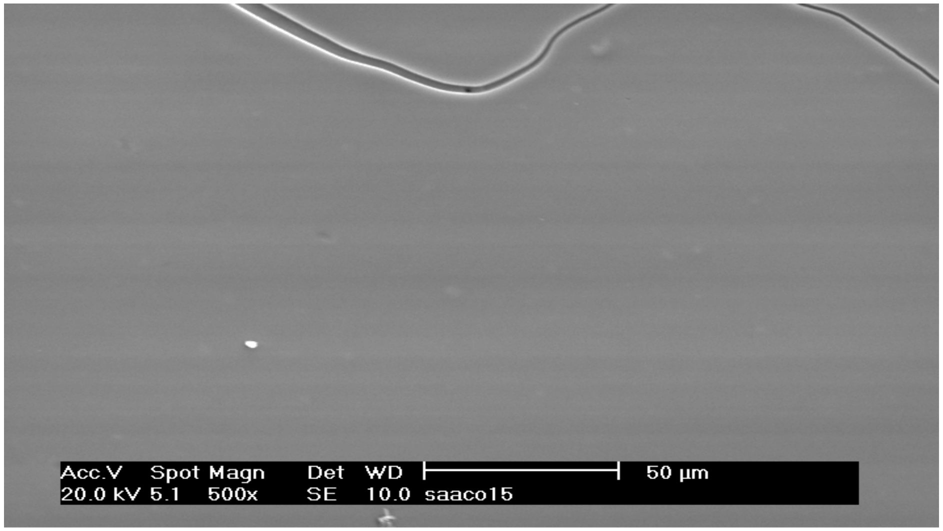
Experimental results: defects

- Problem- cracked films
- Solutions to cracking
- MTES & Ac_2O

Experimental results: defects

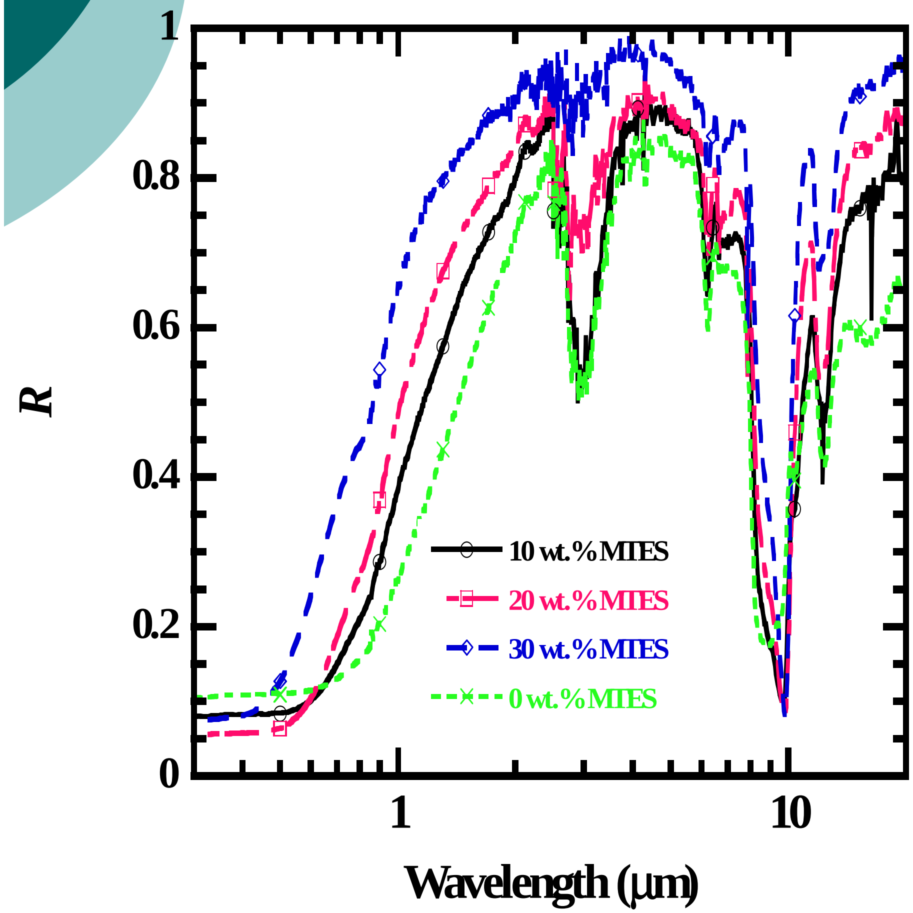


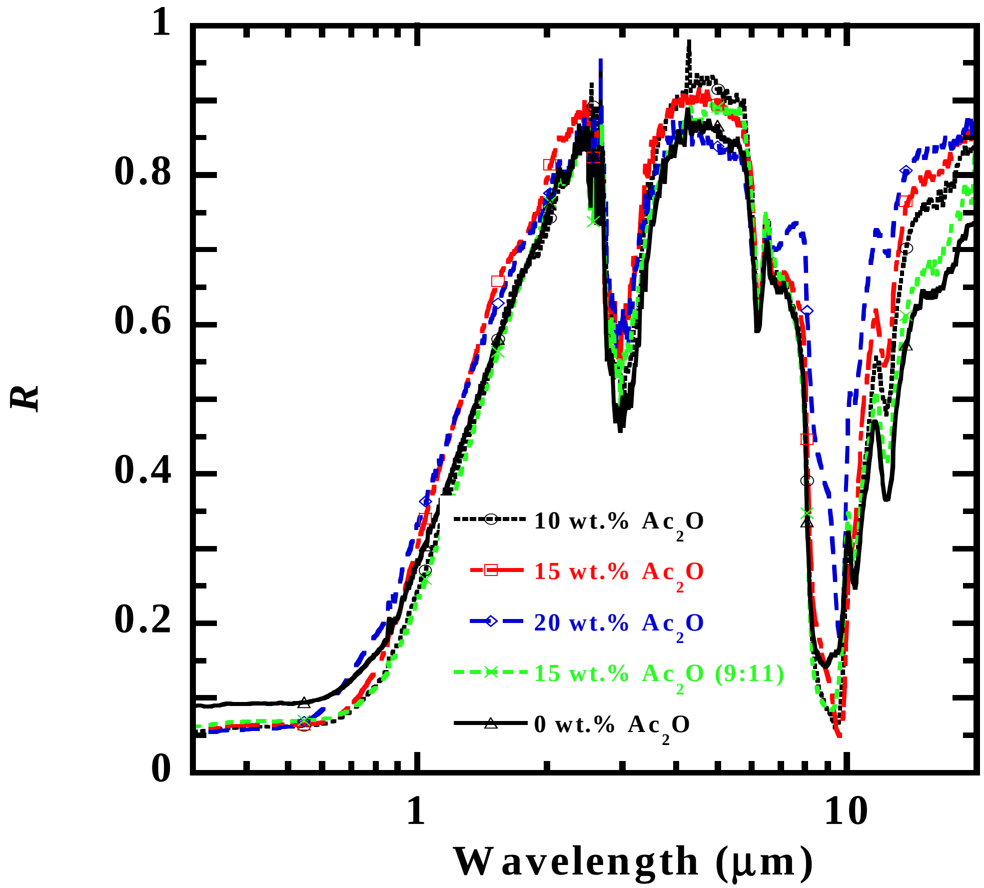




Experimental results: spectra

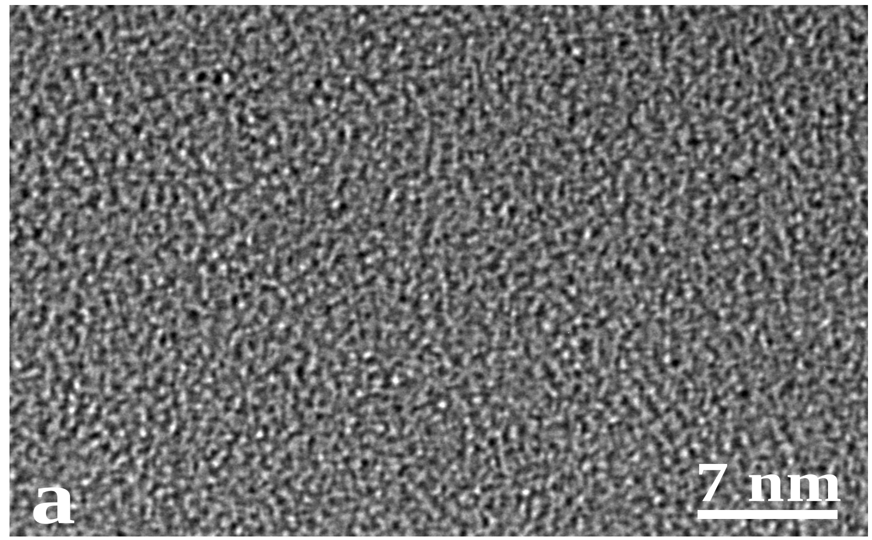
- Addition of MTES
- Addition of Ac_2O

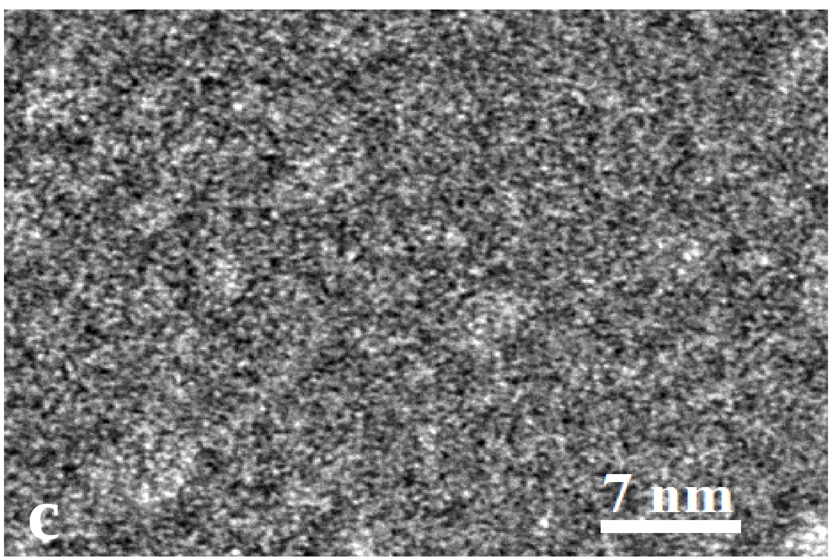


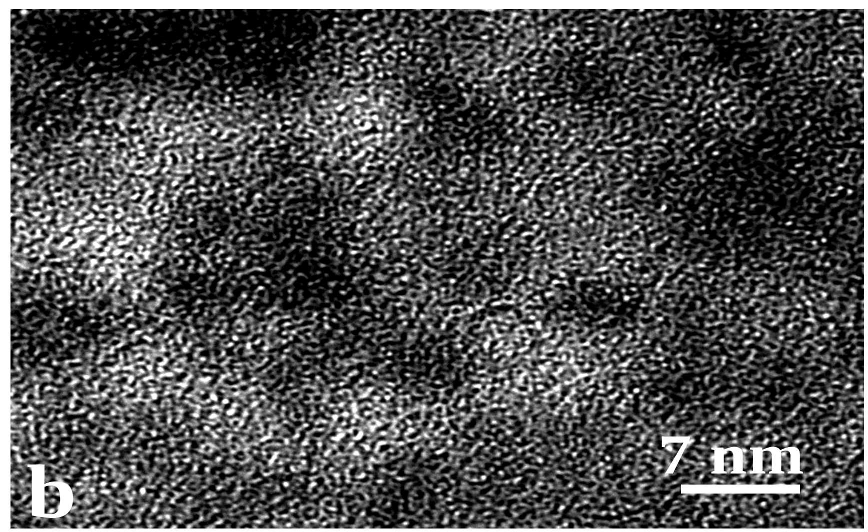


Experimental results: X-HRTEM

- (a) TEOS only
- (b) TEOS + Ac_2O
- (c) TEOS + MTES
- Uniform distribution
- Segregation

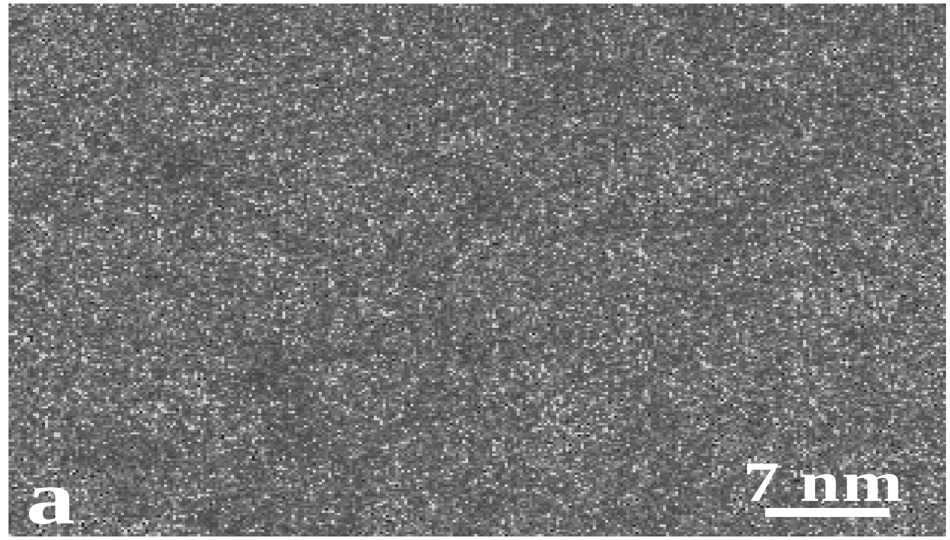


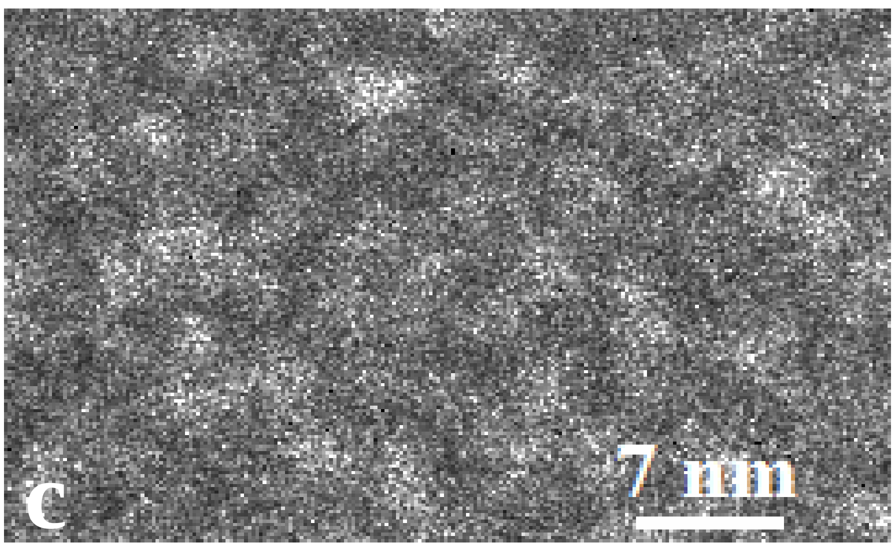


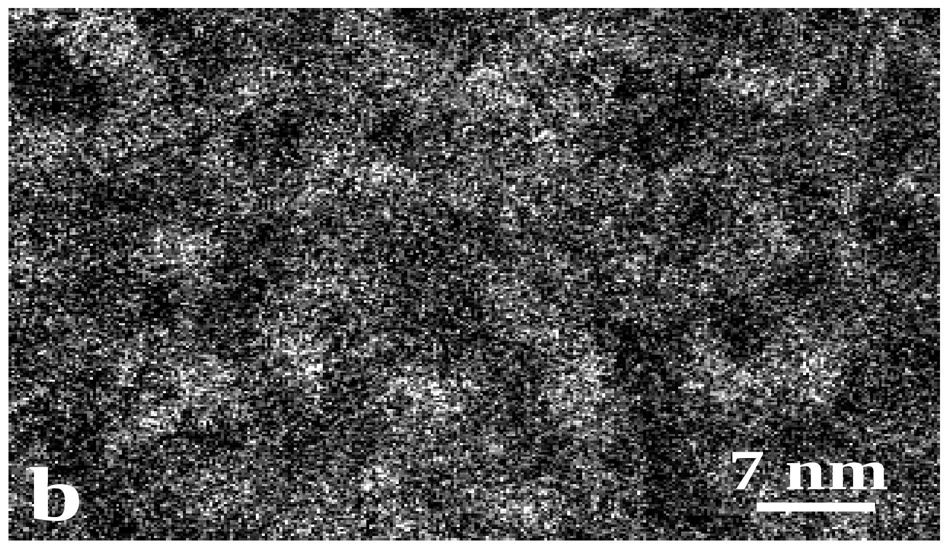


Experimental results: EELS

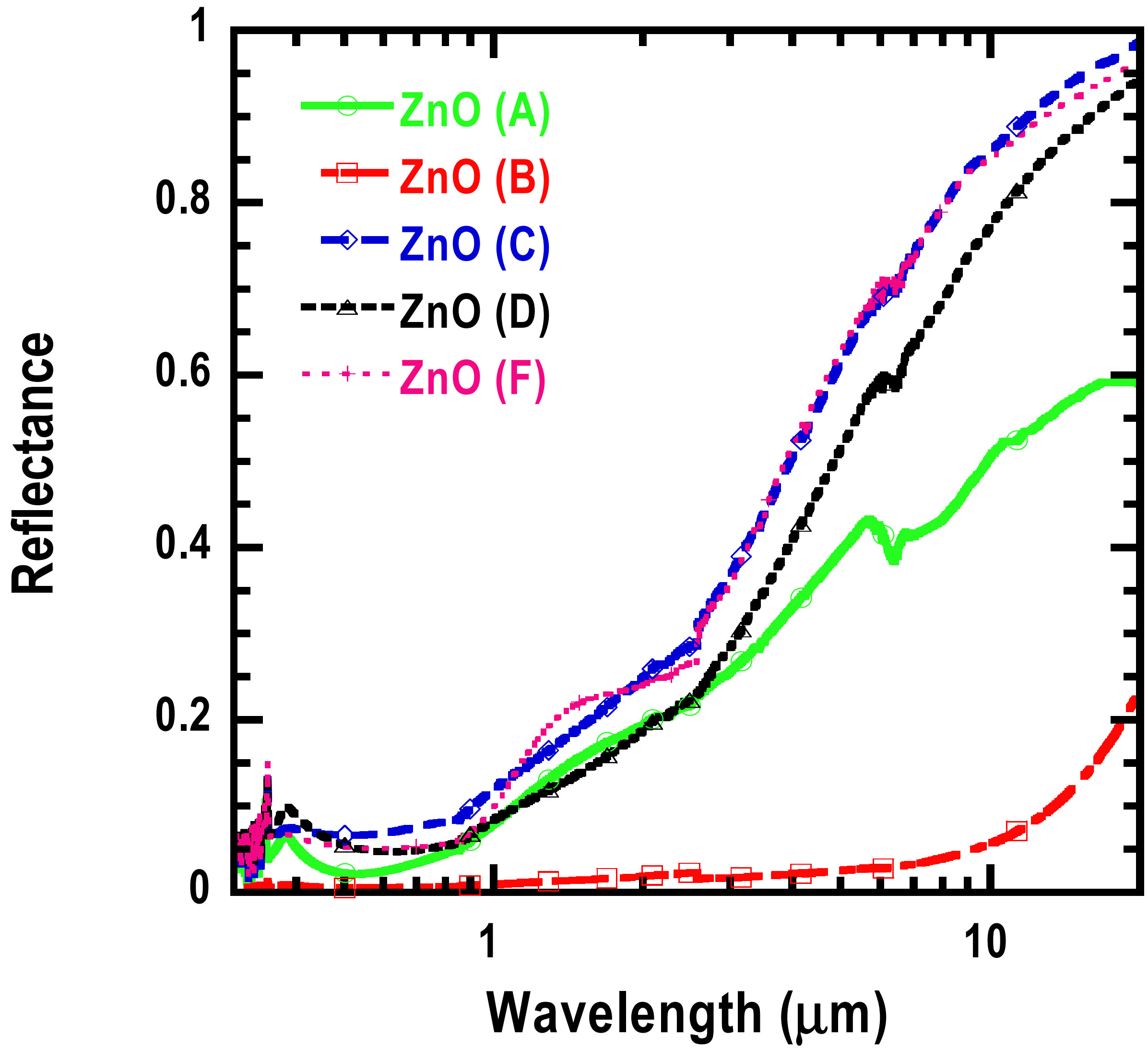
- EELS mapping
- Carbon K peak
- (a) TEOS only
- (b) TEOS + Ac_2O
- (c) TEOS + MTES



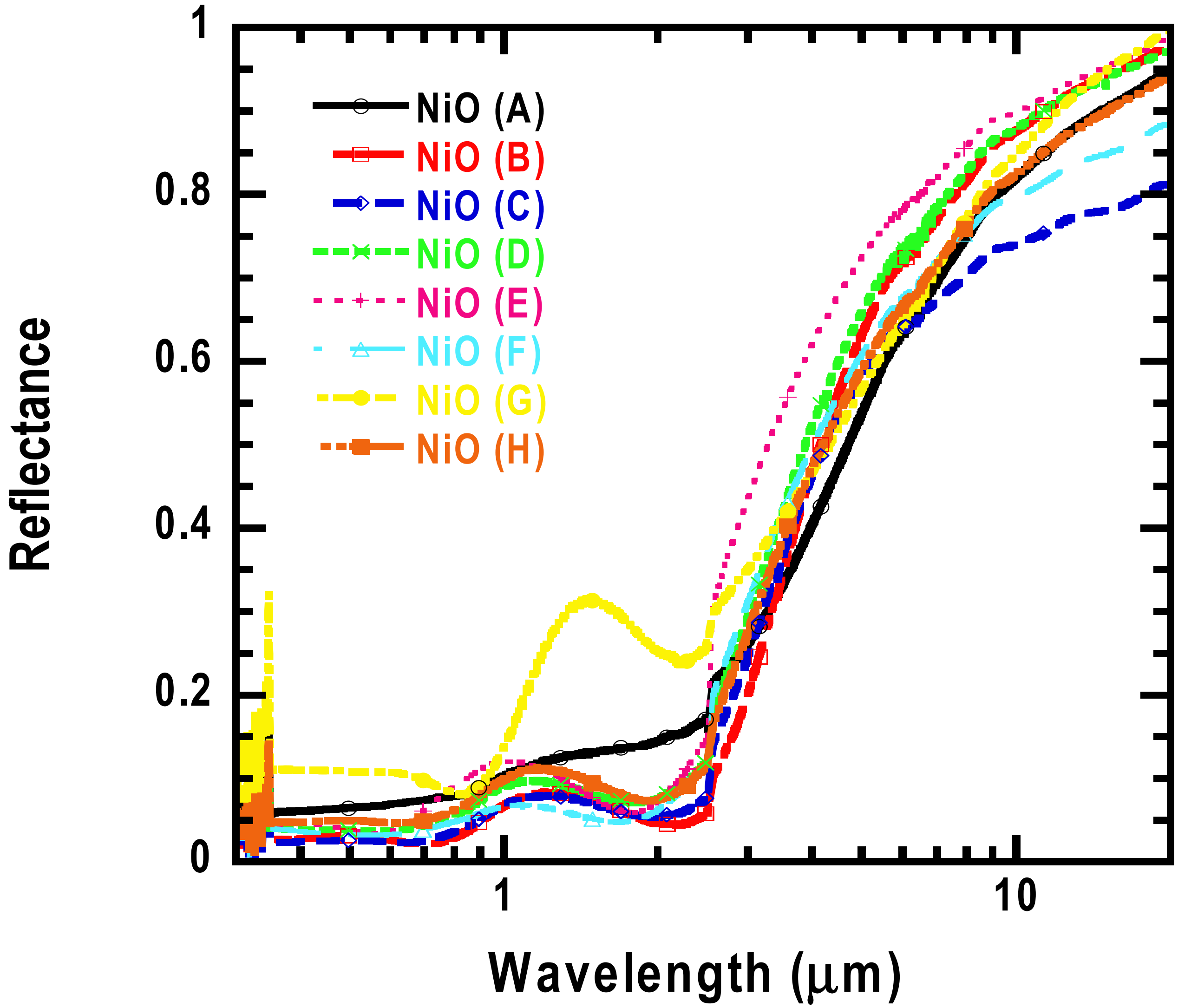




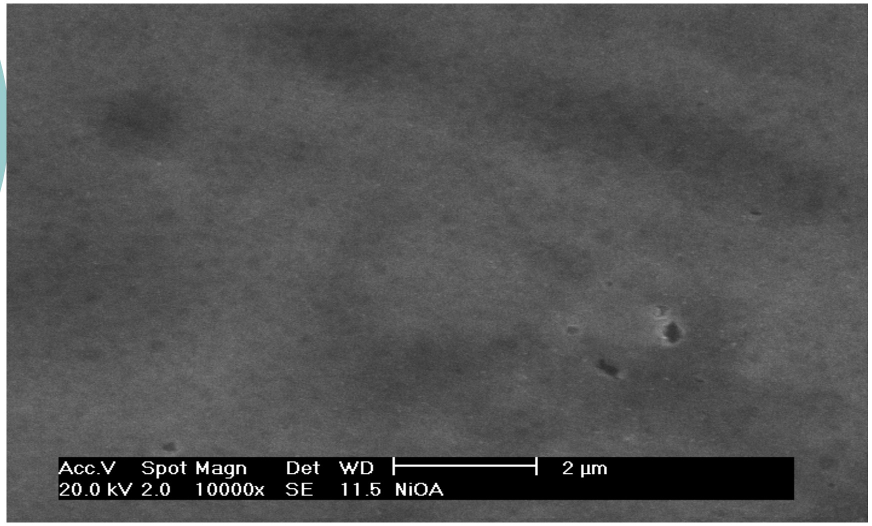
Experimental results: ZnO samples

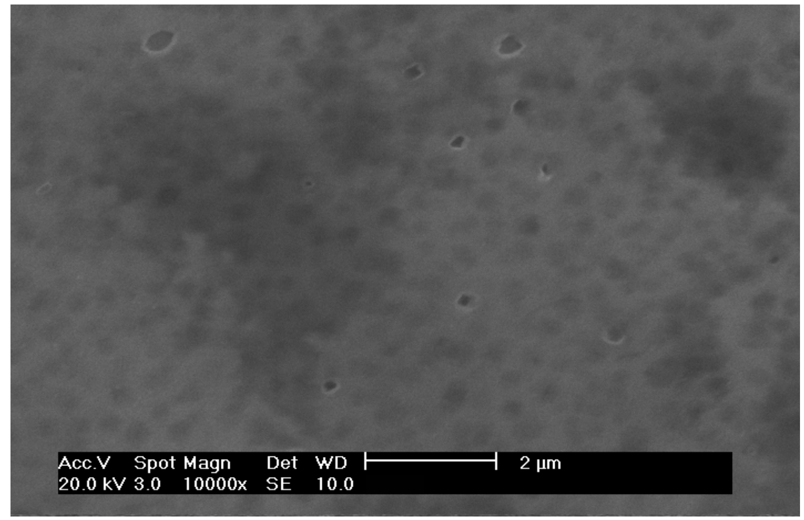


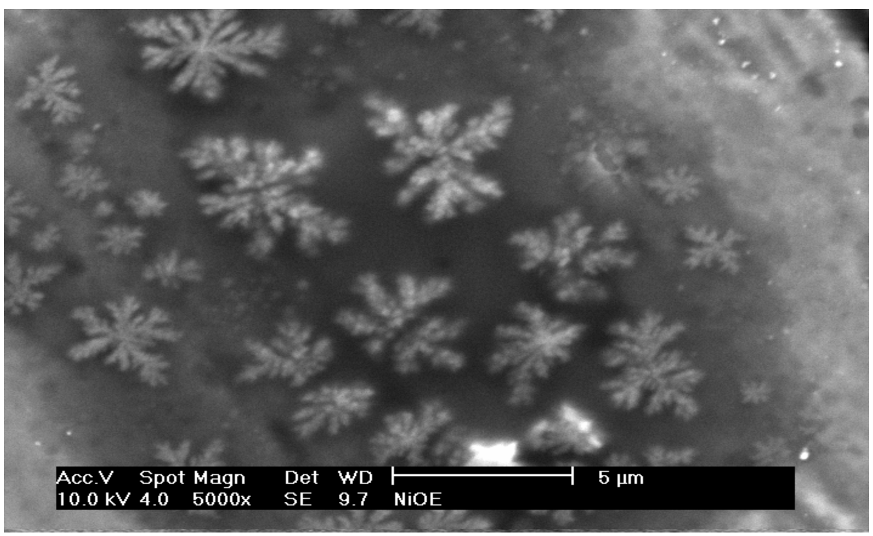
Experimental results: NiO samples

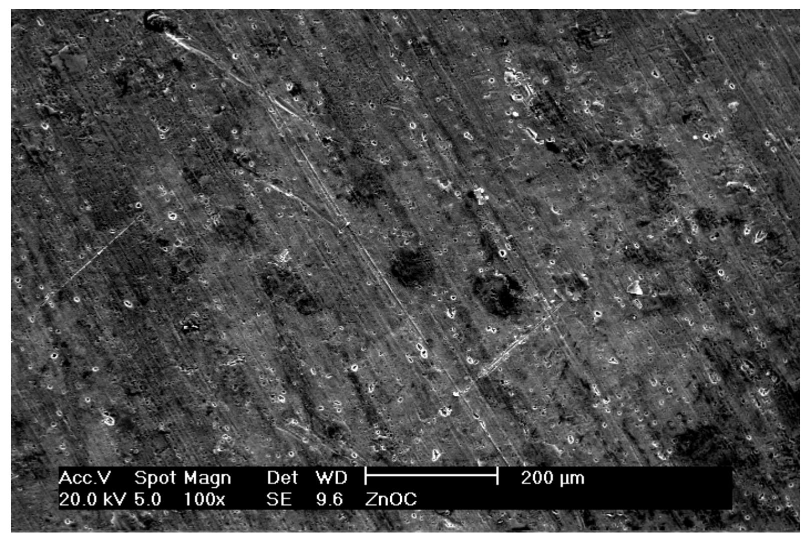


XRD results: NiO and ZnO

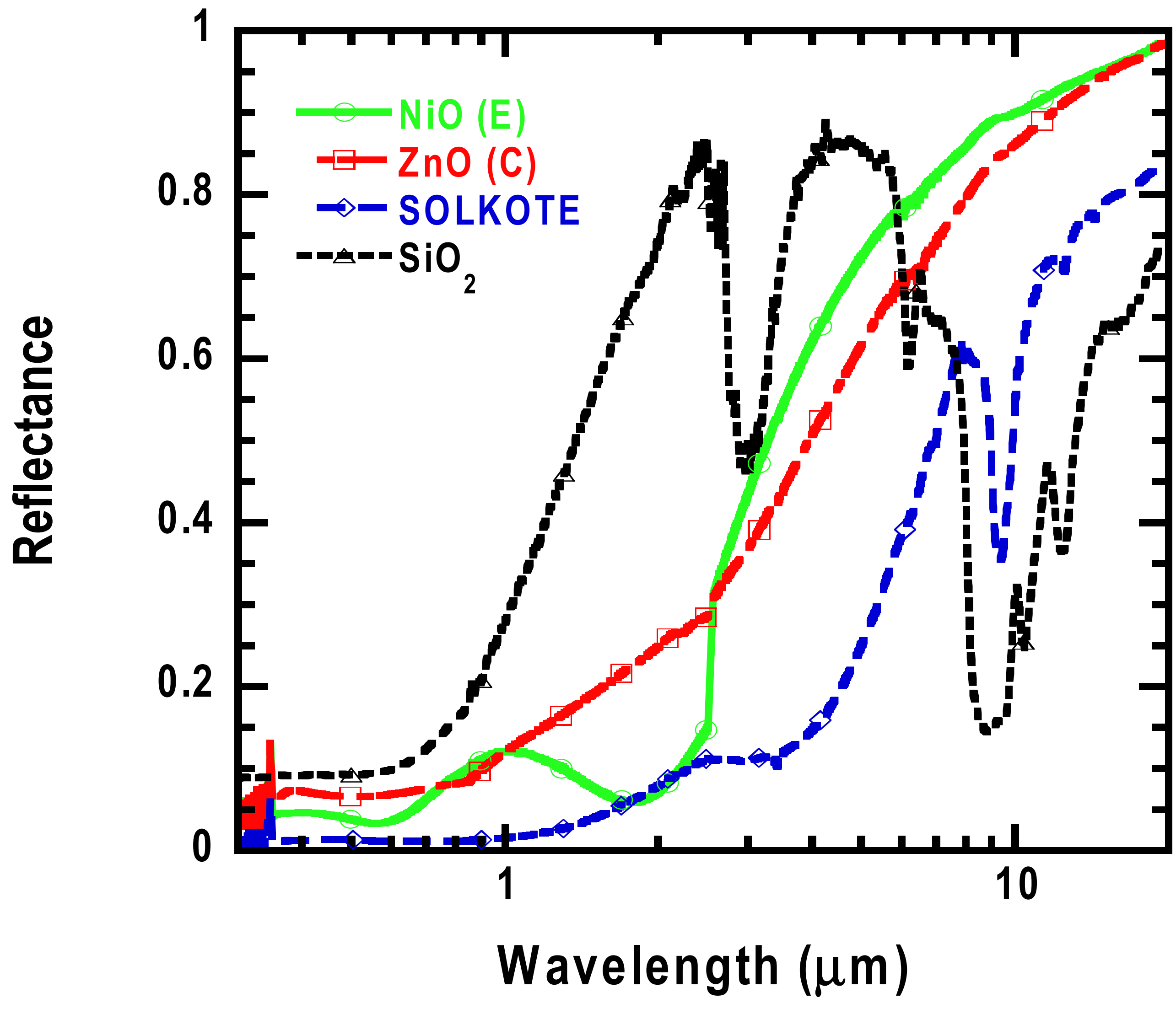




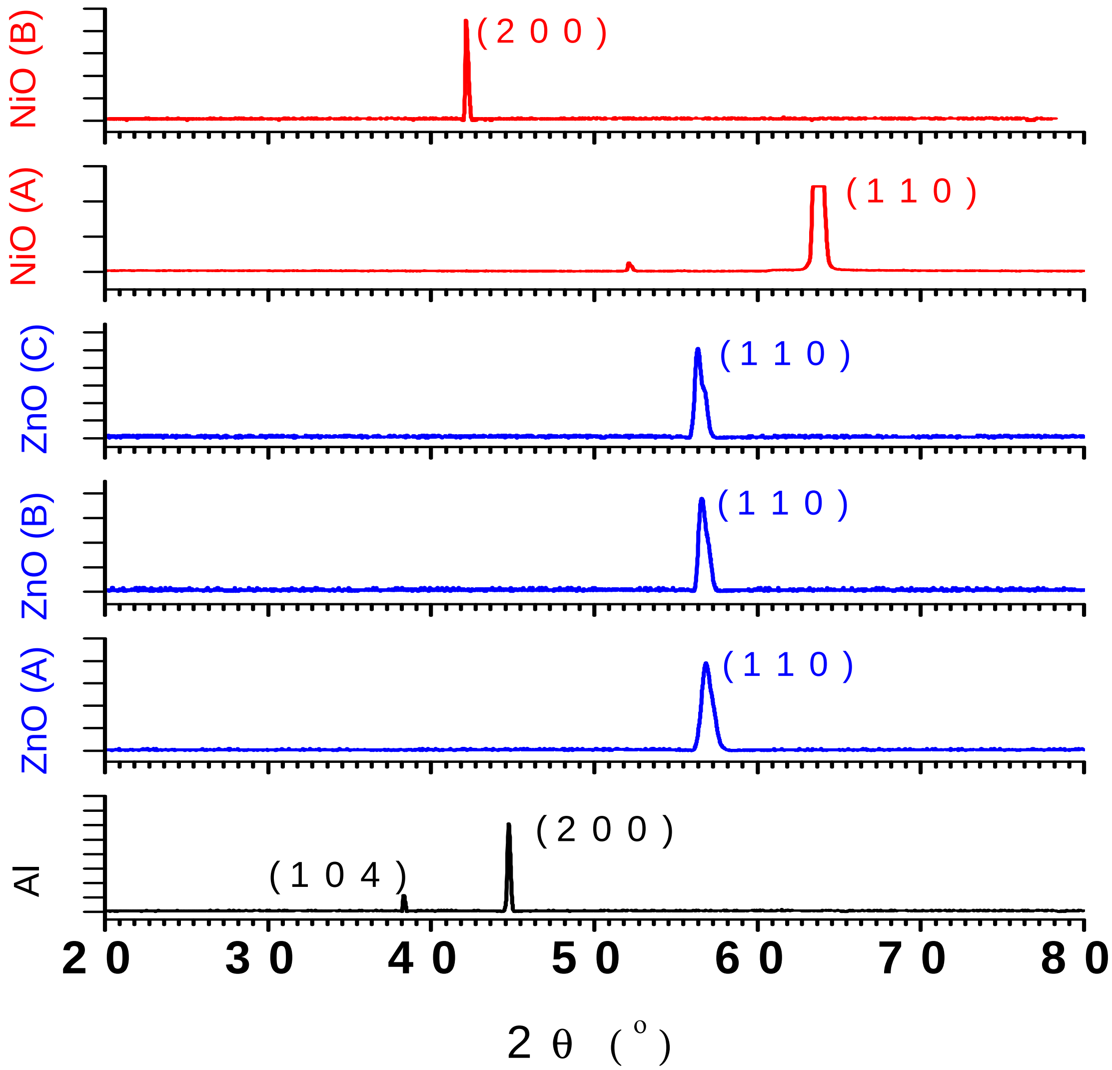




Experimental results: Comparison



Experimental results: XRD



Conclusions

- ∃ a possibility to produce low cost selective solar absorbers with sol-gel technique.
- Addition of 15 wt.% Ac_2O appeared to solve the problem of cracking in SiO_2 samples better than 20 wt.% MTES.

Conclusions

- New and interesting microstructure of the sol-gel derived samples have been revealed:

  A short chain-like structure of both a silica matrix and carbon nanoparticles is quite evident.

- Homogeneity of the coatings at nano-scale is very encouraging.

Conclusions

Sample	α	ε	α/ε
C-SiO_2	0.90	0.31	2.90
C-ZnO	0.89	0.14	6.29
C-NiO	0.93	0.10	8.94

Acknowledgement

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