Effect of heating temperature on the optical properties of sol-gel synthesized C/NiO nanocomposite thin films

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Introduction

For efficient photo-thermal conversion of solar energy a spectrally selective solar absorber surfaces are widely used. An ideal selective surface should have a high absorptance (low reflectance) in the solar wavelength range (0.3 to 2.5 µm) and low emittance (high reflectance) in the infrared wave length range (2.5 to 20 µm) in order to minimize heat losses (Fig. 1). One of the designs that can be used to achieve a combination of high solar absorptance with low emittance is a tandem absorber. This can be realized by using a coating which contains metal particles embedded in an oxide matrix on a highly reflecting metal substrate (Fig. 2). Due to its high absorptance in the visible and its metal-like characteristics, carbon is an excellent choice of material for solar absorber application. However, there are very few reports on carbon containing metal oxide materials [1]. Sol-gel technique has been widely used to prepare spectrally selective coatings on aluminium substrate for solar absorber application in low temperature photo-thermal conversion [1-5]. Katumba et al [1,2] have shown the feasibility of the C/NiO composite coatings for a selective solar absorber application, nonetheless, a detailed systematic investigation on the effect of the sol-gel fabrication process parameters on the structural and optical properties were not reported [6]. It is expected that the heating temperature has a crucial effect on the properties of the final composite coatings [6]. It is therefore the purpose of this work to investigate the effect of heating temperature on the optical properties of the C/NiO composite coatings.

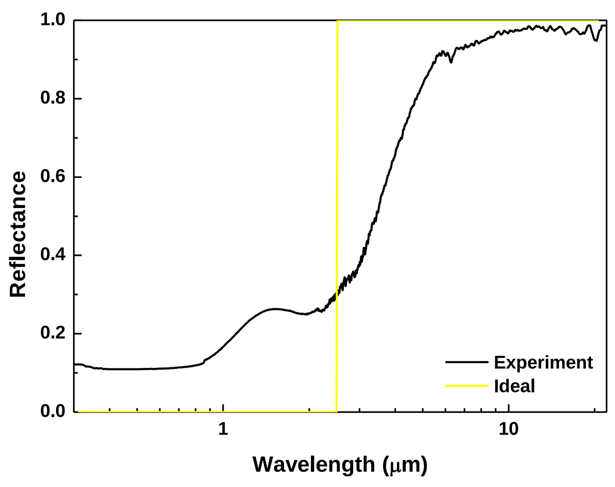

Fig.1. Reflectance spectra of a typical sol-gel prepared C/NiO composite and ideal solar absorber surface.

Fig. 2. Schematic representation of the tandem structure used in this study.

Aim: To investigate the effect of heating temperature on the optical properties of sol-gel synthesized C/NiO nanocomposite thin films

Experimental

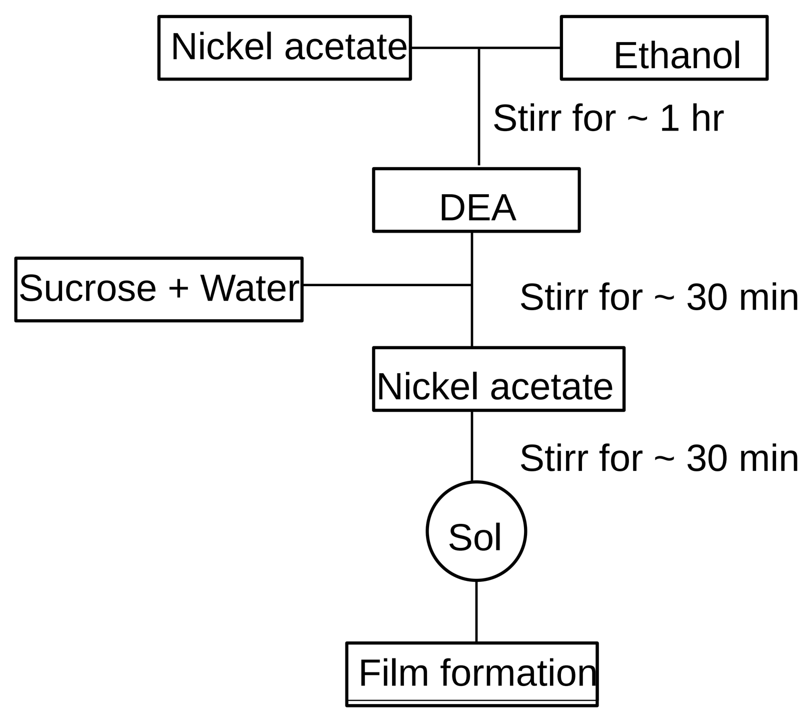

Fig. 3. Schematic diagram of the thin film preparation process.

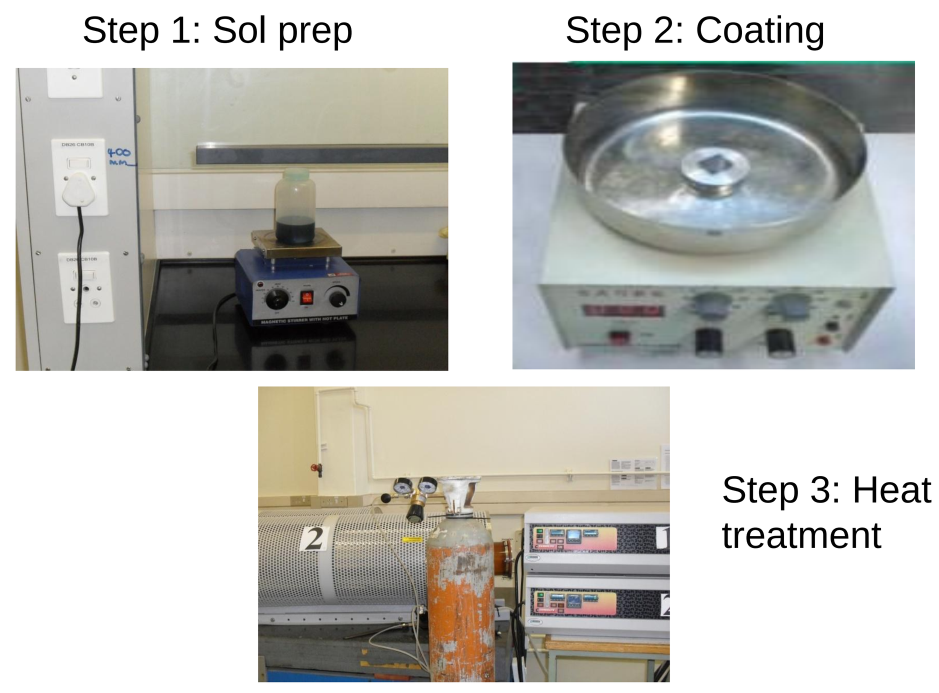

Fig. 4. Photographs of the steps of the thin film preparation.

Characterization

Structural: SEM, Raman
Thermal: TGA, DSC
Optical: UV-Vis, FTIR

Theoretical approach

Bruggeman (Br) formalism has been used to model the reflectance of the C/NiO composite material

$$f_A \frac{\varepsilon_A - \overline{\varepsilon^{Br}}}{\varepsilon_A + 2\overline{\varepsilon^{Br}}} + (1 - f_A)\frac{\varepsilon_B - \overline{\varepsilon^{Br}}}{\varepsilon_B + 2\overline{\varepsilon^{Br}}} = 0$$

Results

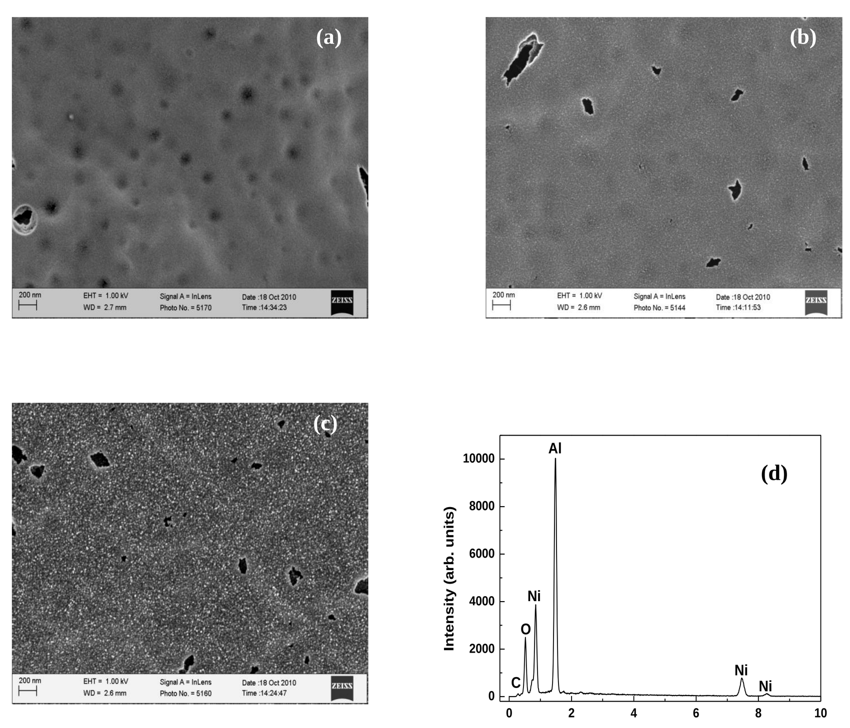

Fig. 4. SEM images of C/NiO nanocomposite coatings heat treated at different temperatures: (a) 350 °C, (b) 450 °C, (c) 550 °C, and (d) a typical EDS spectra.

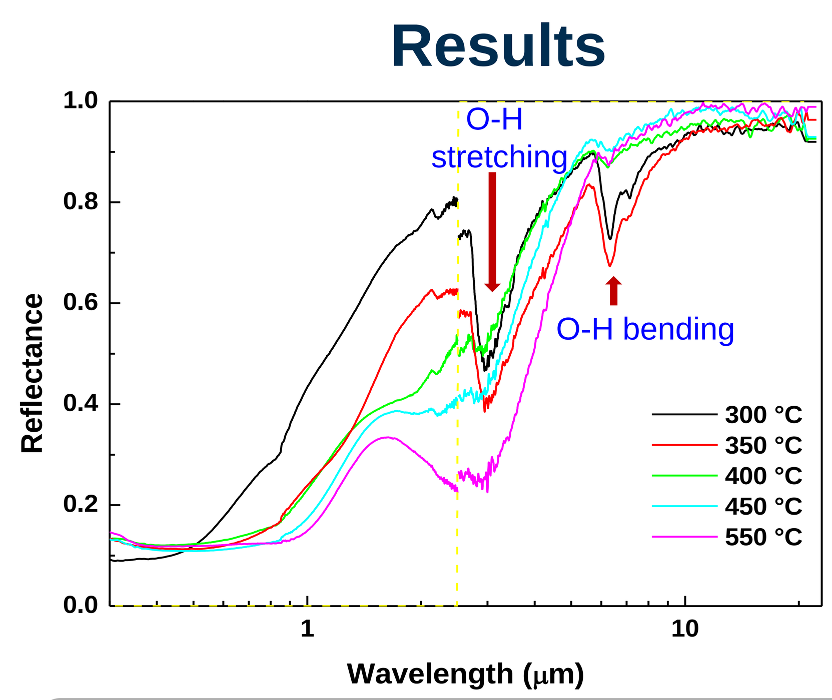

Fig. 5. Reflectance spectra for C/NiO composites as a function of heating temperature.

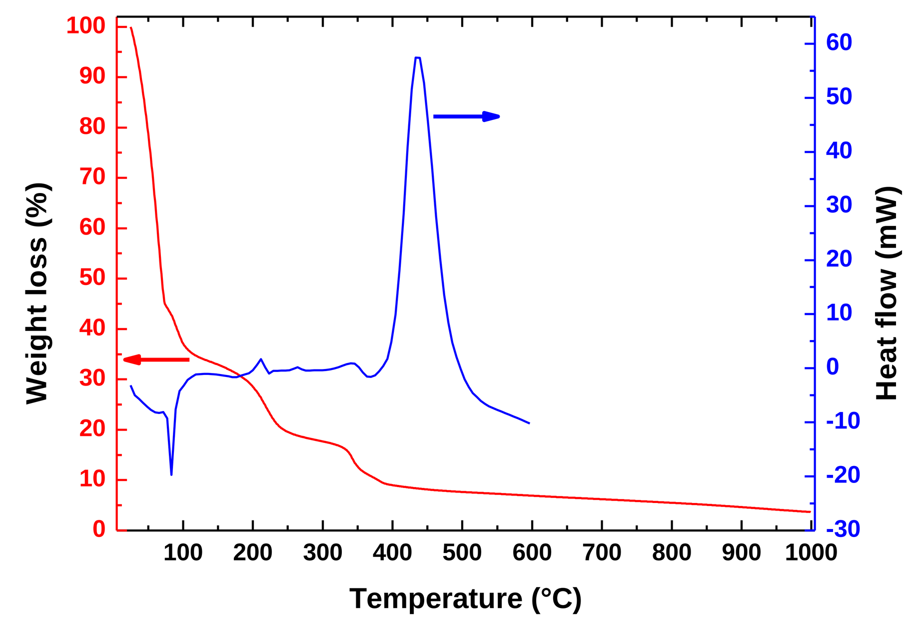

Fig. 6. A typical TGA and DSC spectra for the C/NiO precursor solution.

- The OH stretching and bending peaks for samples heated below 400 °C is due to the remnants of water molecules in the material
- The reflectance values decreases as the heating temperature increases for wave lengths below 2.5 µm
  → improvement in the solar absorption property
- The absorption edge shifts to a higher wave length as the heating temperature increases

Heating temp. (°C)	D band (cm^{-1})	G band (cm^{-1})	I_D/I_G (area ratio)	Mean size of graphitic nanocrystallites (nm)
300	1373.5	1579.7	0.4	1.8
350	1365.4	1587.4	3.5	15.4
400	1370.3	1591.3	3.2	14.3
450	1367.4	1588.7	3.5	15.4
550	1357	1590	3.4	15.0

Table 1. Variation of Raman parameters with heating temperature.

- The G band position and the relative intensities of D and G band increase with heating temperature
  → degree of graphatization increases and the mean size of graphitic nanocrystallities , respectively [7]

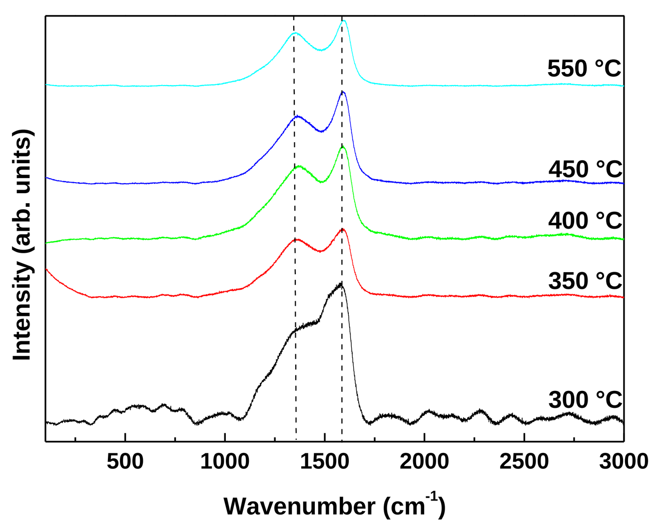

Fig. 7. Raman spectrum of C/NiO nanocomposite thin films heat treated at different temperature.

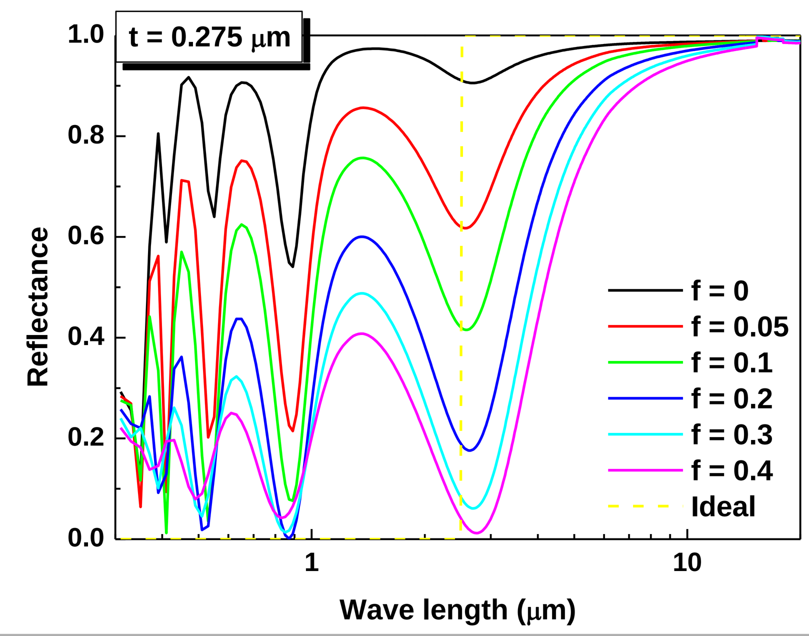

Fig. 8. Reflectance spectra for C/NiO composites obtained from calculations based on the Bruggeman [8] effective medium theory.

Conclusions

❖ The sol-gel technique has been successfully used to deposit C/NiO composite thin films

❖ As the heating temperature increase the porosity increases where as the size of the surface features decrease

❖ The degree of graphatization increase with heating temperature which suggests the increase in carbon content

❖ Heating temperature of about 450 °C or above is necessary to deposit optimal coatings

❖ It has been shown that the absorption edge moves towards the higher wave length due to increase carbon content

References

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