Carbon nanotube/nickel oxide nanocomposite thin films for selective solar absorber

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INTRODUCTION

Nanocomposite thin films are widely used for solar thermal applications [1]. Carbon-based nanostructured composite films consisting of nanosize particles embedded in metal oxide host matrix have attractive properties for selective solar absorber coatings to be used for solar water heating and cooking applications [2, 3]. Recently, Katumba *et al.* [3] have compared carbon embedded in three different metal oxides (SiO_2, ZnO, and NiO). Among the three, carbon in NiO matrix has shown superior optical properties [3]. It is expected that the size and shape of the embedded particles influence the selectivity of the absorbers. In addition, the use of CNTs is appealing because they are highly anisotropic and could bring interesting optical properties to the composite [4]. Thus, the investigation of the properties of MWCNT/NiO nanocomposites will have a basic scientific interest as well as potential technological applications. In this work, MWCNTs were functionalized in order to form MWCNT/NiO composites for selective solar absorbers using a sol-gel route.

Solar energy conversion

The power density ,P, of thermal radiation emitted by a black body of temperature T is

$P = \sigma T^4$, $\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4 (1)

(Stefan-Boltzmann law)

Kirchhoff's Law: $\alpha(\lambda) = \varepsilon(\lambda) = 1-R(\lambda)$ (Opaque surface)

$$\alpha_{sol} = \frac{\int_{0.3}^{2.5} I_{sol}(\lambda)(1-R(\lambda))\,d\lambda}{\int_{0.3}^{2.5} I_{sol}(\lambda)\,d\lambda}; \quad \varepsilon_{therm} = \frac{\int_{2.5}^{20} \rho(\lambda)(1-R(\lambda))\,d\lambda}{\int_{2.5}^{20} \rho(\lambda)\,d\lambda}$$

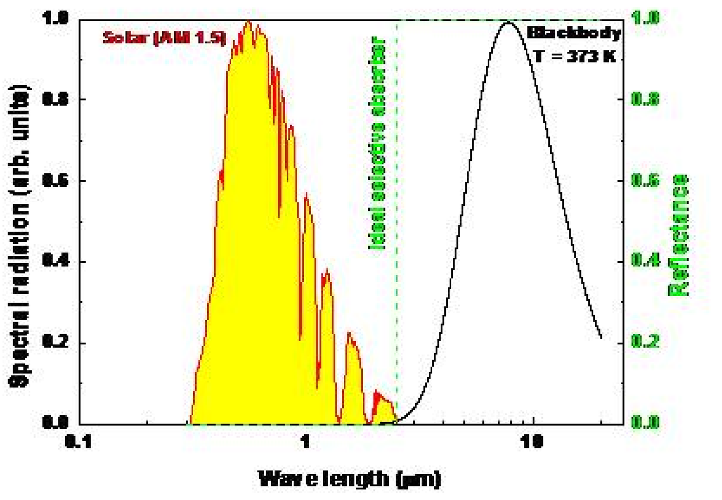


Fig.1. Solar radiation AM 1.5, black body radiation at 100 °C and reflection of an ideal optically selective coatings

At T = 80 °C, from eq. (1), P ~ 900 W/m^2 ~ incident solar energy at the ground

→ An optically selected surface is required

Aim

An attempt is made to investigate the possibility of using MWCNT/NiO nanocomposites for selective solar absorber coatings

Experimental

Nanotubes

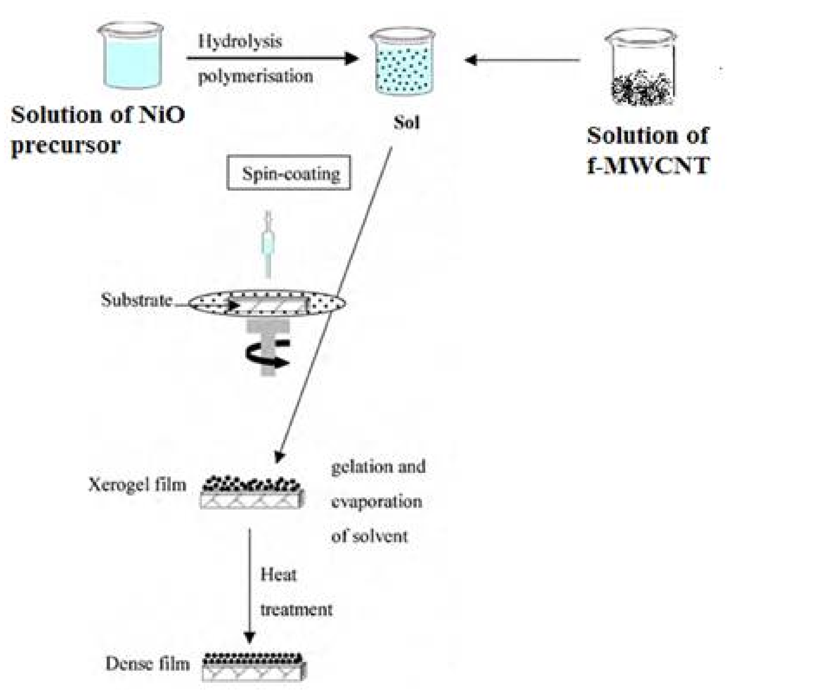
The MWCNTs was purchased from Sigma Aldrich, and the purity of the pristine MWCNTs, as received, was > 90 %.

Samples

The MWCNTs were added to a mixture of concentrated HNO_3 and H_3PO_4 acid solution and refluxed at 120 °C for 2 hrs to treat the carbon nanotubes with the acids. Subsequently, the acidic solution was passed through a filter to collect the acid treated carbon nanotubes. The acid-treated carbon nanotubes were washed several times with distilled water, dried, and powdered.

Precursors:

- Nickel acetate
- Ethanol
- Diethaloamine
- Poly ethylglycol
- Distilled water



Characterization

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

Fig. 2. An overview of the sol-gel synthesis used in this study

Experimental Results: Thermal characterization

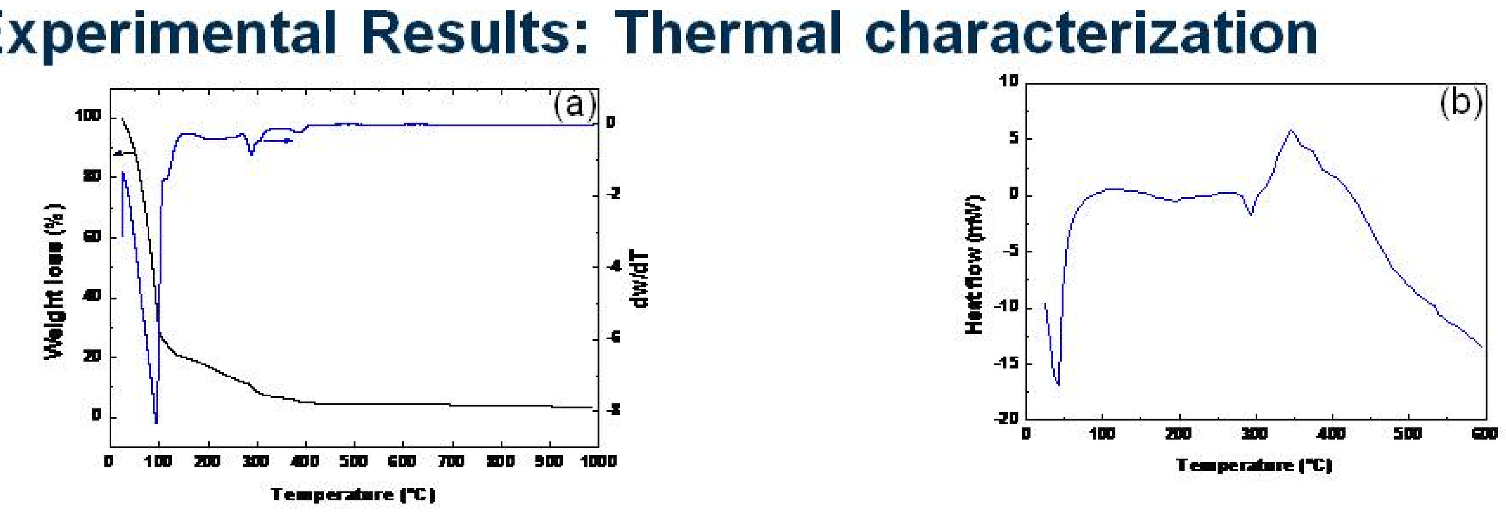


Fig. 3. Thermal behaviour of the final solution used for coating : (a) The mass loss, and (b) the change of heat flow

- From TG, 3 major weight loss: perhaps desorption of water, desorption of residual organics and oxidation
- No weight loss above 420 °C
- From DSC, exothermic reaction occurs at around 346 °C indicating a change in the matrix of NiO and the MWCNT

Experimental results: Structural and Optical Characterization

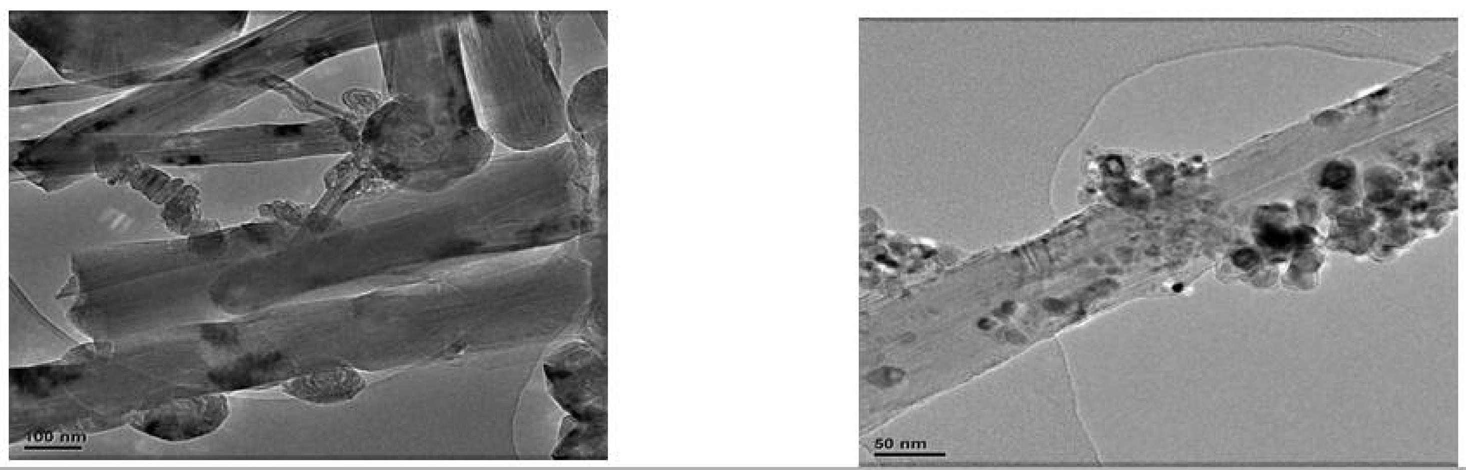


Fig. 4. Typical TEM image of (a) functionalized MWCNT and (b) functionalized MWCNT/NiO nanocomposite coating

- The average diameter of the tubes is about 110-170 nm for functionalized
- NiO grains were chemically bonded to the surface of the MWCNTs during the sol-gel deposition

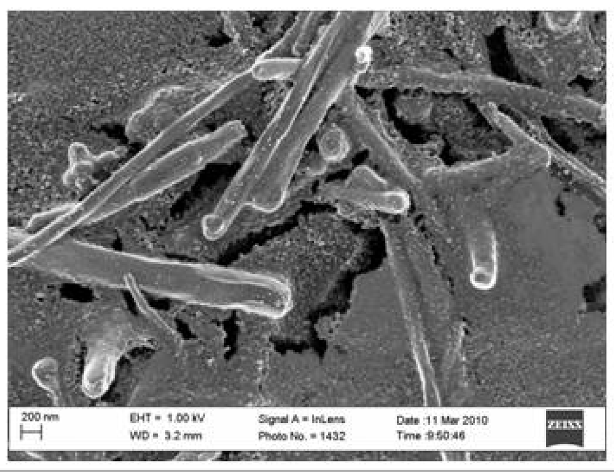


Fig. 5. SEM image of a typical functionalized MWCNT/NiO nanocomposite coating

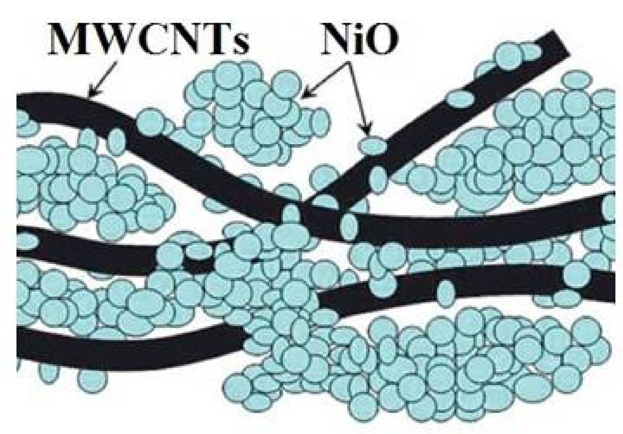


Fig.6. Schematic view of the functionalized MWCNT/NiO nanocomposite structure [5]

- Functionalized MWCNTs are well dispersed and embedded in the NiO grains

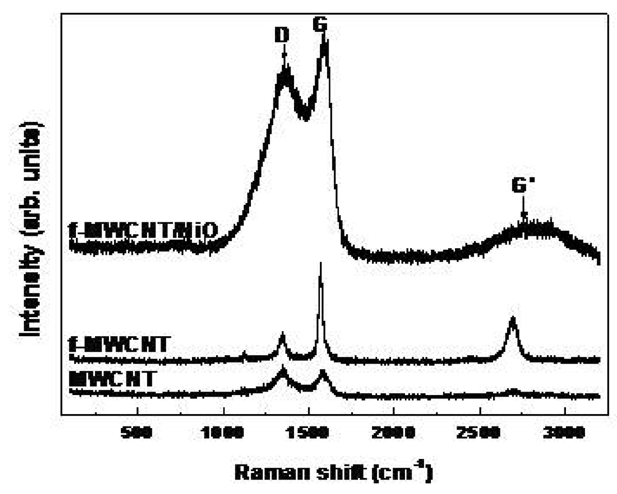


Fig. 7. Comparison of Raman spectra from a typical MWCNT/NiO nanocomposite with functionalized MWCNT and commercial MWCNT

- I_D/I_G ↓ from 0.44 to 2.05 after functionalization → introduction of –COOH by acid treatment [5]
- I_D/I_G ↑from 0.44 to 2.7 for the nanocomposite → metal and/or oxide nanoclusters, preferentially formed at defect sites of pristine CNT to attached to functional groups [5]
- After functionalization the G band red shifted by ~ 13 cm^{-1} while no change in D band → successful functionalization
- In the nanocomposite both peaks blue shifted → stress in the composite due to NiO matrix [6]

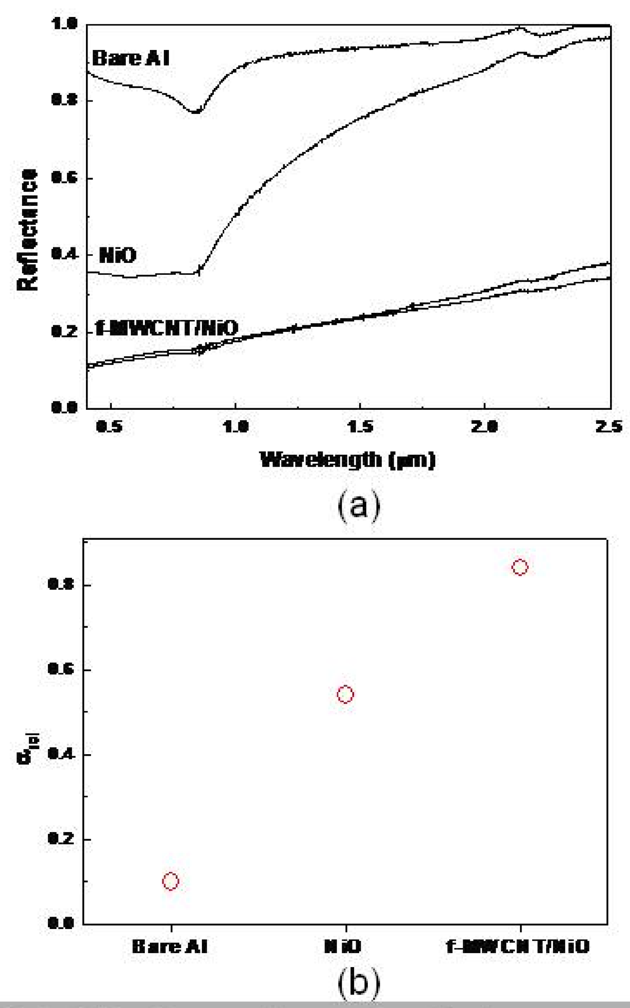


Fig. 8 (a&b) Comparison of reflectance spectra from MWCNT/NiO nanocomposite with NiO and aluminium substrate

Conclusions

- ❖ The sol-gel processing was successfully applied for the preparation of MWCNT/NIO nanocomposite for potential application as a selective solar absorber coatings
- ❖ The dispersion of MWCNTs in NiO was achieved due to the strong adhesion between the MWCNTs and NiO matrix
- ❖ The red shifted of G band by ~ 13 cm^{-1} after functionalization indicates that the functionalization was successful
- ❖ The optical absorptance values of the MWCNT/NiO nanocomposite coatings suggest that MWCNT/NiO nanocomposite coatings could be used as potential selective soalr absorber coatings

References

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