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Study of the Influence of the Annealing Temperature on the Properties of SiC-SiO_2 Thin Films

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Nanocomposite SiC-SiO_2 thin films were successfully synthesized on silicon and glass substrates by a physical vapor deposition method. The aim of this study is to show the influence of annealing temperature on the properties of SiC-SiO_2 thin films. The deposition was carried out by a co-sputtering RF magnetron at 13.56 MHz, using one target of SiO_2 and 2 strands of polycrystalline 6H-SiC. The properties of SiC-SiO_2 thin films were investigated using two different techniques: scanning electron microscopy and reflectance spectroscopy. The SiC-SiO_2 composite thin films showed a considerable decrease in reflectance from 21.63% to 11.85% at varying annealing temperatures in the range 450–900 °C.

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1. Introduction

As the energy consumption is strongly related with the living standards and development of the countries, new energy sources should be created [1]. Solar power is energy from the sun that is converted into thermal or electrical energy. It is the cleanest and most abundant renewable energy source. It is important to know the solar energy potential before setting up any solar energy system [2, 3]. The solar cell is used to convert solar radiation directly into electrical energy. The most widespread photovoltaic cells are made of semiconductors, mainly based on silicon (Si), which has often been described as the material of the century, with its multiple forms and numerous compounds [4–6]. Although, there are other cells called "thin-film solar cells" that are growing in the market because of their low cost and high efficiency.

Thin layers of SiC-SiO_2 composite materials are the subject of our study. SiO_2 is used because it has great technological potential thanks to its specific properties (high chemical stability, high refractive index, transparency in the visible, etc.) that allows its use as thin layers of optical components [7–9]. As for silicon carbide (SiC), it is a semiconductor material belonging to the family of large gaps (large bandgap). Belonging to this family gives it a very coveted potential in high power, high temperature, and high frequency electronics [6]. Long time constrained by the difficulty of obtaining a material with sufficiently powerful electronic properties, and by the cost monocrystalline substrates, thin films of silicon carbide now offer good quality films for more acceptable prices costs [10].

In general, AR coatings with uniform thickness and good optical properties are performed by vacuum and high temperature processes like thermal evaporation, reactive sputtering, chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition (PECVD), and atomic layer deposition method [11–14].

2. Experimental procedure

Thin films of SiC-SiO_2 composite were elaborated by RF magnetron sputtering technique by using one target of SiO_2 and two strands of polycrystalline 6H-SiC. The SiC-SiO_2 films were deposited on *p*-type Si(100) for structural measurements and glass substrates for optical measurements. All substrates were cleaned with ethanol and 10% hydrofluoric acid before deposition. The deposition pressure in sputtering chamber was 8.5×10^{-3} mbar. A mixture of hydrogen (H_2) and argon (Ar) gases with flow rates of 10 sccm, respectively, and a plasma power of 150 W were used. The thin layers obtained were subjected to annealing at several temperatures namely 450, 700, and 900 °C for the duration of 1 h. The structure of thin films deposited was analyzed by an X'pertPlusPANalytical X-ray powder diffractometer (XRD) using Cu K_α radiation with a tube current of 50 mA and a voltage of 40 kV. Surface morphology observation was carried out using a JEOL JSM-7610FPlus scanning electron microscope (SEM) and the total hemispherical reflectance R was measured in the wavelength range 300–1200 nm using a Varian Cary 500 UV-VIS-NIR spectrophotometer equipped with an integrating sphere.

3. Results and discussion

3.1. SEM analysis

Figures 1 and 2 depict a SEM plan view and cross-section of the thin film SiC-SiO_2 deposited on silicon substrate for 30 min deposition time where it shows that thin layers were well-deposited and we have a uniform deposit. Cross-sections show layer thicknesses that vary between 70 and 75 nm where the thinnest layer is attributed to the highest annealing temperature. This allows us to

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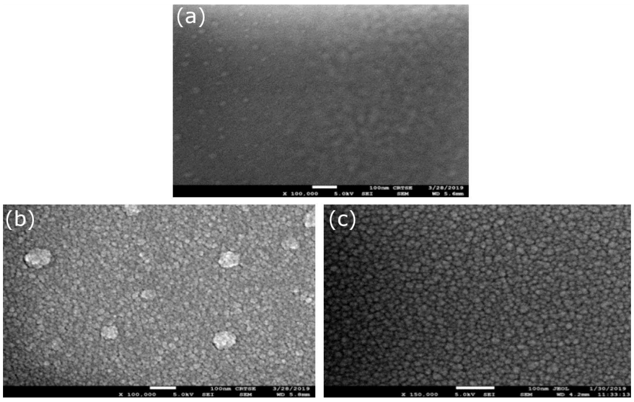

Fig. 1. Surface view SEM images of the SiC-SiO_2 composite thin films at annealing temperatures of (a) 450 °C, (b) 700 °C and (c) 900 °C.

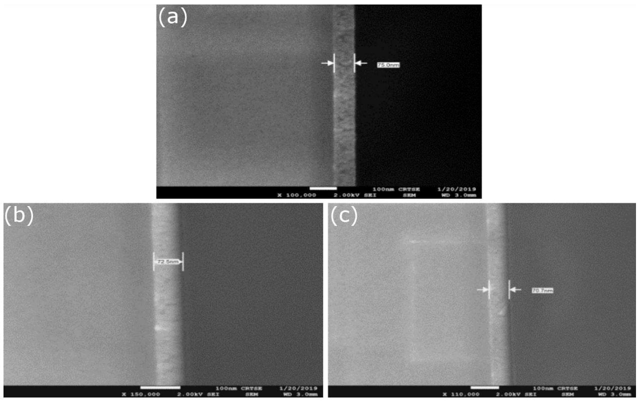

Fig. 2. Cross-sectional SEM images of the SiC-SiO_2 composite thin films at annealing temperatures of (a) 450 °C, (b) 700 °C and (c) 900 °C.

conclude that the annealing temperature does not affect the uniformity of the layers but it has an effect on the thickness. So, the higher the temperature the more the thickness decreases.

3.2. Optical characterization

Figure 3 shows that the reflectance of Si flat is 34% whereas the reflectance of Si deposited by the SiC-SiO_2 thin layer without annealing is 23% which indicates that the deposition of the thin layer has a positive influence on the reflectance and thus on the optical properties.

Figure 4 shows the reflectance spectra of the SiC-SiO_2 composite AR-coated Si wafer at annealing temperatures of 450 °C, 700 °C, and 900 °C. The SiC-SiO_2 composite AR coating at 900 °C has the lowest reflectance of 11.26% at 618 nm. In comparison, the SiC-SiO_2 composite AR coating shows high average reflectance rates of 21.63% and 13.06% at 450 °C and 700 °C, respectively, in the wavelength range of 400–1000 nm. Thus, the low reflectance at the annealing temperature of 900 °C is believed to maximize the incident photons and increase the photogenerated current.

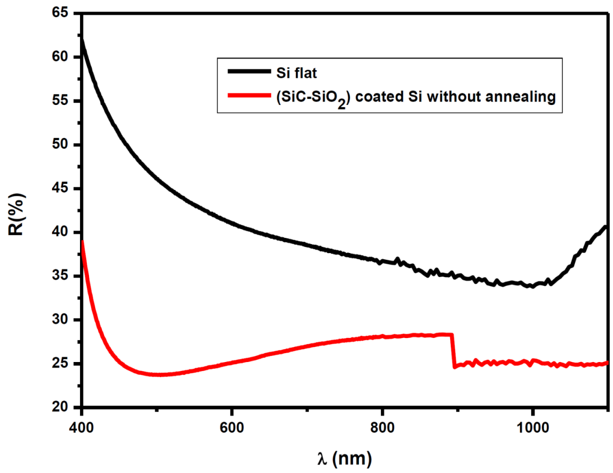

Fig. 3. Reflectance spectra of Si flat and Si-coated (SiC-SiO_2) composite thin films without annealing.

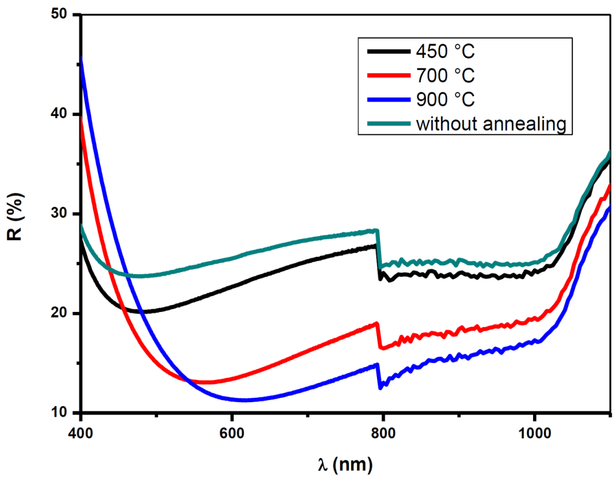

Fig. 4. Reflectance spectra of Si coated with SiC-SiO_2 composite thin films at different annealing temperature.

4. Conclusion

The thin films of a SiC-SiO_2 nanocomposite have been deposited on silicon substrates by RF magnetron sputtering as a function of the annealing temperature. The optical properties of the SiC-SiO_2 composite thin films were successfully modified by simple annealing at 450 °C, 700 °C, and 900 °C for 1 h. The average reflectances of the SiC-SiO_2 composite AR layer at 450 °C, 700 °C, and 900 °C were determined as 21.63%, 13.06%, and 11.26%, respectively, in the wavelength range of 400–1000 nm . This clearly indicated a significant decrease in reflectance with increase in the annealing temperature.

Acknowledgments

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References

[1] M.Öztürk, N. Özek, I. Akkurt, M. Uzunkavak, in: *Proc. 2nd Int. Symp. on Sustainable Development*arajevo 2010.

[2] N.C. Bezir, I. Akkurt, N. Özek, *Energy Sources A*, 995 (2010.

[3] Y. Miyake, *Int. J. Solar Energy*, 47 (2007).

[4] C.A. Wolden, J. Kurtin, J.B. Baxter, I. Repins, S.E. Shaheen, J.T. Torvik, A.A. Rockett, V.M. Fthenakis, E.S. Aydil, *J. Vac. Sci. Technol.* **29**, 030801 (2011).

[5] S. Kaci, R. Rahmoune, A. Keffous, Y. Boudiaf, A. Manseri, H. Cheraga, H. Menari, R. Chalal, *J. Nanoelectron. Optoelectron.* **14**, 1002 (2019).

[6] Ü. Kara, H.O. Tekin, A. Calik, İ. Akkurt, *Acta Phys. Pol. A* **128**, B-335 (2015).

[7] W. Haeringen, P. Bobbert, W. Backes, *Phys. Status Solidi B* **202**, 63 (1997).

[8] H. Li, Y. Lei, Y. Huang, Y. Fang, Y. Xu, L. Zhu, X . Li, *J. Nat. Gas Chem.* **145**, 413 (2011).

[9] M.A. Gondal, M.A. Ali, X.F. Chang, K. Shen, Q.Y. Xu, Z.H. Yamani, *J. Environ. Sci. Health* **47**, 1413 (2012).

[10] F. Azzouz, S. Kaci, I. Bozetine, A. Keffous, M. Trari, S. Belhousse, S. Aissiou-Bouanik, *Acta Phys. Pol. A* **132**, 479 (2017).

[11] D. Hocine, M. Belkaid, M. Pasquinelli, L. Escoubas, J. Simon, G. Riviere, A. Moussi, *Mater. Sci. Semicond. Process.* **16**, 113 (2013).

[12] Y.J. Chang, Y.T. Chen, *Opt. Express* **19**, A875 (2011).

[13] A. Jannat, Z. Yu Li, M.S. Akhter, B. Yong, *J. Electron. Mater.* **46**, 6357 (2017).

[14] J. Yoo, J. So, G. Yu, J. Yi, *Sol. Energy Mater. Sol. Cells* **95**, 7 (2011).