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Influence of Si ion implantation on structure and morphology of g-C_3N_4

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ABSTRACT

Effect of Si ion implantation on structural and morphological features of graphite-like carbon nitride (g-C_3N_4) was investigated. g-C_3N_4 was prepared by using a simple atmospheric thermal decomposition process. The g-C_3N_4 pellets were irradiated with a Si ion beam of energy 200 keV with different fluencies. Structural, morphological and elemental, and phase analysis of the implanted samples in comparison with the pristine samples was carried out by using X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM) with energy dispersive spectroscopy (EDS) and Fourier transform infrared spectroscopy (FTIR) techniques, respectively. The observations revealed that Si ion implantation results in a negligible change in the crystallite size and alteration of the network-like to the sheet-like morphology of g-C_3N_4 and Si ions in the g-C_3N_4 network.

1. Introduction

Over the last two decades, considerable research efforts have been devoted to the synthesis of carbon nitride networks owing to their physical and chemical properties and thermal stability [1–4]. In particular, 2D and 3D structures of C_xN_y composition have been proposed and, in many cases, syntheses have been reported [5–8]. "Graphitic Carbon Nitride (g-C_3N_4)" [9] also known as "Graphene Nitride" represents the family of compounds with formulae close to that of C_3N_4. The g-C_3N_4 structures are typically built on basic heptazine units. A single sheet of g-C_3N_4 is constituted by S-triazine or tri-S-triazine [10] repetitions. The tri-S-triazine is energetically stable [11]. The graphene nitrides (owing mainly to their structure and stoichiometry) have unique semiconducting properties and exhibit unusual catalytic activities in a variety of reactions including "artificial photosynthesis". "Nicanite" [12], a commercially available graphene nitride is used in diverse applications namely electronic displays, tribology, proton exchange membrane fuel cell catalyst, hydrogen production, etc. Recently, graphene nitrides are touted as excellent materials for energy solutions [13]. On the other hand, it is also known that Si incorporated carbon-based materials are effective in reducing friction coefficient of carbon coatings in the humid atmosphere [14], provide outstanding oxidation resistance at elevated temperatures [15] and are used in gas sensors [16,17]. Si doping in carbon nitride like materials can be achieved by magnetron sputtering, pyrolysis, rf plasma enhanced chemical vapour deposition (CVD), hot-filament plasma enhanced CVD [14,18], etc., techniques, which are not as controlled and as selective as doping by ion implantation technique.

In the present study, we report the synthesis of g-C_3N_4 in bulk quantities using simple sustainable chemistry and Si ion implantation of g-C_3N_4 structures. g-C_3N_4 is characterized for structure, morphology and phase information using a multitude of characterization techniques. Different characteristics of g-C_3N_4 before and after Si ion implantation are compared and discussed in this work. The observations reveal that Si ion beam irradiation results in a negligible change in the crystallite size and alteration of the network-like morphology to the sheet-like morphology of g-C_3N_4 and Si ion implantation in g-C_3N_4. This work paves a way for easy modification of materials like g-C_3N_4 using ion beam irradiation.

2. Experimental work

The g-C_3N_4 was synthesized by thermal decomposition of urea at 500 °C. The as-synthesized g-C_3N_4 powder was made into pellets (diameter ~10 mm and thickness ~2.5 mm) by applying a pressure of ~3 ton. These pellets were irradiated with 200 keV Si ion beam with a constant beam current of 2 μA, from a negative ion source (SNICS) at Inter University Accelerator Centre (IUAC), New Delhi. Ion implantation of the samples was carried out at room temperature and under high vacuum conditions (pressure <10^{-7} mbar). Implantation was performed at different fluencies viz., 5×10^{15}, 1×10^{16}, 2×10^{16} and 3×10^{16} ions/cm^2. As per "Stopping and

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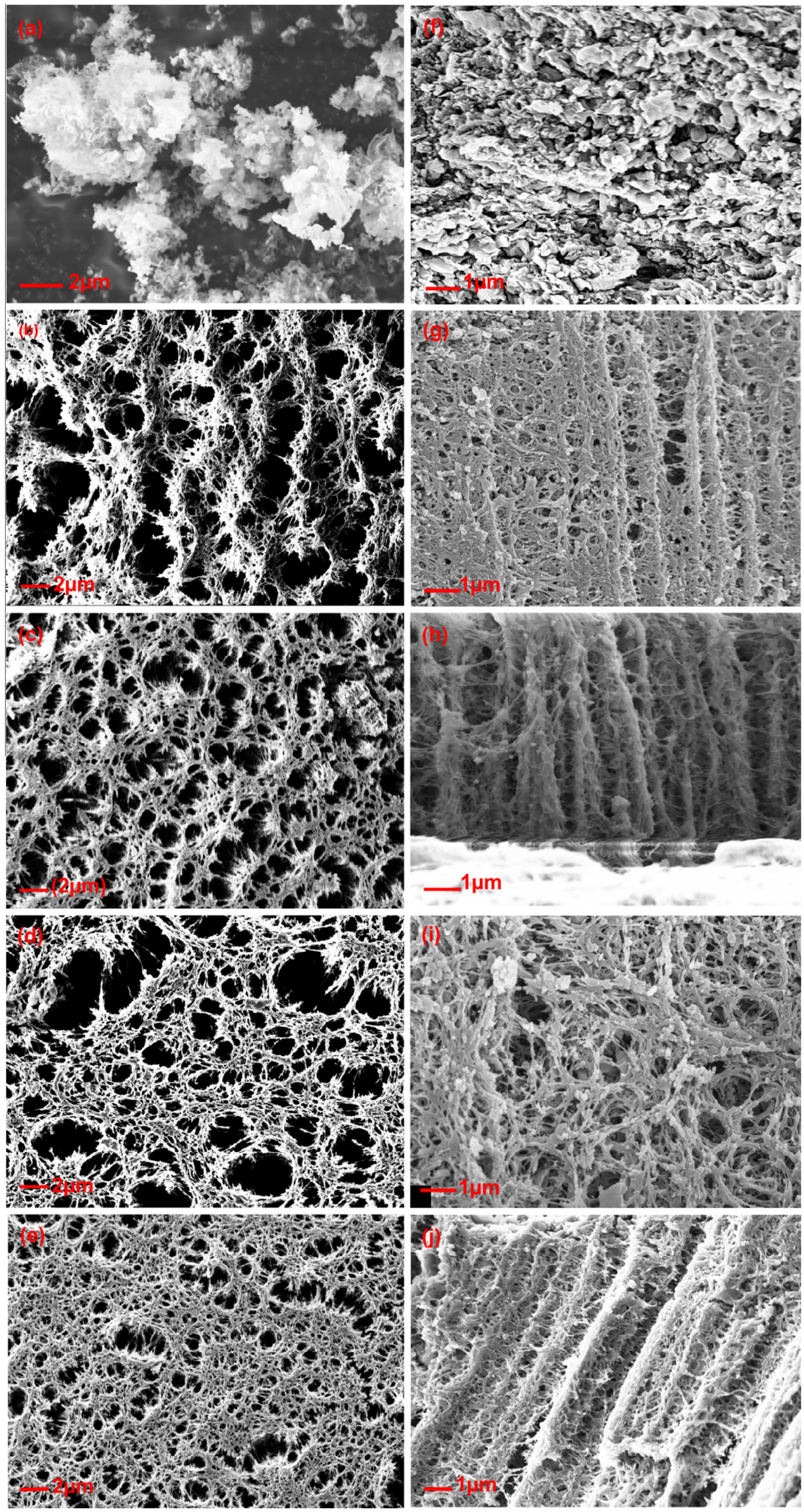

Fig. 1. FESEM plane view images of (a) pristine g-C_3N_4 and g-C_3N_4 irradiated with fluencies of (b) 5E15, (c) 1E16, (d) 2E16 and (e) 3E16 Si ions/cm^2. The corresponding cross-sectional FESEM images are (f), (g), (h), (i) and (j), respectively.

Range of Ions in Matter (SRIM)" simulation, Si ion implantation range (R_p) is ~345 nm while the stopping energies of electronic (S_e) and nuclear (S_n) are 380.3 and 166.4 keV/µm, respectively. Samples were characterized before and after irradiation by using