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NICKEL NANOPARTICLES DECORATED BIOGENIC CARBON NANO FIBERS FOR ENHANCING HYDROGEN STORAGE CAPACITY

[1]Vikaskumar Gupta, [2]Bholanath Mukherjee*, [3]Madhuri Sharon, [4]Maheshwar Sharon

[1]Project Assistant, [2]Head of Department, [3]Director, [4]Joint Research Director

[1,2]Department of Chemistry, [3,4]Walchand Center for Research in Nanotechnology and Bionanotechnology,

[1,2]K.V. Pendharkar College, Dombivli, India, [3,4]Walchand College, Solapur, India

* corresponding author: btmukherjee@gmail.com

Abstract: ***Carbon nano-fibres (CNFs), which possess properties like large surface area, unique physical, mechanical properties, inherent high-aspect-ratio, hollow nano-geometry is studied for its hydrogen adsorption capacity. For enhancing the H-storage, CNF prepared from plants as precursor is decorated with Ni nanoparticles, as it offers hydrogen spill-over effect. The hydrogen adsorption isotherms were measured by static volumetric technique using Sievert's apparatus at ambient temperature. Ni NP decorated CNF showed not only increased surface area as compared to CNF (i.e. from 504.1 to 1080.8 m^2g^{-1}) and pore volume (from 0.2973 to 0.4106 cc/g) but also nearly doubled the hydrogen Wt% adsorption capacity i.e. from 3.25 Wt% to 6.05 Wt%.***

Index Terms - **Carbon Nano Fibers, Hydrogen-adsorption, Plant derived CNF, Sievert's apparatus**

I. INTRODUCTION

In recent years, energy shortage, caused by limited energy resources and environmental calamities, drives the need to find new efficient sources of energy. Hydrogen is an ideal substitute for energy converters due to its high efficiency and essential role in reducing air pollution. The combustion of hydrogen releases useful thermal energy, which can be used as an eco-friendly fuel that does not interfere with natural cycles, and is emerging as an important material in various fields of applied science [1-4].Over the past few years, a number of different hydrogen storage technologies have been proposed *viz.* liquefied hydrogen, compressed hydrogen, metal hydrides and hydrogen physi-sorption on different substrates, including carbon nanomaterials (CNMs). The storage for liquid hydrogen present a risk of explosion at ambient temperature and is costly. Metal hydride alloys are capable of storing hydrogen but its heavy weight making heavy storage system and intrinsically low thermal conductivity makes system uneconomical. To resolve these issues hydrogen storage method using porous carbon materials has been proposed [5-9].

Carbon nano fibres (CNFs), which possess large surface area, unique physical, mechanical properties, inherent high-aspect-ratio, hollow nano-geometry [10] etc. recently attracted a lot of attention both in academic and industrial communities. Attachment or decoration of metal nano particles on CNFs enhances hydrogen storage capacity due to hydrogen spill-over effect [11-13]. Among transition metals for enhancing hydrogen storage capacity, nickel is particularly promising because it is abundant and inexpensive as compared to noble metals and known metal for hydrogen catalysis [14-15]. Edgar et. al. reported 1.2 to 2.0 wt% storage at atmospheric temperature and various pressure. [16] Geng et al. has reported 1.65 wt% of H2 uptake capacity of corncob derived activated carbon at ambient temperature and upto 180 bar. [17] Jaybhaye et al. has also reported hydrogen storage capacity of semiconducting CNF 0.65 wt% and 3 wt% at two different pressure 11 kg/cm^2 and 135 kg/cm^2. [18]. Juarez et al. has reported 6.8 wt% at 8 MPa at -196°C by alkali activated carbon synthesized from coal [19]. CNF is quite interesting material to study its hydrogen storage capacity.

In the present paper results of nickel nano particles decorated CNFs synthesized from plant fibre for hydrogen storage capacity is discussed.

2.0 EXPERIMENTAL

2.1 Synthesis of Carbon Nano-Fibers (CNF)

Cotton fiber was used as precursor for making CNF was collected from local market Mumbai, India. All the chemicals were AR grade and were used without further purification. The natural cotton was first cleaned. The synthesis of CNF was carried out by pyrolyzing cotton fibers in Lyndberg's horizontal furnace, at 650° C temperature for 4hours in presence of carrier gas Argon. The as-obtained CNF was then treated with 1N NaOH solution and was treated by two different methods viz. (1) as prepared CNF was annealed at 700°C for 2 hours in presence of CO_2 gas and named as ACNF. (2) CNFs was decorated with Nickel nano-particles during annealing at 700°C for 2 hours in presence of CO_2. It was named as Ni-CNF. Both these CNFs were used for hydrogen adsorption study.

2.2 Measurements of Hydrogen adsorption by ACNF and Ni-CNF

Carbon sample (ACNF/Ni-CNF) weighing 10 grams each were used for the study. The hydrogen adsorption isotherms were measured by static volumetric technique using Sievert's apparatus at ambient temperature. [9, 18] The apparatus was loaded with the sample of carbon and the study was carried out at 6 MPa by method described by Mukherjee et al. [14]

Table 1: Impact of Surface Area (as measured by BET) and Pore volume on Hydrogen Adsorption Capacity of ACNF and Ni-CNF as Measured using Sievert's Apparatus at ambient temperature.

Sample	BET Surface area m^2g^{-1}	Pore Volume cc/g	Adsorption Wt%
ACNF	504.1	0.2973	3.25
Ni-CNF	1080.8	0.4106	6.05

3. Result and Discussion

3.1 Morphology of Ni-CNF

The scanning electron microscopy (SEM) micrograph (Fig. 1(A)) of CNFs shows inherent design on its surface along with uniform distribution of the Ni-nps having thickness in the range of 20-30 nm addition to usual aberrations. The transmission electron microscopy (TEM) micrograph [Fig. 1 (B)] of the sample shows multi-layered carbon particle and also confirming large surface area as detected by BET.

3.2 Characterisation of Ni-CNF

The CNFs obtained by pyrolysis is analyzed by X-Ray Diffraction (XRD). XRD of CNFs shows broad peak at 2θ = 26° corresponding to (002) plane indicating partial graphitization of carbon materials and sharp peaks at 2θ = 43.9°, 56°and 78° shows presence of nickel nano-particles (Ni-nps) which is co-related with JCPDS file number 04-850. [Fig. 2].

3.3 Raman Spectroscopy Analysis of Ni-CNF

A Raman spectrum [Fig. 3] shows one peak at 1580 cm^{-1} of G band and second at 1360 cm^{-1} of D band and its Ig/Id value is more than which are the characteristic for partial graphitic material containing some disorder structure as well as presence of crystalline graphene. This suggests that the sample is a mixture of amorphous and partial graphitic carbon materials [21-22].

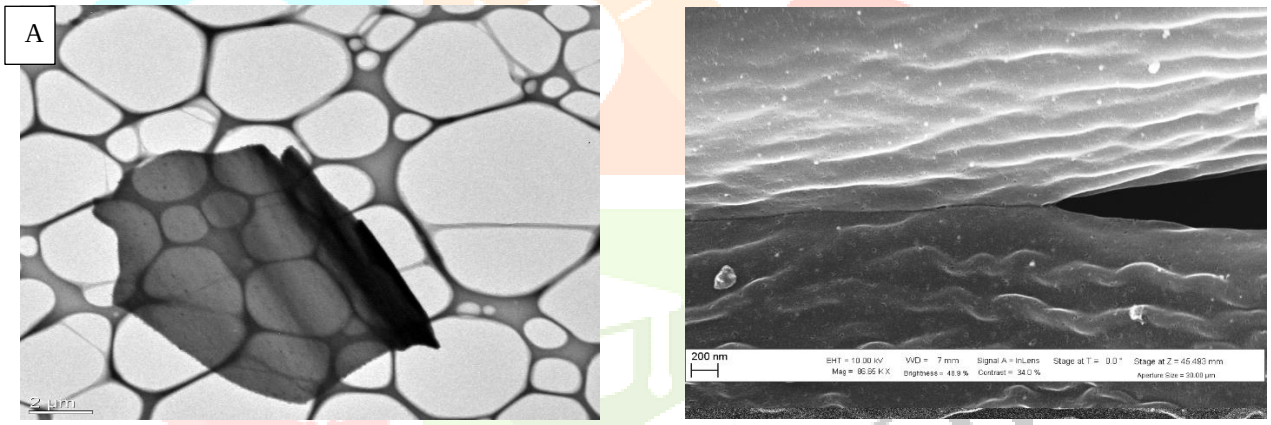

Fig. 1. Carbon nano-fibers. (A) Transmission electron microscopy (TEM) micrograph of transparent single sheet type CNFs. (B) scanning electron microscopy (SEM) micrograph of Ni-CNF [in figure give A and B]

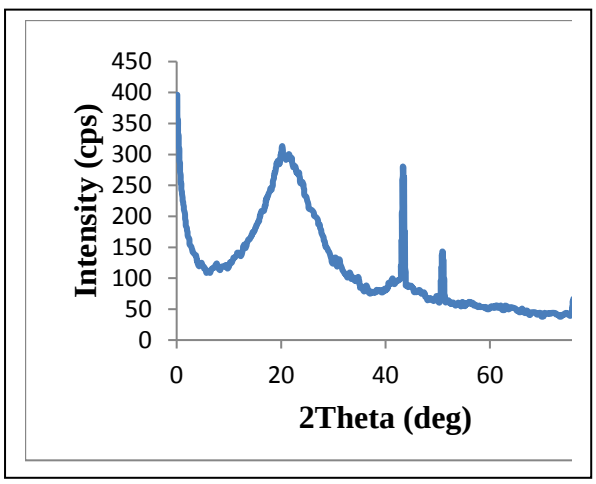

Fig.2. X-Ray Diffraction of Ni-CNFs

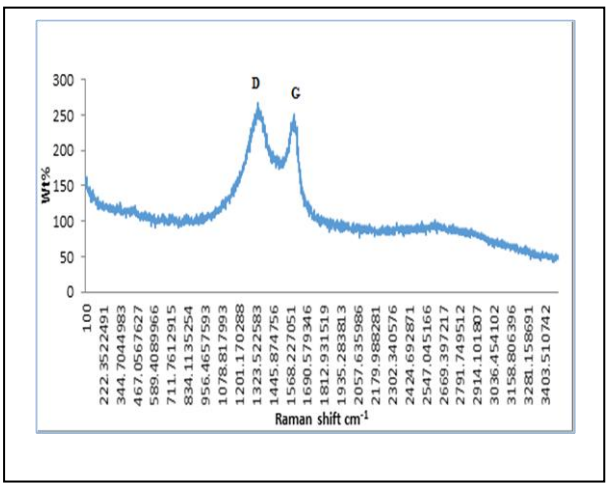

Fig.3. Raman spectra of Ni-CNFs

4. Hydrogen Adsorption Studies

There are two samples of CNF are used to check the comparative study of the hydrogen adsorption capacity. Table 1 shows the hydrogen adsorption measurement of ACNF and NCNF at ambient temperature. Hydrogen adsorption values do not reflect their dependence on specific surface area. The increase in the extent of adsorption of hydrogen by Ni-CNF subscribe to the Spill-over theory. For instance, ACNF and Ni-CNF have hydrogen adsorption capacity of 3.25 wt% and 6.05 wt% respectively measured at ambient temperature and 6.0 MPa pressure. The Brunauer-Emmett-Teller (BET) surface area of CNF and Ni-CNF are 504.1 m^2g^{-1} and 1080.8 m^2g^{-1} also the pore volume of CNF and Ni-CNF are 0.2973 cc/g and 0.4106 cc/g respectively. Mukherjee *et*. al. and Zacharia *et. al*. have reported that incorporation of metal particles into carbon causes metal nanoparticles embedded into carbon sheets. Incorporation of metal particles into carbon surface is known to increase the hydrogen adsorption by increasing the surface area and porosity of carbon materials. [9, 21] These metal particles dissociate hydrogen thus enhancing the hydrogen adsorption capacity. Thus, the present work confirms enhancement of hydrogen storing capacity of sample Ni-CNF. It is found that specific surface is much higher than reported earlier [18] Moreover, the mass of CNFs used in the present work was 10 gm which is significantly larger quantity in comparison to papers reported earlier.

Conclusion

In summary, the hydrogen storage capacity of CNFs and NCNFs synthesized from cotton fibre was determined at ambient temperature using Sievert's apparatus. The hydrogen uptake capacity for NCNF at ambient temperature was measured to be 6.05 wt%. The results show considerable extent of hydrogen uptake capacity in the scale up process using 10g of CNF.

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