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Bimetal decorated carbon nano material synthesized from waste cotton (plant based precursor) for enhanced hydrogen uptake capacity

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Abstract: Carbon nanomaterials (CNMs) known for large surface area, unique physical and mechanical properties are studied for their hydrogen adsorption capacity. For enhancing hydrogen uptake capacity, CNMs prepared from waste cotton are decorated with metal nano particles like Ni and Cu separately and in combination. Hydrogen adsorption capacity was measured by static volumetric technique using Seivert's apparatus at ambient temperature. Metal decoration on CNMs enhances capacity is observed before but this comparative study shows promising results for further exploration with increasing the hydrogen uptake capacity for bimetal decorated CNMs.

Keywords **- Waste Cotton, CNMs, Bimetal, Thermal rapid evaporation, Hydrogen adsorption.**

I. INTRODUCTION

The efficient storage of energy as well as the effective capture and conversion of unwanted greenhouse emissions are considered the major challenges towards a progressive, sustainable and environmental friendly society on a global scale (Ren et. al., 2017). Hydrogen is highly advantageous over fossil fuels. It is lightest fuel, richest in energy per unit mass (Jain, 2009). The combustion of hydrogen provides thermal energy, which can be used as eco-friendly fuel and it is emerging as the important material in various fields of Applied Science (Schlapbach et. al., 2001; Liu, 1999; Rosi, 2003; Xia et. al., 2014). Automobile industry is one of those, in this sector the 500 km driving range requires 5-10 kg of usable hydrogen depending upon the size of the vehicle. Therefore, a lot of research is invested in finding a compact, safe, reliable and inexpensive and energy efficient method of hydrogen storage (Durbin et al., 2013). For past few years, a number of different hydrogen storage technologies have been proposed viz. liquefied hydrogen, compressed hydrogen, metal hydrides and hydrogen physisorption on different substrates, including carbon nanomaterials (CNMs). Metal hydride alloys are capable of storing hydrogen but its heaviness and intrinsically low thermal conductivity makes system uneconomical. The storage for liquid hydrogen is costly and has a risk of explosion at ambient temperature. To overcome these issues hydrogen storage method using porous carbon materials has been proposed (Fukuzumi and Suenobu, 2013; Brooks et. al., 2014; Silambarasan et. al., 2013; Jung et. al., 2009; Mukherjee et. al., 2013). Currently, activated carbons are available in other physical forms such as bars, pellets, cloths or felts in order to satisfy advancing industrial technological needs, recent developments in activation procedures and/or precursors allow a better control over the pore size distribution (Sevilla and Mokaya, 2014). Our work includes synthesis of such CNMs extracted from waste cotton, its activation and study of effect of metal decoration on capacity of hydrogen adsorption. Attachment or decoration of metal nano particles on CNMs enhances hydrogen storage capacity due to hydrogen spill-over effect (Zhou et. al., 2014; Orimo et. al., 2007; Yaghi et. al., 2003).

II. EXPERIMENTAL

2.1 Synthesis of Carbon nanomaterials (CNMs)

Waste cotton was used for synthesis of CNMs. AR grade chemicals were used for process so further purification of chemicals was not done. Pyrolysis method was used to synthesize CNMs. Properly cleaned waste cotton was pyrolyzed in Lyndberg's horizontal furnace at 750°C for 3 hours with inert atmosphere created by Argon. Obtained CNMs were treated with 1N NaOH. Treated CNMS was then decorated with Nickel by using Nickel nitrate solution prepared with distilled water (DW) with thermal rapid evaporation and then annealed at 700°C in CO_2 atmosphere for 2 hours, named as (Ni-CNM) Similarly CNM was decorated with Copper (Copper nitrate solution prepared with DW) and then annealed with temperature 700°C in CO_2 atmosphere for 2 hours named as (Cu-CNM). Process is repeated for bimetal decoration on CNMs by using mixture of Copper nitrate and Nickel nitrate solutions with thermal rapid evaporation named as (Cu+Ni-CNM) for comparative study of hydrogen adsorption.

2.2 Measurements of Hydrogen Adsorption:

Hydrogen adsorption comparative study was carried out with standard sample quantity of 5 gram in weight. Adsorption capacity was measured by Seivert's apparatus by volumetric method at ambient temperature, which are tabulated in Table 2. The samples were kept in Seivert's apparatus which was leak tested for 24 hours and readings were recorded by method described by (Sharon et al., 2011).

III. RESULT AND DISCUSSION

3.1 Morphology of Metal Decorated CNMs:

The scanning electron microscope (SEM) image of CNMs without any metal decoration is shown in Fig. 1(a), Fig. 1(b) shows distribution of Ni particles on CNM, Fig. 1(c) depicts distribution of Cu particles on synthesized CNM. Whereas Fig. 1(d) shows decoration of Cu and Ni particles on CNM, which all is confirmed by EDAX.

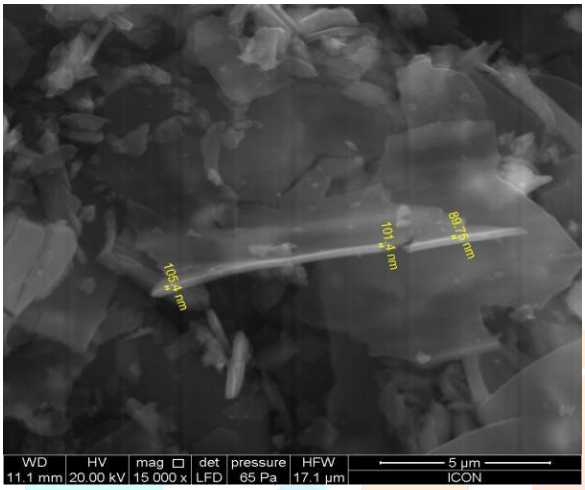

Fig. 1 (a). SEM of Carbon nano material

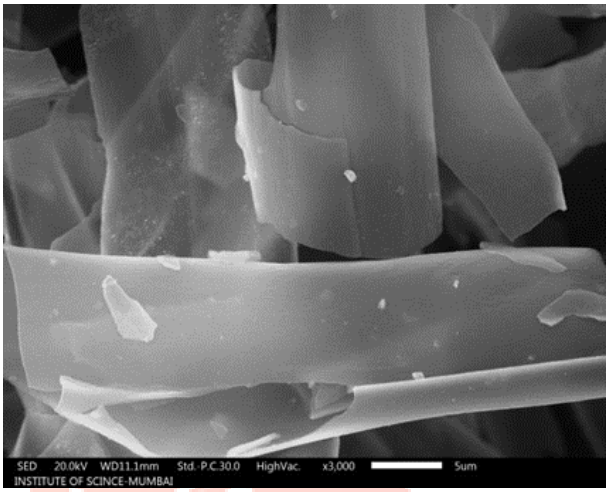

Fig. 1 (b). CNM decorated with Ni particles

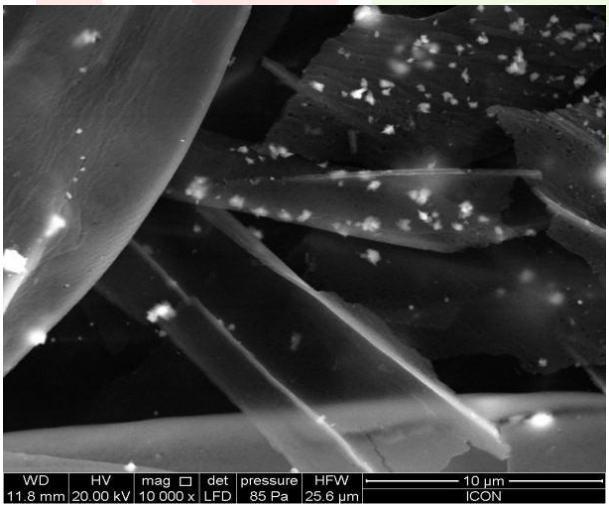

Fig. 1 (c). CNM decorated with Cu particles

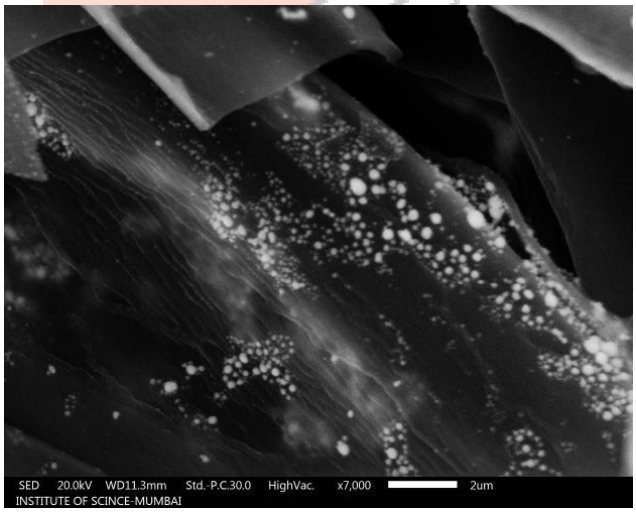

Fig. 1 (d). CNM decorated with Cu+Ni particles

3.2 Characterization of Metal Decorated CNMs:

Decoration of Cu particles is confirmed in Table I while Table II confirms decoration of Ni particles on CNMs. These two type of metal particles were used for decoration in combination also which is confirmed by Table III. Significant Increase in BET Surface area and pore volume can be seen with metal decoration on CNMs.

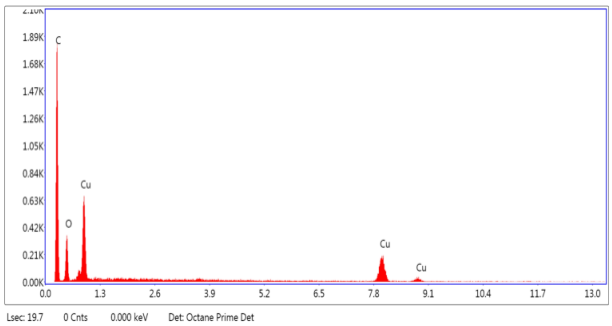

Table I. EDAX for CNM decorated with Cu particles

Element	Wt%	Atomic%
CK	60.98	76.32
OK	20.56	19.32
CuK	18.47	4.37
Totals	100	100%

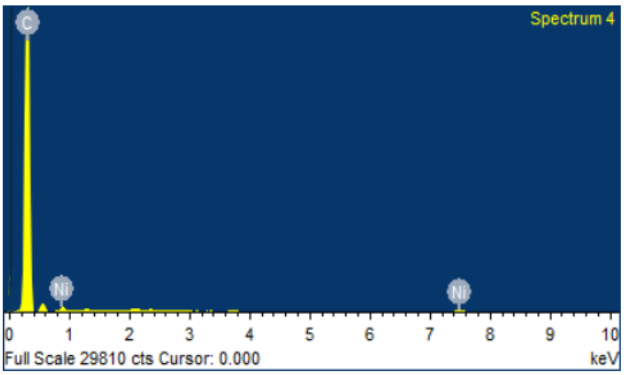

Table II. EDAX for CNM decorated with Ni particles

Element	Wt%	Atomic%
CK	97.29	99.43
NiK	2.71	0.57
Totals	100	100%

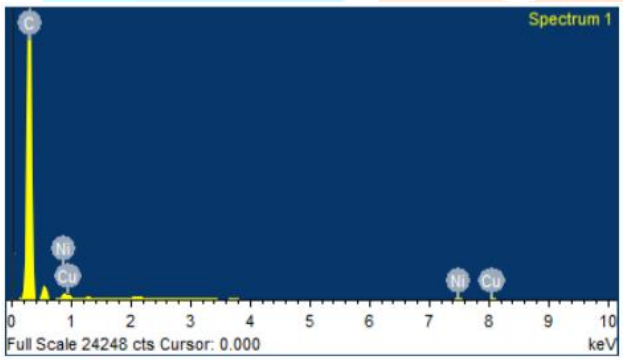

Table III. EDAX for CNM decorated with Cu+Ni particles

Element	Wt%	Atomic%
CK	95.77	99.14
NiK	2.15	0.45
CuK	2.09	0.41

3.3 Study of Hydrogen Adsorption capacity of Metal Decorated CNMs:

Hydrogen adsorption study includes comparative study of FOUR samples tabulated in Table IV which shows hydrogen adsorption measurement at ambient temperature and 6 MPa pressure, adsorption values indicate that they do not have direct correlation with surface area of corresponding sample. CNMs without decoration has BET surface area 447.29 m^2g^{-1} and 0.1902 cc/g pore volume shows 3.25 wt% hydrogen adsorption. When decorated with Cu metal particles BET surface area and pore volume rises to 836.96 m^2g^{-1} and 0.4526 cc/g respectively and shows 4.65 wt% of H_2 adsorption. Ni metal decoration shows significant rise in BET surface area and pore volume to 1024.84 m^2g^{-1} and 0.5521 cc/g respectively with 5.38 wt% of adsorption. Finally the fourth sample with combine decoration of Cu and Ni has shown promising values of hydrogen adsorption 6.5 wt% which is due to enhanced spillover effect.

Table IV.

Sample	BET Surface Area m^2g^{-1}	Pore Volume cc/g	Adsorption wt%
CNM	447.29	0.1902	3.25
Cu-CNM	836.96	0.4526	4.65
Ni-CNM	1024.84	0.5521	5.38
Cu+Ni-CNM	1229.68	0.6627	6.5

IV. CONCLUSION:

Study based on comparison of undecorated CNMs, single metal decorated CNMs and bimetal decorated CNMs shows Bi-metal decoration on CNMs presents promising increase in hydrogen uptake capacity to 6.5 wt% which is due to enhanced spillover effect, which is encouraging for further exploration.

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