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MICROWAVE ABSORPTION EFFICIENCY OF CNM DECORATED WITH COBALT NANOPARTICLES

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Abstract: Carbon Nano Materials (CNMs) have many applications because of their super catalytical, mechanical, electrical, optical, thermal and strong electromagnetic wave absorption properties. In this work, CNM were synthesized from plant fiber and decorated with cobalt nanoparticles (Co-NPs). Microwave absorption efficiencies were studied in the frequency range of 2- 8 GHz having thickness ranging from 2-5 mm. The study concludes that CNMs decorated with Co-NPs exhibit excellent microwave absorption capability. The prepared sample shows strong microwave absorption of 96-99%, whereas -20 dB Reflection loss for 2-8 GHz frequency range of 4-5mm thickness having specific surface area of 648 $m^2.g^{-1}$.

Index Terms - Microwave absorption, Cobalt nanoparticles* (Co NPs)*, BET, Vector Network Analyzer (VNA), Ferromagnetic, paramagnetic.

I.INTRODUCTION

In 1991 Iijima discovered the Carbon nanotube and subsequently various applications of the material were studied including microwave absorption. (Iijima 1991, Poncharal *et. al.* 1999, Mintmire *et. al.* 1992 and Wang *et. al.2005*) Number of studies have indicated that nanoscale carbon changes its physical, mechanical, and chemical properties which have many industrial applications, as well. Researchers working on microwave absorption have used different carbon nano forms prepared using various resources. (Sharon *et. al.* 2005 and Kshirsargar *et. al.* 2006). In an earlier publication by the authors, microwave absorption was studied by CNMs decorated with nickel nanoparticles and were found to be excellent candidates for L, S and C band frequency ranges having thickness of 2-3 mm. (Mukherjee *et. al.* 2017) In a comparative study, Sharon *et. al.* studied the microwave absorption using melamine composites with carbon nano fiber activated with the mixture of Co + Ni oxide (CNF synthesized from cotton fiber) for 2-8 GHz frequency ranges at various thickness from 3-10 mm. (Sharon *et. al.* 2017) study reported maximum 94-96% microwave absorption observed at 3-6 mm thickness. while some other researchers like Kailash R. Jagdeo obtained much lower microwave absorption using carbon nano materials synthesized by CVD method form Eucalyptus oil and Ting Zang *et. al.* studied microwave absorption of Fe_3O_4 -carbon nano fiber composites prepared by electrospinning polyacrylonitrile (PAN)/ acetyl acetone iron (AAI) / dimethyl formamide (DMF) solution and found enhancement in microwave absorption by prepared composites than individual materials. (Jagdeo *et. al.* 2013 and Ting *et. al.* 2013). Cobalt metal in nano forms has strong ferromagnetic properties while CNMs have paramagnetic in nature. In addition, the ferromagnetic property of cobalt nanoforms helps electromagnetic radiation absorption. Thus, Co-NPs supported on CNM can became excellent candidate for microwave absorption. Sui *et. al.* showed that mixtures of Carbon nanotubes (CNT) and Co-NPs exhibit higher microwave absorption than individual CNT and Co-NPs. (Sui *et. al.* 2012). Other researchers have also reported that cobalt is one of the good candidates for microwave absorption in presence of components like Fe_3O_4. (Che *et. al.* 2006). Similar findings were reported by other researchers viz. the synergic effect of Co-NPs in presence of another component can enhance the efficiency of microwave absorption than single a component. (Yi *et. al.* 2009, Dong *et. al.* 2008, Duan *et. al.* 2008 and Khan *et. al.* 2014). Very few researchers have worked in 2-8 GHz frequency band using CNMs decorated with Co-NPs, and at the same time, have reported lower microwave absorption values. Liu *et. al.*, reported upto 90% microwave absorption in the same ranges with composites of cobalt –Buckypaper whereas some authors like Li *et. al.* reported that the composites of Co-C doesn’t show microwave absorption. (Liu *et. al.* 2013 and Li *et. al.* 2013) Haicheng Wang *et. al.* found Co-NPs enhance the microwave absorption capability of porous carbon-based nanocomposite materials and results possess a maximum reflection loss (RL) value -31 dB at 11.03 GHz. (Haicheng Wang *et. al.* 2017) Tianchun Zou *et. al.* synthesis a carbon encapsulated Co-NPs using CVD method and composites with paraffin which shows a RL of -10 dB in the frequency range of 7.4 – 11.8 GHz. (Zou *et. al.* 2018) Jiushui Deng *et. al.* prepared composite of Co with CoO, composite of Co, CoO and paraffin, Co with CoO shows 90 % microwave absorption between 13.4-18 GHz frequency range. (Deng *et. al.* 2018) Jun He *et. al.* studied the microwave absorption potential of $CoFe_2O_4$ nanoparticles decorated Ti_3C_2 Mxene composite fabricated in situ solvothermal process between 2-18 GHz frequency range, it shows reflection loss < -10 dB at 8.5 GHz frequency bandwidth. (He *et. al.* 2019) Ruiwen

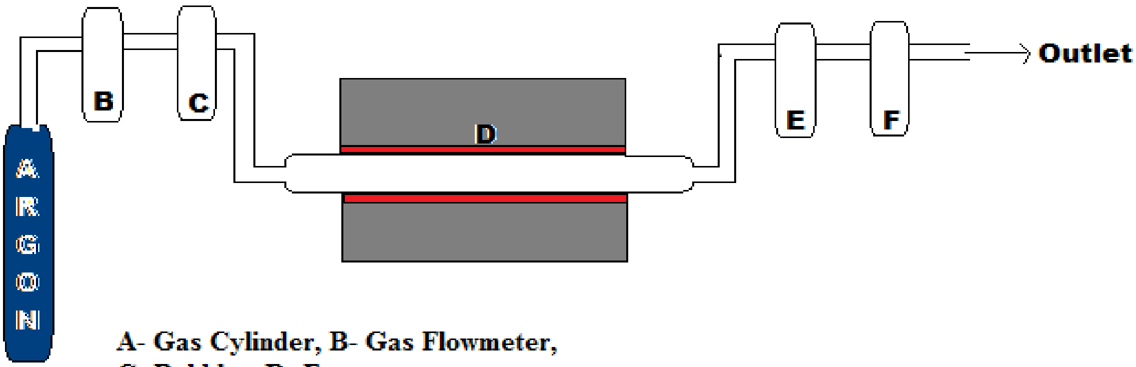
Shu *et. al.* prepared nitrogen doped cobalt oxide, Cobalt, Carbon (CoO/ Co/C) nano composites by pyrolysis of heterobimetallic zeolitic imidazolate frameworks (Co/ Zn-ZIFs) which shows 88.5% microwave absorption at 14.16 GHz frequency bandwidth between 2-18 GHz and 1.5.to 5.0 mm thickness. (Shu *et. al.* 2019) Gang Shao *et. al.* synthesized aerogel composites of porous microstructure Co/ SiCN ceramic through a reverse microemulsion method, studied its microwave absorption efficiency between 18 – 26.5 GHz frequency range. (Shao *et. al.* 2020)

In the present work, microwave absorption efficiency of CNM synthesized from plant fiber and decorated with cobalt nano particles were studied on 2-5 mm thickness, it shows excellent result on 3 mm and 4 mm thickness for 2-8 GHz frequency ranges.

II. EXPERIMENTS:

Preparation of metal decorated CNM:

A planned synthesis method was followed for preparation of CNM decorated with cobalt nanoparticles. The procedure starts from soaking cotton fibers in alkali solution, washed till neutral using chloride free distilled water and dried at room temperature. The cotton was then treated with cobalt salt solution, dried and pyrolyzed in an inert atmosphere of argon gas at 650^{0}C temperature in a Horizontal Tubular Furnace (Fig.1).



A- Gas Cylinder, B- Gas Flowmeter,
C- Bubbler, D- Furnace,
E- Trap, F- Bubbler

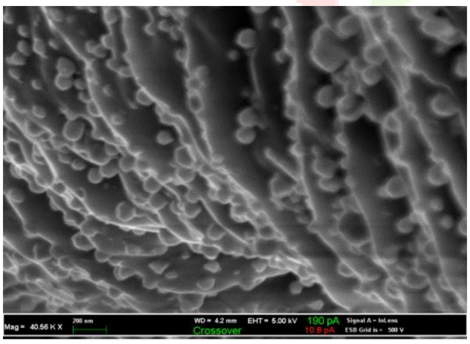
Fig.1: Schematic representation of Horizontal Tubular furnace.

III. RESULT AND DISCUSSION:

Characterization:

Morphological study of as obtained CNMs decorated with cobalt nanoparticles were characterized by scanning electron microscopy (SEM), Raman spectra, and X-Ray Diffraction (XRD). The Specific Surface Area (SSA) was studied by the BET method, microwave absorption capacity studied with the help of Vector Network Analyzer (VNA) apparatus in 2-8 GHz frequency ranges of 2-5 mm thickness.

In (Fig.2) the SEM image of the reported sample shows specific design on the carbon surface with Co-NPs of less than 50 nm distributed all over the surface of obtained CNMs. The reported CNM sample thickness is about 70 to 130 nm. The SSA of the sample was obtained by Brunauer-Emmett-Teller (BET) method and was found to be 648 $m^2.g^{-1}$.



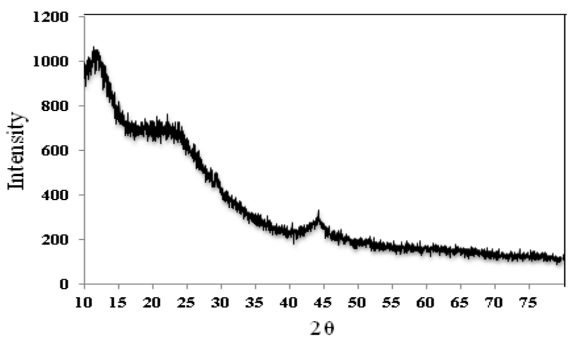


Fig.2: Scanning electron micrograph (SEM) of Cobalt decorated CNM **Fig.3:** XRD Spectrograph of CNM decorated with cobalt

In (Fig.3) XRD graph of CNM sample shows sharp peak at 2θ=11.3° is of Graphene oxide (GO) and the broad peak at 2θ =23.5° shows presence of a mixture of graphitic carbon and amorphous carbon. (www.nanoinnova.com/uploads/features/3941440.pdf). The peak at 2θ =44.5° and at 2θ= 47.3° indicates the presence of cobalt nanoparticles, whereas the sharp peak at 2θ= 26.7° is of graphite. (Salman *et. al.* 2014 and Blanton *et. al.* 2012) Therefore as obtained the sample is a mixture of amorphous and crystalline nano carbon nature.

Raman Spectra

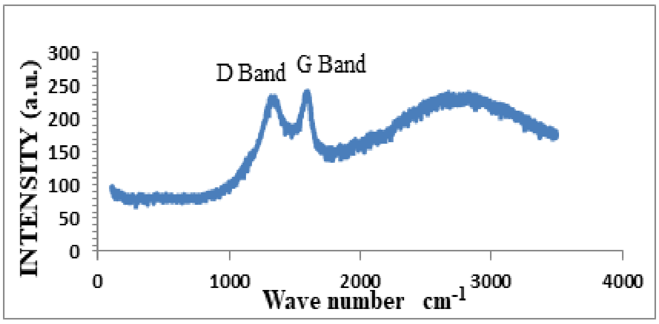


Fig.4: Raman spectrograph

In (Fig.4) Raman Spectrograph having two peaks D band and G Band in the range of 1250 cm^{-1} -1650 cm^{-1} whereas the G band having more intensity than D band therefore prepared carbon sample is of graphene oxide (Childres *et. al.* 2013) and the presence of broad peak in the range of 1750 cm^{-1}- 3500 cm^{-1} indicate the presence of amorphous carbon in the carbon sample. (Dresselhous *et. al.* 2010).

Microwave absorption study

The microwave absorption ability of the obtained sample was carried out with VNA on various thicknesses from 2-5 mm for 2-8 GHz frequency band. It is observed that 2 mm thickness microwave absorption results were not satisfactory. In (Fig.5) prepared CNMs shows maximum upto 35% microwave Absorption at 2 mm thickness on 8 GHz frequency whereas at 3 mm thickness it shows equal microwave absorption of 95-97% for 2-8 GHz frequency ranges in Fig.6 and 4 mm, 5 mm thickness shows excellent result almost 98-99% absorption for the same ranges in Fig.7 & Fig.8.

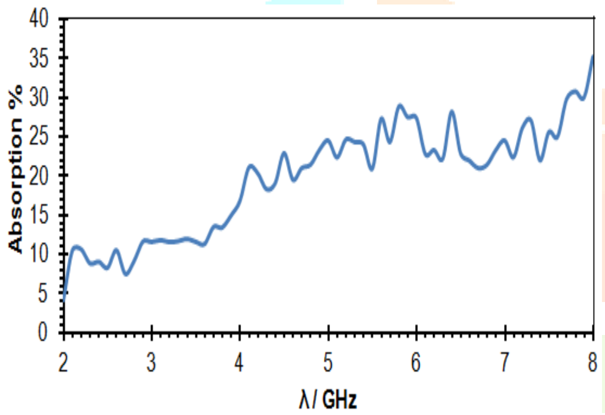


Fig.5: Microwave Absorption in % by 2mm

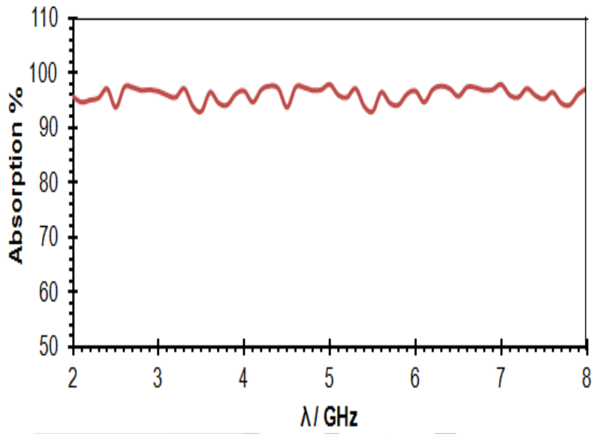


Fig.6: Microwave Absorption in % by 3mm

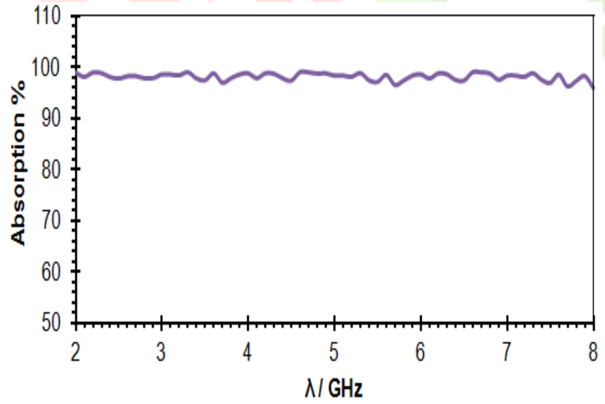


Fig.7: Microwave Absorption in % by 4mm

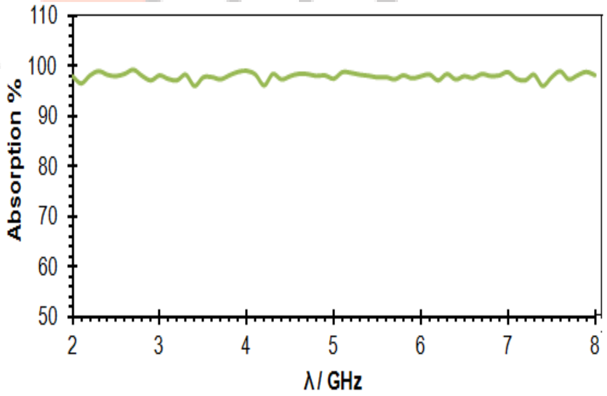


Fig.8: Microwave Absorption in % by 5mm

Reflection Loss in –dB at 2 mm thickness found less than -5 dB from 2 GHz to 8 GHz frequency range, while 3 mm thickness shows nearly -15 dB Reflection Loss from for 2-8 GHz whereas 4 mm and 5 mm shows -17 dB to -20 dB Reflection Loss from 2 GHz to 8 GHz frequency range in Fig.9.

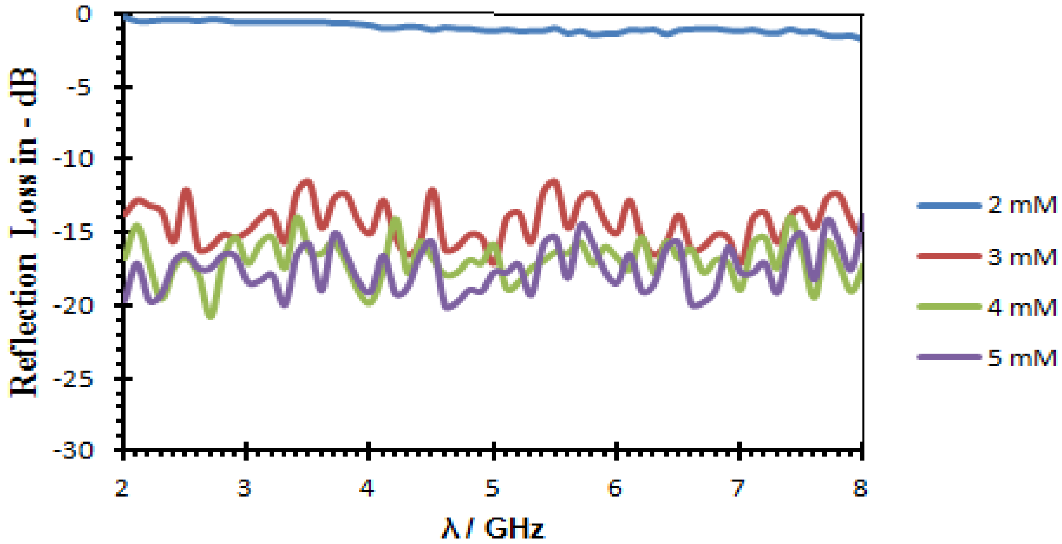


Fig.9: Reflection Loss in % (-dB)

IV. Conclusion

CNM decorated with Co-NPs is an excellent material for microwave absorption for RADAR systems in the 2-8 GHz frequency band. The paramagnetic property of CNMs and ferromagnetic property of Co-NPs exhibits a synergic effect on microwave absorption. Thus, Co-NPs electromagnetic wave absorption property acts as a catalyst to enhance the efficiency of Microwave absorption.

The presence of GO, RGO and amorphous carbon, as observed in XRD and Raman Spectrographs, has the enhanced absorption of Microwave. This confirms that the presence of defects and amorphous carbon enhances the absorption of microwaves more than pure crystalline carbon.

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