ENVIRONMENTALLY FRIENDLY SYNTHESIS OF C-$NiCu_2O_4$ via CAMELLIA SINENSIS EXTRACT: STRUCTURAL AND OPTICAL PROPERTIES

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ABSTRACT

Transition metal oxides play vital role in energy storage and environmental remediation. This study explores the synthesis and characterization of C-$NiCu_2O_4$ nanocomposites for potential applications in structural and optical properties.The material was successfully synthesised and characterized using X-ray Diffraction, UV-Visible spectroscopy.XRD confirms the crystalline structure of the C-$NiCu_2O_4$.UV-Visible spectroscopic study reveals the direct band gap energy of C-$NiCu_2O_4$ to be 1.29 eV. These findings suggest that C-$NiCu_2O_4$ nanocomposites are promising candidates for both energy storage and environmental remediation.

KEYWORDSC-$NiCu_2O_4$, X-ray Diffraction, UV- visible spectroscopy, Bandgap, Energy Storage, optical properties

INTRODUCTION

Technology and materials for electrochemical energy storage have drawn remarkable attention due to their high energy efficiency and potential for clean power generation. In the field of electrochemical energy storage systems, supercapacitors are the most attractive option due to their mechanism, which exploits conventional electrochemical capacitors and ionic batteries and bridges thesss energy gap between two. Hence, supercapacitors have been utilized in salient energy storage platforms such as electronic communications, aerospace, electric transportation.

Transition metal oxides, particularly nickel and copper oxides, are well known for their excellent electrochemical properties, environmental friendliness and low cost. The formation of $NiCu_2O_4$ spinel structure offers synergistic advantages by combining the redox behavior of both Ni and Cu ions, enhancing charge storage capabilities and catalytic efficiency. Furthermore, the doping of carbon into metal oxides has emerged as an effective strategy to improve their conductivity, surface area and stability.

The novelty of this work lies in the green synthesis of carbon doped $NiCu_2O_4$ nanocomposites using environmentally benign method, avoiding toxic solvents or high-temperature pyrolysis. This project also explores the dual functionality of the synthesized nanocomposites in both energy storage and photocatalytic applications, making it a multifunctional material with practical relevance in clean energy technologies [1].

MATERIALS AND METHODS

Synthesis of carbon from coconut coir

High quality coconut coir is purchased from the local market. The coir was rinsed thoroughly with deionized water to remove any impurities, dust and residual minerals or contaminants. The coir is then sun-dried until all moisture is evaporated, ensuring it is completely dry before proceeding. Once dried, cut the coconut coir into small pieces, and 20g of coir is weighed. Place the coir in a muffle furnace and set the furnace temperature to 600°C and allow the coir to undergo the decarboxylation process for 3 hours. During this period, the coconut coir will undergo pyrolysis, resulting in the formation of carbon. After the 3-hour heating period, remove the sample from the furnace and allow it to cool. The resulting product will be a fine, powdered form of carbon, which can be collected and used for further analysis or applications.

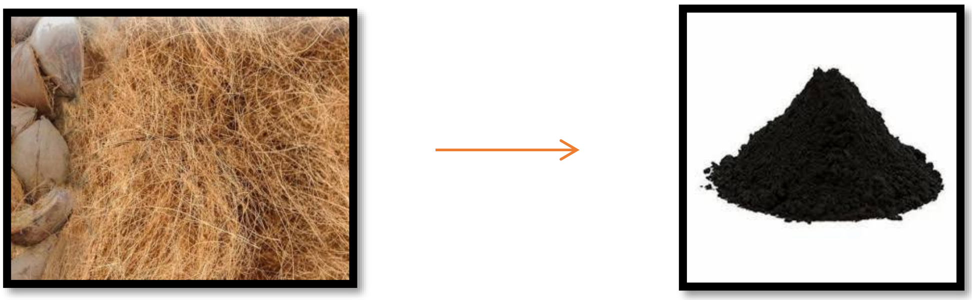

Fig 1 Synthesis of Carbon

Preparation of camellia sinensis extract

High quality tea leaves are used for the preparation.15g of tea leaves is weighed. Heat the deionized water. Seep the tea leaves for about 5 min. After seeping time is completed allow the liquid to cool, and filter it with Wattman's Filter paper no.1. Now the filtered liquid is used for further synthesis.

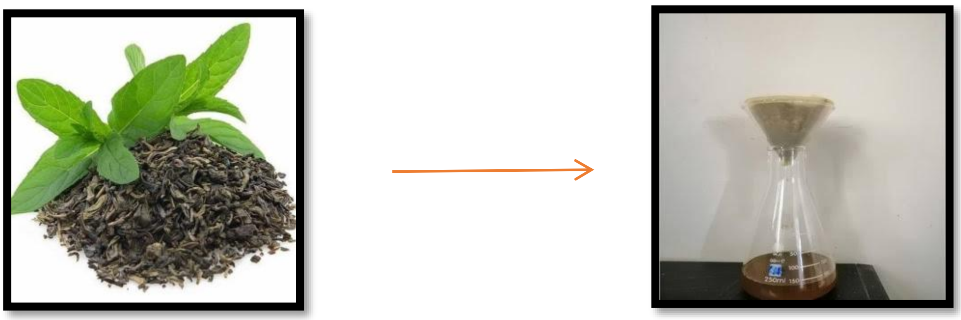

Fig 2 Extraction of Camellia sinensis extract

Synthesis of $NiCu_2O_4$ nanocomposite

The process starts by taking nickel nitrate and copper II sulphate in the ratio of 1:2, having concentration of 0.2M of Molar mass. The green extract for reduction is prepared by mixing camellia sinensis extract and deionized water in the ratio of1:1. Then 0.1g of carbon synthesized from the coconut coir is taken along with 5.8g of nickel nitrate and 9.9g of copper II sulphate which is mixed with the camellia sinensis extract. The sample is kept in the magnetic stirrer for about 3 hrs maintaining a constant temperature of 80°C to ensure the constant dispersion of particles. The sample is allowed to cool. The cooled sample is centrifuged at 1000rpm for 5 mins to collect the sedimented particles. The collected sample is then washed with ethanol and deionized water and kept in magnetic stirrer for about 30-40 mins. The sample is kept at rest overnight. The settled particles is collected and dried at 110°C for 4 hrs using hot air oven. The dried sample is powdered and calcinated at 600°C for about 4 hrs in the muffle furnace. Finally, the calcinated sample will be C-$NiCu_2O_4$ which is then used for the characterization study.

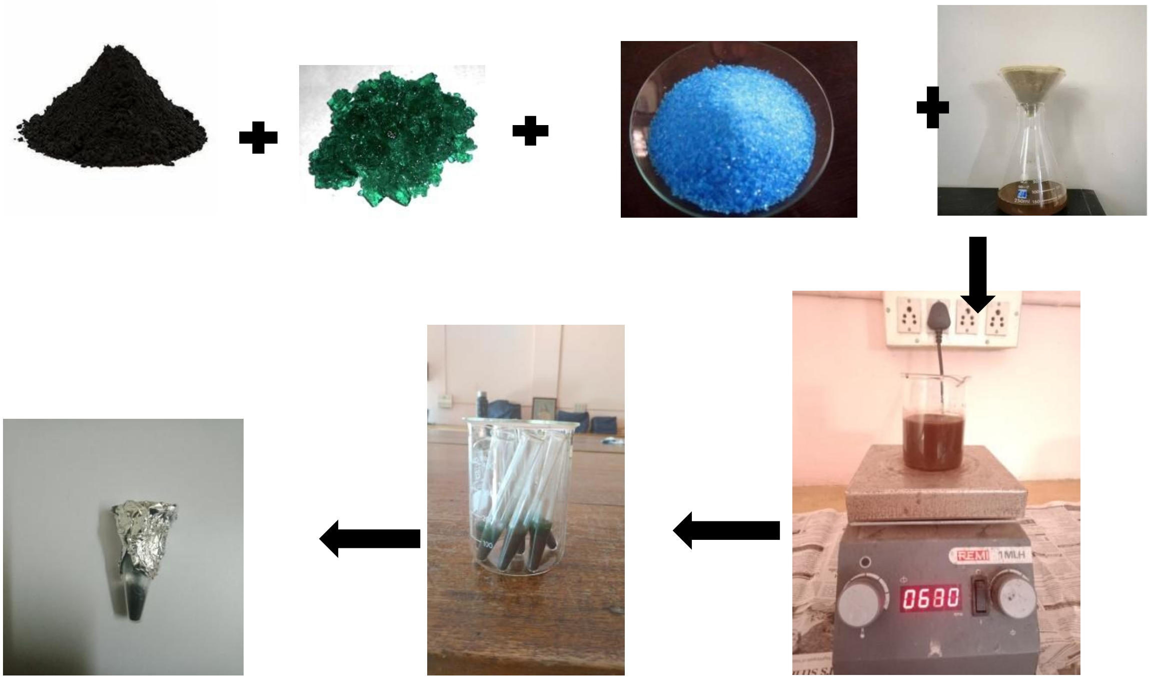

Fig 3 Synthesis of C-$NiCu_2O_4$

RESULT AND DISCUSSION

X-RAY DIFFRACTION ANALYSIS

The structural characterization of C-$NiCu_2O_4$ is performed by XRD analysis. The X-rays produced are in the wavelength of 1.5406A°. The scan type is continuous ranging from 10°-80°. The graph shows the intensity of diffracted X-rays as a function of 2θ. Peak in the pattern corresponds to constructive interference of X-rays from specific crystallographic planes.

The average particle size is found by the Debye-Scherer formula,

$$D=\frac{k\lambda}{\beta\cos\theta}$$

where, D is the particle size, β is the Full Width Half Maximum[FWHM], λ is the wavelength, k is the shape factor, θ is the Bragg's angle

The microstain is found out using the following formula

$$\varepsilon=\frac{\beta}{4\tan\theta}$$

ε is the microstain.

According to JCPDS reference card (006-0720), eight characteristics peak was absorbed for C-$NiCu_2O_4$ at 2θ=37.010, 41.345, 43.805, 61.799, 64.17, 72.545, 76.012, 78.845 corresponding to the Miller indices (111), (002), (200), (202), (220), (310), (311), (222). The estimated crystal system of C-$NiCu_2O_4$ is tetragonal. The XRD graph shows the maximum peak is obtained at 35.4232°.

Table1 Structural Parameters

Crystallite size (nm)	41.19nm
Dislocation density(lines/nm^2)	0.392148083
Micro stain(e×10^{-3})	2.231598
Lattice parameter a(A°)	4.1170
Lattice parameter b (A°)	4.1170
Lattice parameter c(A°)	4.3680
Volume of unit cell	74.04

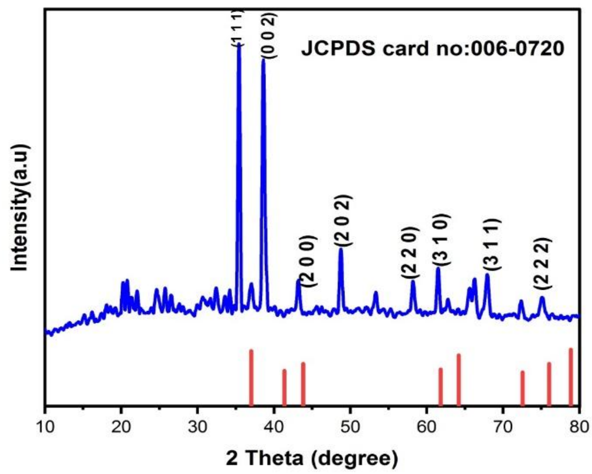

Fig 4 XRD pattern of C-$NiCu_2O_4$ Nanocomposites

UV-VISIBLE ANALYSIS

The UV- visible analysis shows several peaks and absorption bands, which indicate the sample absorb light strongly at specific wavelengths. The overall shape of the curve provides information about the electronic transitions occurring within the sample. The band gap is found by using the following formula,

$$E_g = (\alpha h\gamma)^{1/2}$$

α- Absorption coefficient, $h\gamma$- photon energy

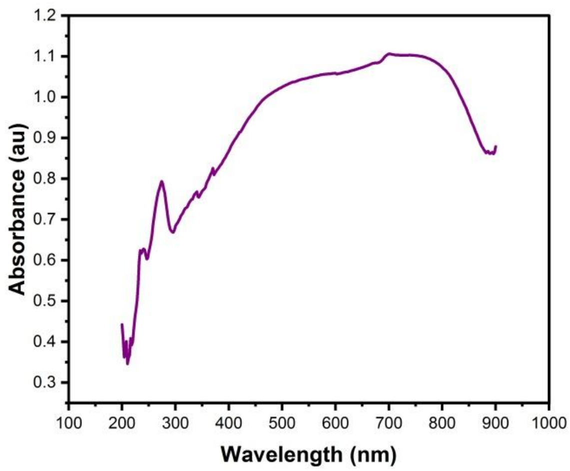

Fig 5 Absorbance spectra of C-$NiCu_2O_4$ Nanocomposites

The graph displays the absorbance of C-$NiCu_2O_4$ Nanocomposite as a function of wavelength in the UV-Visible range (100 nm to 1000 nm). There is a significant increase in absorbance in the UV region particularly below 400 nm. This indicates strong absorption of UV light by the C-$NiCu_2O_4$ nanocomposite. The strong absorption in the UV region is due to the electronic transitions within the C-$NiCu_2O_4$ nanocomposite. The carbon can introduce defects which can change the band gap and absorption properties. The strong UV absorption suggests that C-$NiCu_2O_4$ could be useful in applications where UV light absorption is desired, such as UV Shielding or as a component in photocatalytic process that utilise UV light.

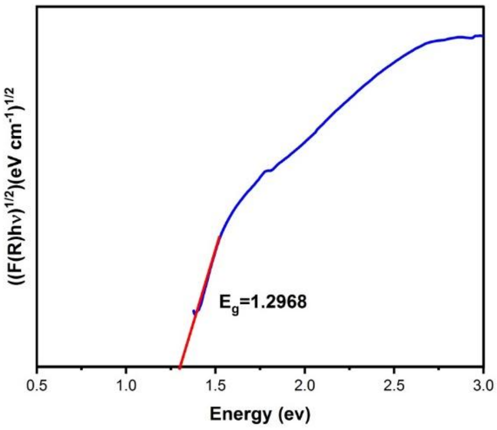

Fig6 Band gap of C-$NiCu_2O_4$ Nanocomposites

The Direct band gap of C-$NiCu_2O_4$ is found to be 1.2968 eV. This means that at least 1.2968 eV of energy is required to excite an electron from the valence band to the conduction band in the prepared C-$NiCu_2O_4$.

CONCLUSION

This study focused on the synthesis and characterization of C-$NiCu_2O_4$ as a potential electrode material for supercapacitors. The synthesis method is carried out via green and eco-friendly route which is a good alternative to the conventional methods. The carbon used in the process is derived from coconut coir by decarboxylation process. Camellia Sinensis extract is used as a reducing agent.The XRD characterization revealed the crystalline nature of the preparedC-$NiCu_2O_4$,indicating tetragonal structure. The average particle size is found out to be 41.19 nm. From the UV analysis provides direct band gap energy about 1.29 eV. The carbon doped can affect the band gap and absorption properties.

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