Synthesis and physical characterization of CuS-graphene oxide nanocomposite materials

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Abstract

Supercapacitors or electrochemical capacitors are receiving greater interest because of their high power density, long life, and low maintenance. Copper Sulfide (CuS) and CuS/GO are inexpensive, and have been shown to be promising in the development of high capacity supercapacitors [1]. We have synthesized CuS nanoparticle and CuS/GO nanocomposite for supercapacitor applications. A number of characterization techniques were then employed. The phase purity of each material was determined using XRD studies. Thermal behavior/phase transitions were observed using DSC/TGA. Band-gap was determined by UV/Vis spectroscopic studies. TEM images revealed nano-scale morphology of the synthesized particles.

Background

Electrochemical supercapacitors are useful in a variety of applications where charge has to be accepted and delivered quickly, and high power density is required. Supercapacitors can satisfy many modern energy needs, with applications from hybrid electric vehicles to portable electronic devices. Carbon-based materials like graphene oxide in supercapacitor electrodes contribute to charge-storage capability through the electric double layer effect, while oxides of transition metals contribute to charge-storage via oxidation-reduction reactions that transfer charge between electrolyte and electrode.

X-Ray Diffraction Studies

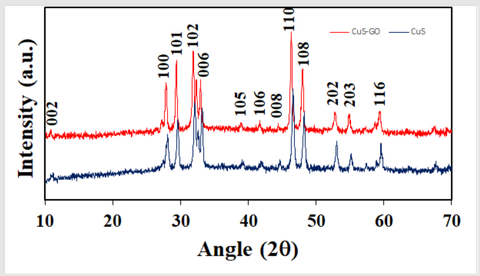


Figure a: X-ray Diffraction pattern

Scherrer's equation was used to calculated the average crystallite size of our material.

X-Ray diffraction studies were carried out using a Rigaku (Miniflex II) X-Ray diffractometer.

- Scan Rate: 10°/min.
- Cu-K_α wavelength: 1.5402 Angstroms

DSC/TGA

Two steps of thermal decomposition have been identified.
$CuS{\cdot}H_2O \rightarrow CuS + H_2O$ at 325 degrees (Not seen in CuS-GO) [2].
$1.8CuS \rightarrow Cu_{1.8}S + 0.8S$ at 400 degrees (Seen in Both samples).

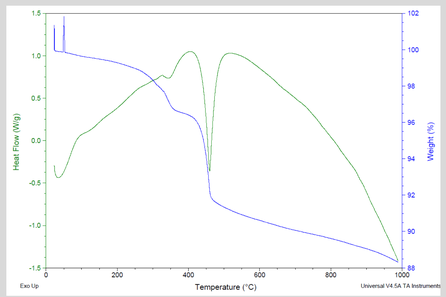


Figure f) Heat Flow (W/g) and Weight (%) of CuS

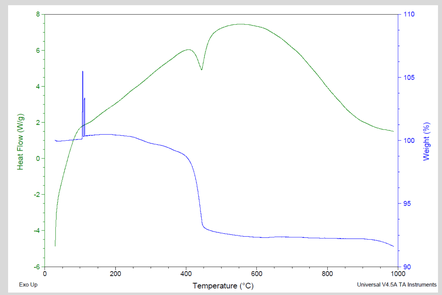
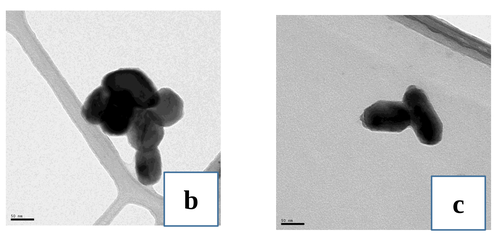


Figure g) Heat Flow (W/g) and Weight(%) of CuS-GO

Synthesis

We have synthesized CuS materials by dissolving copper acetate in a water-butanol solution followed by addition of thiouria, which was dissolved after 30 minutes of stirring. The appropriate quantity of graphene oxide (GO) was then added, and the solution was stirred for another 15 minutes. The resulting solution was placed in an autoclave at 180oC for 24 hours. The precipitated CuS and CuS/GO material was collected using a centrifuge and then dried in an oven for 24 hours.

TEM Studies



TEM image of (b) CuS nanoparticle (c) CuS-GO nanocomposite

UV-Visible Spectroscopic Studies

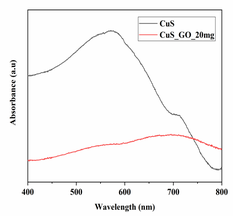


Figure d) Absorption Spectra of Cus andCuS-GO

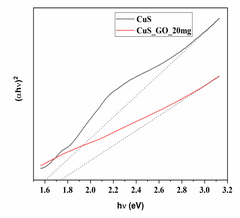


Figure e) Tauc Plot of Cus and CuS-GO

Results and Discussions:

- The average crystallite size for CuS nanoparticle and CuS-GO nanocomposite materials were found to be as 40 nm and 35 nm, respectively.
- The band gap for CuS and CuS-GO was found to be as 1.6 eV and 1.75 eV, respectively.
- From TEM studies, average particle diameter of CuS and Cus-GO was found to be as 70 nm and 63 nm, respectively.
- DSC/TGA data showed only one phase change in both materials, $1.8CuS \rightarrow Cu_{1.8}S + 0.8S$, which occurs at around 400 degrees.

References

1)Heydari, Hamid, et al. "Facile synthesis of nanoporous CuS nanospheres for high-performance supercapacitor electrodes." Journal of Energy Chemistry, vol. 26, no. 4, 2017, pp. 762–767., doi:10.1016/j.jechem.2017.03.007.

2) M. Nafees, et al. "Thermal behavior and decomposition of copper sulfide nanomaterial synthesized by aqueous sol method" Digest Journal of Nanomaterials and Biostructures, vol. 10, no. 2, April - June 2015, pp. 635 - 641.

Future Work

- To make the electrodes of the synthesized materials.
- To study the electrochemical properties such as capacitance, rate capability, and cycleability of the fabricated electrodes.

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