SUSTAINABLE SYNTHESIS OF SiO_2 – $NiMoO_4$ FROM PULVERISED FUEL ASH FOR ELECTROCHEMICAL ENERGY STORAGE

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ABSTRACT

This study presents the synthesis of a bifunctional octahedral SiO_2 – $NiMoO_4$ nanocomposite through co-precipitation method. The material was characterized using analytical techniques such as XRD, UV to examine its phase composition, optical properties and morphology. The average crystallite size of the characteristic peak was found to be 25. 94nm.The bandgap of SiO_2-$NiMoO_4$ was found to be 1.61eV Therefore, these significant values making SiO_2 – $NiMoO_4$ a promising material for supercapacitor and photocatalyst applications

KEYWORDS

Silicon dioxide (SiO_2), Nickel Molybdate ($NiMoO_4$), Pulverized Fuel Ash (PFA),

Supercapacitor, Photocatalyst.

1.INTRODUCTION

Supercapacitors represent the alternative to common electro chemical batteries, mainly to widely spread lithium-ion batteries. The most common type of supercapacitors is electrical double layer capacitor (EDLC). Other types of supercapacitors are lithium-ion hybrid supercapacitors and pseudo- supercapacitors. supercapacitors operate with electrochemical redox reactions and the energy is stored in chemical bonds of chemical materials.[1] Transition metal oxides are compounds composed of oxygen atoms bound transition metals. They are commonly utilized for their catalytic activity and semiconducting properties. Transition metal oxides are also frequently used as pigments in paints and plastics. Spinel phase materials are involved in several technical areas such as magnetic recording, batteries, catalysis, biomedicine. The spinels are any of a class minerals of general formulation AB_2X_4 which crystallize in the cubic (isometric) crystal system, with the X anions (typically chalcogens, like oxygen and sulfur) arranged in a cubic close-packed lattice and the cations A and B occupying some or all of the octahedral and tetrahedral sites in the lattice.[2] In that, Pseudo capacitors or faradaic supercapacitors are devices that are different from EDLCs. The electrodes of this capacitor include redox-active materials to store electrical energy. Supercapacitors, which can operate in harsh environments across a wide range of operating temperatures offering high-power density and high reliability, and are also ideal for use in Internet of Things (IoT), Sensor and communication designs

AIM OF THE STUDY

*To utilize the sol-gel process to synthesize SiO_2 nano matrix from pulverized fly ash and analyze it by different characterization methods.

*To synthesize SiO_2 – $NiMoO_4$ nanocomposites using co-precipitation route for supercapacitor applications.

*To investigate the structural, morphological and optical properties of SiO_2 – $NiMoO_4$ nanocomposites.

2.MATERIALS AND METHODS

2.1. Silicon dioxide (SiO_2)

Silicon dioxide, also known as silica, is an oxide of silicon with the chemical formula SiO_2, commonly found in nature as quartz. In many parts of the world, silica is the major constituent of sand. Silica is one of the most complex and abundant families of materials, existing as a compound of several minerals and as a synthetic product. Examples include fused quartz, fumed silica, opal, and aerogels. It is used in structural materials, microelectronics, and as components in the food and pharmaceutical industries. All forms are white or colorless although impure samples can be colored.[3]

2.2. Nickel Molybdate ($NiMoO_4$)

Nickel Molybdate is a green, crystalline powder, slightly soluble in water until the addition of Ammonium Hydroxide which significantly increases the solubility. Nickel (II) Molybdate is generally immediately available in most volumes. High purity, submicron and nano powder forms may be considered.[4]

2.3. Pulverized fuel ash

Pulverized ash (PA) also known as pulverized fuel ash is a fine powder obtained from the combustion of powdered coal in an electricity generating plant. Temperature may exceed 1600 degree Celsius during the burning process and may melt most of the inorganic materials present in the coal. The inorganic matter present in it gets fused during the combustion of coal. After combustion, mineral matters within the coal are excluded, liquefied, vaporized or condensed or agglomerated. PA is produced from thermal power plants in large quantities.[5]

Fig2.1 Pulverised fuel ash

2.4. Preparation of Sio_2 from Pulverized Fuel Ash

Fly ash collected from the Tuticorin Thermal Power Station was processed using the sol-gel method to synthesize SiO_2 nanoparticles. Initially, 50g of fly ash was washed with distilled water and the dried at 85°C for three hours. A mixture of 35g of pulverized ash and 80g of NaOH pellets was prepared in a 500ml beaker with 250ml of distilled water. This solution was stirred at 85°C for 2.5 hours, then cooled. The solution was centrifuged at 5000 rpm for five minutes using a REMI R-8C centrifuge. The clear Na_2SiO_3 solution obtained was treated with concentrated HCL and aged for 24 hours. The resulting gel was again centrifuged, washed with ethanol and distilled water, stirred for 30 minutes, and dried at 100°C. For two hours, calcination was carried out at 400°C in a muffle furnace

Fig: 2.2. Mixture of Pulverized Ash with NaoH Pellets

2.5. Preparation of Aloe vera solution

Fresh aloe vera leaves were collected and split into two sections. The inner gel was grinding into a fine paste, and the liquid extract was filtered using filter paper. A 10ml portion of the aloe vera extract was mixed with an equal amount of distilled water, and the solution was stirred for 30 minutes until it developed a pale-yellow color.

2.6. PREPARATION OF SiO_2 AND $NiMoO_4$ NANOCOMPOSITES

In a 250ml beaker, 0.1g of SiO_2 was mixed with 4g of sodium molybdate and 2g of nickel nitrate in a 2:1 molar ratio. The silica was dispersed in an aqueous solution, followed by the addition of 10ml of aloe vera extract. This mixture was stirred at 80°C for three hours and then centrifuged at 5000 rpm for five minutes. The precipitate obtained was washed with ethanol and distilled water, stirred for 30 minutes, and dried at 100°C for two hours. A final calcination step was inducted at 400°C in a muffle furnace for four hours.

Fig: 2.3. Mixture of Silica and Aloe vera Solution

3. Results and Discussions

3.1. Xray Diffraction

It is a rapid analytical technique primarily used for phase identification of a crystalline material. It is used to identify the crystalline structure of a nanomaterial.[6]

The average crystalline size of the material is calculated by Debye Scherrer equation,

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

Where,

D is the crystallite size (nm)

K is the shape factor

λ is the wavelength

β is the Full Width Half Maximum.

θ is the Bragg's angle

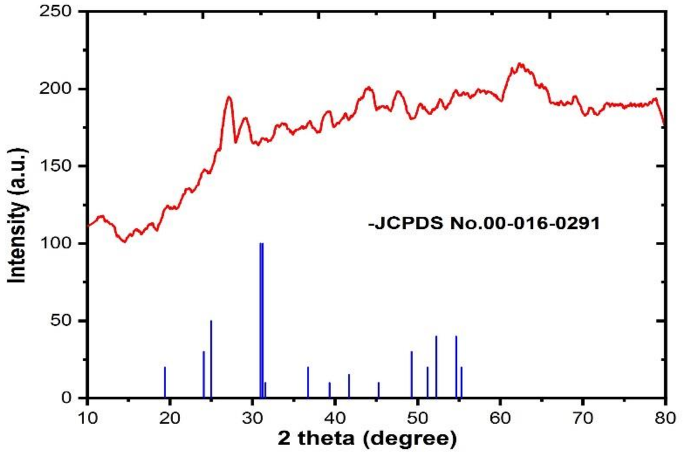

Fig: 3.1 XRD Patterns for SiO_2 – $NiMoO_4$ Nanocomposite

The structure of crystal and phase analysis of the sample were characterized by using X-ray diffraction. Powder. The average crystalline size of the particle is calculated for the largest peak and it was found to be 25.94nm. It shows that SiO_2 nanomatrix forms an amorphous nature. The calculated lattice parameters area= 4.5800, $\dot{A}$, b = 5.6700 $\dot{A}$, and c = 4.8700 $\dot{A}$, which are in good agreement with JCPDS file card No.00-016-0291

3.2. UV Visible

UV-Vis spectroscopy is a analytical technique that measures the amount of discrete wavelengths of UV or visible light that are absorbed by or transmitted through a sample.[7]

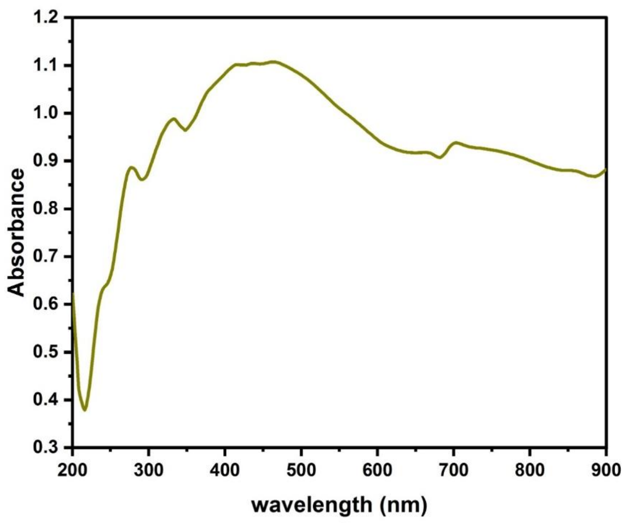

Fig.3.2. Absorbance as an ordinate and wavelength as abscissa for SiO_2-$NiMoO_4$

There is a strong absorption peak around 250-300nm followed by a relatively high absorbance across the visible range with a slow decline after 600nm.this indicates the presence of nanoparticles. The spectral shape suggests the presence of organic compounds, nanoparticles or dyes which absorb in the UV-Vis range.

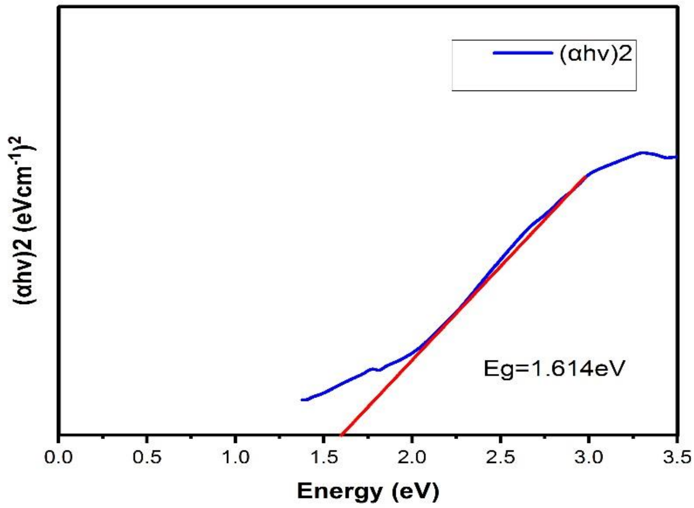

Fig 3.2.1. Bandgap of SiO_2-$NiMoO_4$

From fig.3.2.1.the bandgap energy of the prepared nanocomposite is determined as 1.61eV.

4.Conclusion

In this study, a facile, self-template, co-precipitation technique is applied for the synthesis of $NiMoO_4$ and SiO_2 nanocomposites.

- The XRD results verify that the SiO_2 nano matrix forms an amorphous nature, whereas the $NiMoO_4$ nanocomposites exhibit a cubic phase structure.
- The average crystallite size of the particle was identified for the largest peak and was found to be 25.94 nm.
- From the UV-visible analysis, the prepared nanocomposites have higher optical absorption and obtained the bandgap values of 1.61eV for SiO_2, $NiMoO_4$ and SiO_2 - $NiMoO_4$ nanocomposites.

5. References

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