

# Preparation and Structural Characterization of $Ni_3V_2O_8$ Nanoparticles for Supercapacitor Applications

N. Nallamuthu, K. Ramesh, Ramesh Chandra Mallik



**Abstract:** Energy perception and Energy consumption are major consideration in daytoday life in every place in world. Electrochemical energy storage devices are best remedies to fullfil the energy consumption and also serve as a alternate energy source of renewable energy devices. Here,  $Ni_3V_2O_8$  is developed by hydrothermal process. The crystalline phase, size and structural properties are identified using X-ray Diffraction techniques. The functional group and molecular bond formations are analysed using Fourier transform Infrared spectroscopy. The prepared  $Ni_3V_2O_8$  nanoparticles are most applied for electrode of supercapacitor applications.

**Keywords:**  $Ni_3V_2O_8$ , Hydrothermal method, supercapacitors, XRD, FTIR, SEM.

## I. INTRODUCTION

Nowadays, Supercapacitors have been more specific attention to researchers due to their lower maintenance, greater cyclic stability and high power density and it is distinguishes as environmental free green energy storage system [1-3]. Supercapacitors are broadly used in several electronic items such as digital cameras, interruptible power supply, pulse laser techniques, electric vehicles, electric consumable devices, etc. [4]. Generally, Supercapacitors have very lower energy density, compared with solid state batteries. Hence, the extensive research work has been implemented to enhancement and retain in value of energy density [5,6]. Due to charge transfer and storage phenomena, Supercapacitors are formed as two different kind of parts such as i) pseudocapacitors (in which fast surface charge transfer or faradiac transfer of charges) ii) Electric double layer capacitors (in which charges are accumulated through the way of non-faradiac functions) [7]. Due to the lower energy density formed on electric double layer capacitor, its applicability is limited as a supercapacitor device. Currently, metal oxides; particularly transition elements based metal

oxides are providing excellent performance in fast charge transfer reaction and revise faradiac process with higher energy density values. Higher energy density measurements are evaluated through the identified specific capacitance of the materials. Ruthenium oxide is one of the best transition metal oxide which provide better performance of specific capacity as  $720 \text{ Fg}^{-1}$  [8]. Moreover, it has certain sensible limitations of toxic in nature, highly expensive and lower abundance. Hence, the scientific interest of this metal oxide has reduced for supercapacitor applications. To overcome these higher obstacles, several kinds of single transition metal oxides, double (metal) oxides has been evaluated as electrode component of supercapacitor. In past years, lower cost transition metal oxides of  $NiO$ ,  $MnO_2$ ,  $V_2O_5$ ,  $Co_3O_4$ ,  $CoO$  and  $WO_3$  have been revealed to enhance the electrochemical performance with higher energy density by different scientific researchers. [9,10] Due to availability of different existing oxidation states in transition metal oxides, it response the enhance redox reaction by faradiac transfer which is granted the better quality of specific capacitance. [11] Furthermore, some variety of transition binary metal oxides of  $ABO_4$ ,  $AB_2O_4$ ,  $A_2B_2O_7$ ,  $A_3B_2O_8$ , etc. (where A and B are Transition metals with different oxidation states) are also examined to improve the specific capacitance. This representation results aggravated us to develop  $A_3B_2O_8$  based metal oxide where the enormous amount of A has best electrochemical performance and B is taken as pentavalent element. Vanadium is assigned as a pentavalent B ion in  $A_3B_2O_8$  type metal oxide and Ni is allocated as A element in this type. Superior electrochemical and catalytic performance of elements A and B are responsible to formation of superlative structural characteristics [12-18]. Wang et. al have revealed the prepared  $Ni_3V_2O_8$  for lithium batteries and reported the specific capacitance as  $500 \text{ Fg}^{-1}$ . [19] B. Prusty et. al have also investigated vanadium nickel oxide with specific capacitance of  $412 \text{ Fg}^{-1}$  [20]. Liu et al. also examined nickel vanadium oxide and cobalt vanadium oxide for supercapacitor applications [21]. Here, we have planned to develop the lower cost with high electrochemical performance electrode material of  $A_3B_2O_8$  material as  $Ni_3V_2O_8$ . Due to multitalented properties and various device applications, several methods has been investigated to development of nanoparticle including thermal oxidation, microwave, ultrasonic spray pyrolysis, pulsed laser deposition, sputtering, electro deposition, combustion, pechni process, sol-gel, surfactant templating method, etc.

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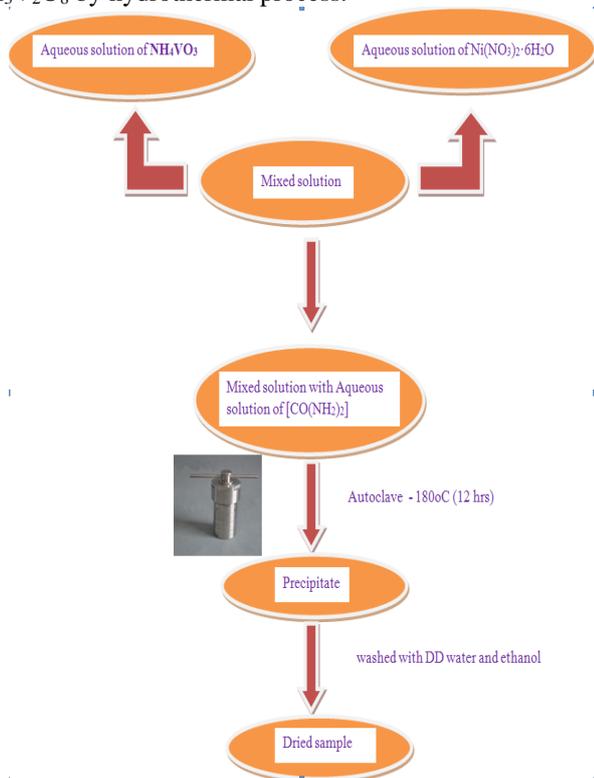
Due to some inconvenience and difficulties of the above methods, such as complicated experimental procedure, necessity of sophisticated instruments, high processing temperature, time consumption, multi-step reaction and limitation for large scale applications. Hence, developing easy and simple, lower expensive and robust approach to preparation of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> by hydrothermal process is highly desired for supercapacitor device applications.

## II. EXPERIMENTAL SECTION

### A. Preparation of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> by hydrothermal process

The starting materials purchased as analytical grade chemicals of Ni(NO<sub>3</sub>)<sub>2</sub>·6H<sub>2</sub>O (Nickel nitrate hexa hydrate) and NH<sub>4</sub>VO<sub>3</sub> (Ammonium meta vanadate) from Merck scientific chemicals, India, are used to prepare the Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> nanomaterials. Urea is used as chelating agent in hydrothermal process. All aqueous solutions of chemicals are made using double distilled (DD) water.

The aqueous solution of ammonium metavanadate and the aqueous solution of nickel nitrate hexa hydrate are mixed based on stoichiometric ratio. 2ml of HNO<sub>3</sub> is mixed to prohibit the precipitation of ammonium meta vanadate. The solutions are stirred constantly to make it as clear transparent solution. Urea is formed as aqueous solution and also mixed with the previous transparent solution. After one hour, the resultant solution is filled as 150 ml in Teflon-lined autoclave setup. It is allocated in muffle furnace for heat treatment of 180°C for 12 hours. After cooling to room temperature, the obtained precipitates are collected and washed with distilled water for three times and also with ethanol once. Thus, it is dried to 70°C for 6 hrs. The dried precipitates with heat treatment are characterised for various techniques such as XRD and FTIR. Scheme 1. represent the preparation of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> by hydrothermal process.



**Scheme.1. Preparation of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> by hydrothermal process**

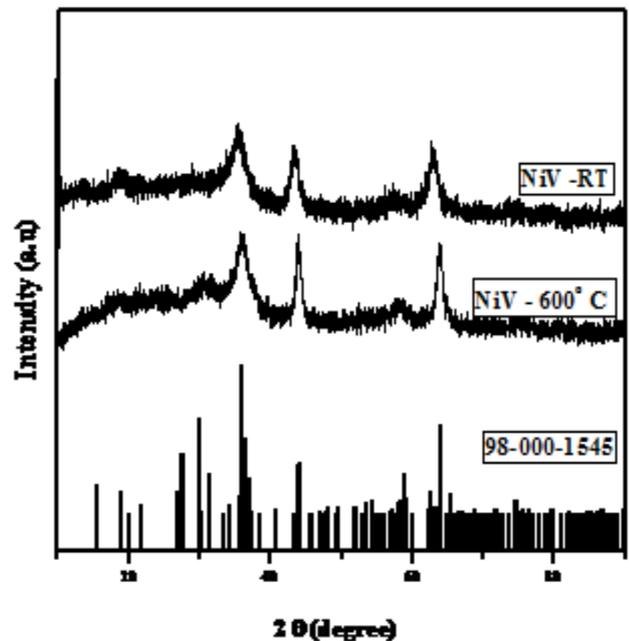
## III. RESULTS AND DISCUSSION

### A. Powder X-Ray Diffraction Analysis

Diffraction X-ray pattern is collected for synthesized ZnO nanoparticles by using D8 advance ECO XRD instrument of SSD160 1D X-ray detector with Cu-K $\alpha$  (1.5406 Å). Powder sample of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> is scanned from 10° to 80° with a scanning rate of 0.02° per sec. X – Ray diffractogram for Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> is displayed in Fig. 1. Fig.1 shows X – Ray diffractogram of the prepared sample, every part of the characteristic diffraction peaks could be matched to orthorhombic Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub>. It is verified by XRD peaks appeared in JCPDS data (Ref. NO. 98-000-1545). At 600o C, the intensity of XRD peaks increased which means increase size of the crystallites. X- ray Diffraction peaks belonging to impurities could not be found, indicating that the precursor was completely transformed into Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> metal oxides. The size of the crystallite is estimated by Scherrer's equation.

$$D = 0.9\lambda/\beta\cos\theta$$

Where,  $\beta$  is full width and Half maximum of X-ray diffracted crystalline peaks and  $\lambda$  is indicated as wavelength of X-ray [22]. The estimated average crystallite size is obtained about ~25 nm.



**Fig. 1. PXRD pattern of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub>, heat treated at various temperatures**

### B. FTIR

Shimadzu IR Trace-100 spectrometer instrument is used to record the FTIR spectra by the KBr pellet technique. The 400-4000cm<sup>-1</sup> range is recorded as shown in Fig.2

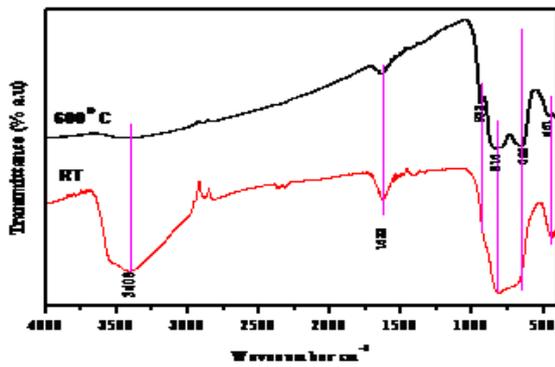


Fig. 2. FTIR spectrum of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub>, heat treated at various temperatures

The Fig.2, described FTIR spectra of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> nanocomposites at ambient temperature and heat treated for 4h at 600°C. Several IR bands are found to be observed at 3408 cm<sup>-1</sup>, 1622cm<sup>-1</sup>, 932cm<sup>-1</sup>, 816 cm<sup>-1</sup>, 655 cm<sup>-1</sup> and 461 cm<sup>-1</sup>[23]. A broad band around 3408 cm<sup>-1</sup> attributes the stretching mode of OH group which is contributed by adsorbed water molecules. Band formed at 1622 cm<sup>-1</sup> can be contributed due to OH group in the sample. IR peak at 932cm<sup>-1</sup> is obtained corresponds to V-O bond in stretching mode. The band at 816 cm<sup>-1</sup> and 655 cm<sup>-1</sup> are ascribed due to symmetric and asymmetric stretching of V-O-V formation. IR band at 461 cm<sup>-1</sup> is observed indexing the confirmation of the occurrence of crystalline Ni -O bond formation. [22]

#### IV. CONCLUSION

Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> nanoparticle has been successfully synthesized by hydrothermal process. The XRD revealed the orthorhombic phase of Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> nanomaterials and verified by JCPDS data. The average crystallite size is calculated as 25nm. No diffraction peaks belonging to impurities could be found, indicating that the precursor was completely transformed into Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub> metal oxides. The FTIR spectrum confirmed the formation pure metal oxides Ni<sub>3</sub>V<sub>2</sub>O<sub>8</sub>.

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