ISSN 2231-3478 (Print)
JUSPS-B Vol. 34(5), 41-45 (2022). Periodicity-Monthly
(Online) ISSN 2319-8052
Section B

JOURNAL OF ULTRA SCIENTIST OF PHYSICAL SCIENCES
An International Open Free Access Peer Reviewed Research Journal of Physical Sciences
website:- www.ultrascientist.org
Estd. 1989

Chemically Synthesized Alq_3 and Ni-doped Alq_3 Nanorods for Spintronics Applications

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http://dx.doi.org/10.22147/jusps-B/340501

Acceptance Date 27th June, 2022, Online Publication Date 30th June, 2022

Abstract

In this research we demonstrate the synthesis of pristine tris(8-hydroxyquinoline) aluminium (Alq_3) and nickel-doped Alq_3 nanorods as well as their characterization. The thermal vapour transport method was used to synthesize nanomaterials in the morphology of nanorods. The surface morphology was studied using scanning electron microscopy (SEM). The structural properties were analyzed using X-ray diffraction. UV-Visible and photoluminescence (PL) spectroscopy were used to examine the optical characteristics. Doping of Ni introduced ferromagnetic properties in the Alq_3 and also retained its semiconductor properties. Ni-doped Alq_3 nanorods are useful for the development of spintronics devices.

Key words : FESEM, Spin FETs, Spin LEDs, Curie temperature, Spintronics devices.

1. Introduction

For upcoming spintronic technologies like, quantum computers, spin-field effect transistors (Spin FETs), and spin-light emitting diodes (Spin LEDs), ferromagnetic semiconductors with a high Curie temperature (>300 K) are thought to be appropriate[1]. When compared to conventional devices, these gadgets have more information density, reduced power consumption, and faster processing speeds[2]. The sudden rise of organic semiconductors with magnetically aligned spins is especially intriguing since low-temperature processing and mechanical flexibility permit them to be produced under much less restrictive parameters than inorganic semiconductors. For instance, the long spin diffusion length and enormous magnetoresistance of π -conjugated organic semiconductors like 8-hydroxy-quinoline aluminium (Alq_3) may make them excellent for the transport of spin-polarized carriers[3,4]. However, the working temperature was below 300 K, and the spin injection efficiency was too low to be employed in spin devices[5,6]. In this article we report the synthesis and characterization of pristine Alq_3 and Ni-doped Alq_3 nanorods and their characterization through several techniques for their possible use in the spintronics devices for the storage of information.

2. Experimental Details

Alq_3 and Ni-doped Alq_3 powder were synthesized using the chemical method. In this study 5 grams of 8-hydroxyquinoline (8-HQ) were dissolved in 25 ml of distilled water and 25 ml of acetic acid. To eliminate insoluble impurities, the solution was filtered after being heated at 60^0C for 20 min. Also 4.30 grams of $Al(NO_3)_3.9H_2O$ were dissolved in 110 ml of di-water and heated at 60^0C for 20 min to get pristine Alq_3. After mixing the 8-HQ solution with $Al(NO_3)_3.9H_2O$ solution, a yellow precipitate was produced. To get a high yield, ammonium hydroxide solution was added to the above solution. The yellow precipitate that had been synthesized was filtered and cleaned with distilled water until the pH was neutral. The obtained material was dried at 60^0C for 4 hours. The same process was used to synthesize Ni-doped HQ metal complexes with Alq_3, adding aluminium nitrate to the nickel nitrate mixture in the correct molar ratio. Alq_3 and Ni-doped Alq_3 nanorods were synthesized by using the thermal vapour transport method. During this process, Alq_3 materials were heated in a cylinder-shaped furnace. The temperature of the furnace was increased from ambient to the growing temperature of 300^0C at a rate of 10^0C/min. To get the vapours of Alq_3, the furnace was heated at 300^0C for 30 minutes. When the temperature reached 300^0C, the furnace was filled with argon (Ar) gas, which carried the Alq_3 vapour to the quartz substrate that was set on the bottom end. These vapours produced a uniform film on the collecting substrate. The Ni-doped Alq_3 nanorods were also synthesized using the thermal transport method.

3. Results and Discussions

The FESEM micrograph of (a) pure Alq_3 and (b) Ni-doped Alq_3 films is represented in Fig 1. This micrograph shows the 1-D (dimensional) properties of as-synthesized films. The diameters of the as-fabricated nanorods range from 100 to 150 nm with a length of several microns. These nanorods are densely covered all over the films.

In Fig. 2, the crystal structures of pristine Alq_3 and Ni-doped Alq_3 nanorods were investigated by X-ray diffraction. These nanorods of pristine Alq_3 and Ni-doped Alq_3 are polycrystalline in nature, as confirmed by XRD patterns. Diffraction peaks of pristine Alq_3 nanorods are similar to JCPDS 26-1550 Alq_3 peaks[6,7]. Further, it is observed that the peak positions of Alq_3 and Ni-doped Alq_3 nanorods are different. Some of the new peaks are observed in Ni-doped Alq_3 nanorods. The peak of pristine Alq_3 at position 10.59° disappeared in Ni-doped Alq_3 nanorods XRD pattern. This confirms that Ni is

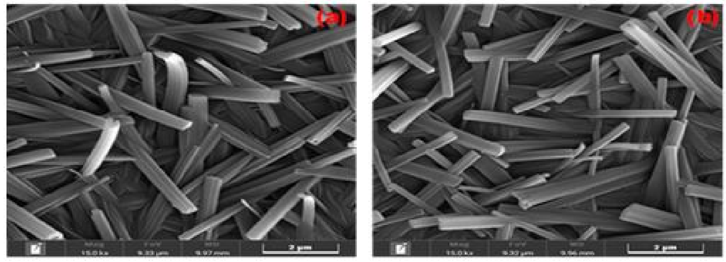

Fig. 1. Scanning Electron Micrographs of (a) pristine Alq_3 and (b) Ni-doped Alq_3 nanorods

doped in the Alq_3 matrix and altered its crystalline structures. Ni doping introduced ferromagnetic properties in Alq_3 molecules.

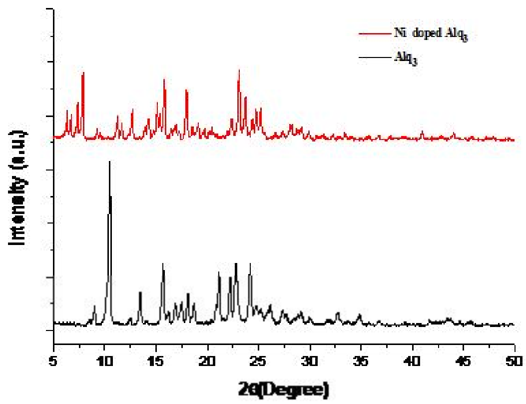

Fig. 2 XRD patterns of pristine Alq_3 and Ni (5 wt%)-doped Alq_3 nanorods

The UV-Visible spectrum of pristine Alq_3 and Ni-doped Alq_3 nanorods is represented in Fig. 3. It can be seen that the absorbance property of the Alq_3 matrix improved as the doping concentration of Ni increased. Doping of Ni ions introduces a local field enhancement around Alq_3 molecules, resulting in an overall enhancement in the absorbance of Ni-doped Alq_3 nanorods[7].

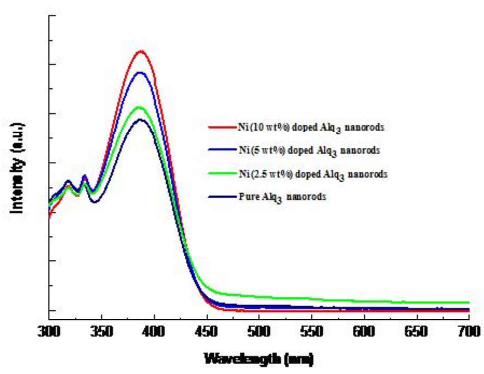

Fig. 3 The UV-Visible spectrum of pristine and Ni-doped Alq_3 nanorods

Fig. 4 shows the photoluminescence spectra of Ni-doped Alq_3 and pristine Alq_3. At around 510 nm, the PL emission peak of pure Alq_3 is seen. It is also observed that there is no change in PL peaks for Ni-doped Alq_3. Higher PL intensity is observed as the concentration of Ni-doping increases. Ni-doped Alq_3 nanorods with Ni content of 2.5 wt% of Alq_3 exhibit the highest PL emission. Further, when the concentration of Ni increases to 5 wt % of Alq_3, a PL quenching is observed. Ni ions close to the Alq_3 molecules are responsible for the increase in PL enhancement. The local field of Alq_3 molecules is strengthened by the presence of Ni ions when illuminated[8]. The reason for the increase in PL intensity of Ni-doped nanorods may be due to the enhancement of absorption and emission of Alq_3 molecules. Furthermore, an increase in absorbance is seen in fig 3. However, the rate of non-radiative decay rises with an increase in the number of Ni ions nearby Alq_3 molecules, which may be the cause of PL quenching with an increase in the Ni concentration[9, 10].

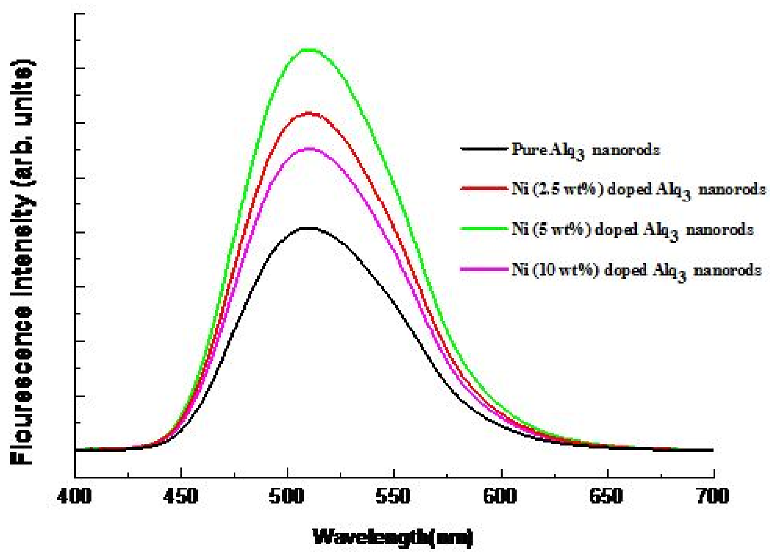

Fig. 4 Fluorescence emission spectra of pristine and Ni-doped Alq_3 nanorods

4. Conclusions

Pristine and Ni-doped Alq_3 nanorods were successfully synthesized using the Thermal Vapour Transport method. Morphology of as-synthesized pristine and Ni-doped Alq_3 nanorods has been confirmed using Scanning Electron Microscopy. The diameter of these as-synthesized nanorods ranged from 100 to 150 nm, and they were just a few microns long. Ni was found in the Alq_3 matrix, according to XRD spectra. In Ni-doped Alq_3 nanorods, an abrupt increase in PL intensity was seen, which rises with Ni concentration up to a specific limit.

Future research may be focused on the study of magnetic properties of these pristine Alq_3 and Ni-doped Alq_3 nanorods for their diluted magnetic semiconductor applications.

These findings may be definitely useful in the development of spintronics devices which are actually going to form the future electronics.

Funding: The present study received no financial aid from any governmental/non-governmental agency.

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