Fabrication of Nanoparticle Embedded Polymer Nanorod by Template Based Electrodeposition

Won-Seok Kang*, Guang-Hyun Nam*, Hyo-Sop Kim*, Kyu-Jin Kim**, Shin-Won Kang** and Jae-Ho Kim*†

* Department of Molecular Science and Technology, Ajou University, Suwon, 443-749, Republic of Korea, Fax; +82-31-601-8426, Tel; +82-31-219-2950; E-mail: kangfx@ajou.ac.kr
** Department of Electronic Engineering, Kyungpook National University, Daegu, 702-701, Republic of Korea, Fax; +82-53-950-7932, Tel; +82-53-950-6829; E-mail: swkang@knu.ac.kr

ABSTRACT

Inorganic semiconductor materials in nano-dimension have drawn intense attention in recent years because of their size-tunable optoelectronic properties arising from the quantum confinement effect. These materials often require to be incorporated into other materials, often polymers, to acquire necessary processability to the various shape and preservation of the quantum confinement effect.

One of the most frequent forms of incorporation is the polymer / semiconductor nanocomposites. This paper describes the templated based synthesis of 5 nm CdSe nanoparticles (NEP) embedded polypyrrole nanorods.

The electrochemical deposition (ECD) to the AAO membrane was used to construct the NEP-rod. In order to preserve quantum confinement effect of CdSe-NEP in the polypyrrole nanorods, distribution and total population of the particles were carefully controlled by concentration of the particle and monomeric pyrrole and electrodepostion parameters including current density and applied potentials.

The transmission electron microscope and near-field scanning fluorescence microscopic measurement showed that NEP-rod are homogeneously dispersed in the polypyrrole nanorod with diameters and length of 200 ~ 320 nm and 15 μm respectively. This structure can be applied in the applications of solar cell, light-emitting diode, and sensors.

Keywords: Nanorod, Electrodeposition, Nanoparticles, Polymer, Nanocomposites

1 INTRODUCTION

Conducting polymers and nanoparticle have attracted much attention because of their physical and chemical properties and technological applications. Embedding of nanoparticle inside conducting polymers has become one of the popular and interesting aspects of nanocomposites because they often exhibit improved chemical and physical properties, and hence can be used in a broader range of applications such as nonvolatile electronic memory,[1] independently addressable remotely triggerable switches and gates,[2] spinnable bioactive coatings,[3] and gas - sensing devices.[4]

An attractive route for preparing nanorod involves electrochemical deposition (ECD) to the AAO membrane.[5] Electrochemical deposition (ECD) synthesis is a very simple process to obtain a nanorod using various materials that have a dielectric pole. Template syntheses, one of the ECD, are widely used for the deposition of nanocylindrical materials including the polymers, metals, semiconductors. Nanomaterials prepared in such templates present an assembly of geometrically and chemically uniform objects.

Thus the studies on the nanorod of polymer composites are increasing. However, to the best of our knowledge, there are no reports on the fabrication of NEP-rod by template based electrodeposition.

In this paper, we synthesized the NEP-rod using the ECD and presented the most suitable condition.

2 EXPERIMENTAL AND RESULT

2.1 Nanorod Manufacturing

The nanorod which was used in this experiment was synthesized by anodic aluminum oxide (AAO) template using electrochemical deposition (ECD) method. AAO was used as Anodisc ^{13TM} that is sold in Whatman Company by template using electrochemical evaporation. Anodisc ^{13TM} is usually used as a filter that the pore size is about 230 nm uniformly. The radius of nanorod could not be control if AAO template was used but we can control the length of the nanorod and the nanorod is which the quality of the material fabricated, such as metal, semiconductor or macromolecule and we also can made the nanorod in several material synthesizing. Synthesis process of the NEP-rod is shown in figure 1.

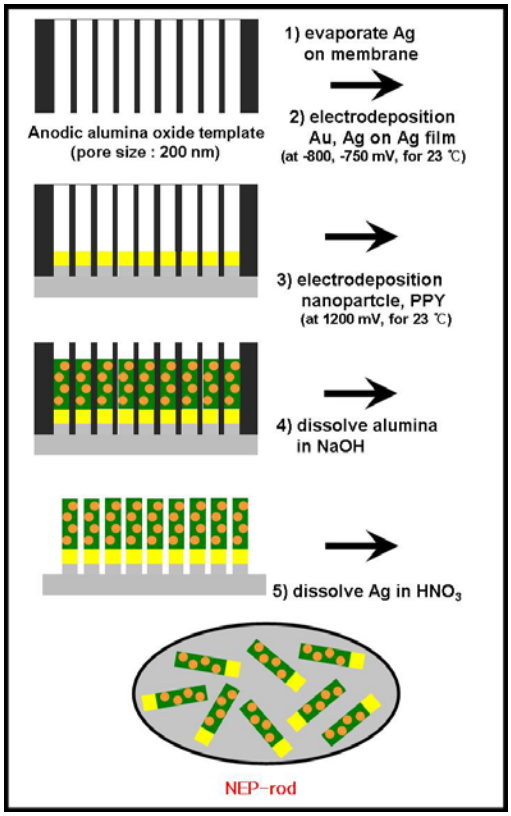


Fig. 1 The experimental schematic for synthesis of CdSe particel embedded polymer nanorod

First of all, an Ag layer (70 or 100 nm thick) was deposited on one side of the AAO template used as working electrode. Pt plate and Ag /AgCl were used as a counter electrode and reference electrode, respectively.

Then, the Ag nanorod was fabricated using Ag plating solution (Technic. Inc., Techni Silver 1025) with the voltage of -800 mV for 5 min. Au nanorod was fabricated using Au plating solution (Technic. Inc., Oretemp 24 Gold Salts) with the voltage of -750 mV for 30 min.

NEP-rod was electro-polymerized usining plating solution (0.1 m pyrrole, 1 mg CdSe nanoparticle and 0.1 m tetra-buthylammonium tetra fluoroborate and in tetra-hydrofuran) with the voltage of 1200 mV for 2 hr. After that, the template was put into 3M HNO_3 solution for 3 hours so as to melt the Ag layer.

Then it dissolve the AAO by NaOH with the concentration of 3 M about 3 hours. Following several centrifugation and rinsing steps, the nanorod fabrication was finally suspended in an aliquot of EtOH.

2.2 Characterization of CdSe particle size

The absorption spectra and photoluminescence spectrum of 32~43 A diameter CdSe nanoparticle samples are shown in Figure 2. CdSe absorptions are shifted dramatically from 485 and 580 nm bulk band gaps. [6]

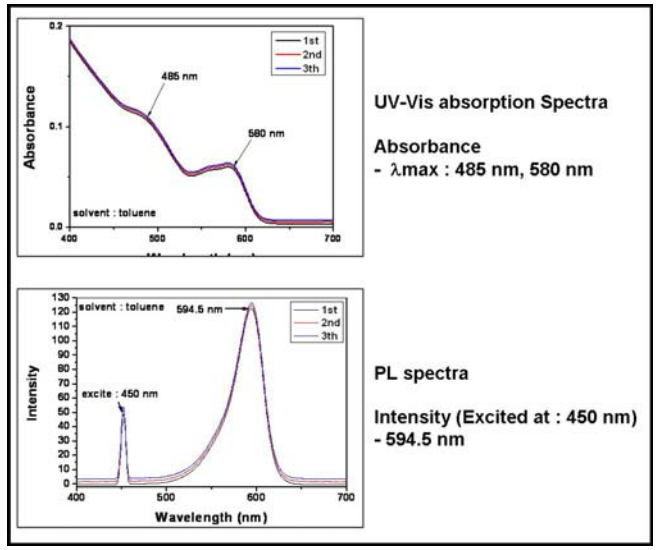


Fig. 2 The theoretical and experimental characterization of the CdSe particle size.

2.3 Analysis of the NEP-rod

The morphologies of the nanorod were analyzed using transmission electron microscopy, field emission scanning electron microscopy (FE-SEM) and optical microscope.

The TEM image of the nanorods was shown in figure 3. These images illustrate how effective the polypyrrole is at filling the CdSe nanoparticle.

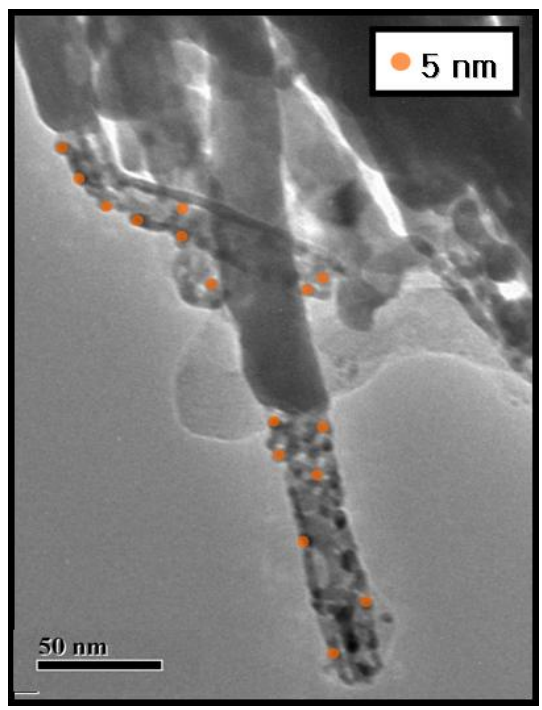
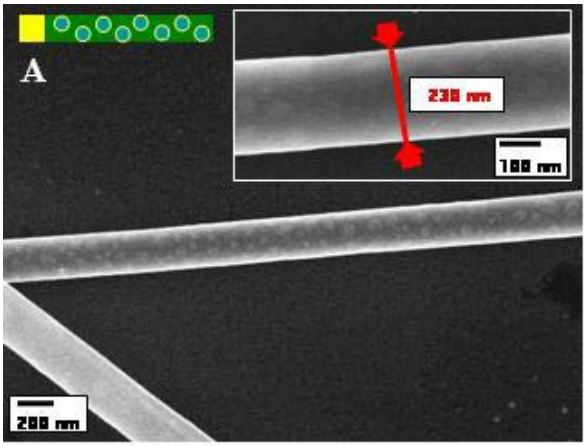


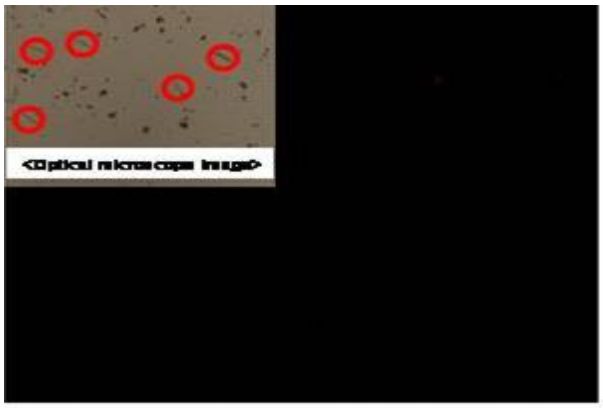
Fig. 3 Transmission electron microscope (TEM) image of NEP-rod



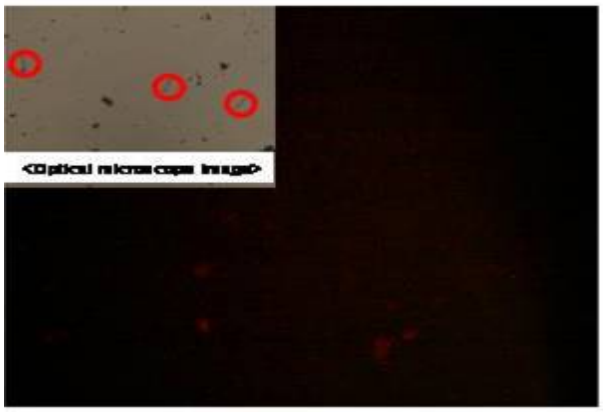
<SEM image>

Fig. 4 (A) Field emission scanning electron microscopy (FE-SEM) image of CdSe particle embedded polymer nanorods.

The manufactured nanorod was 230 nm diameters and 5 μm long. The SEM image of the nanorods was shown in figure 4.



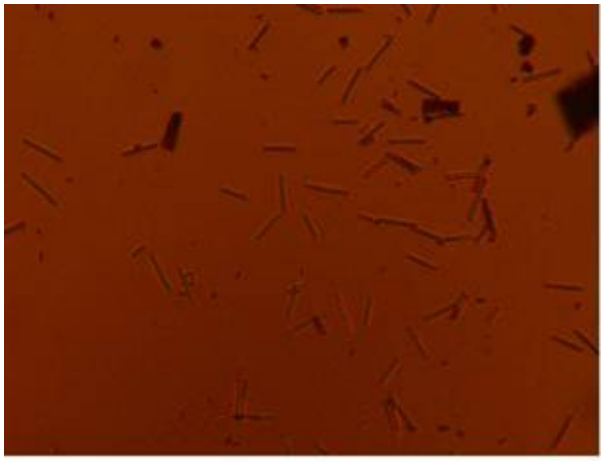
< Fluorescent microscope image>



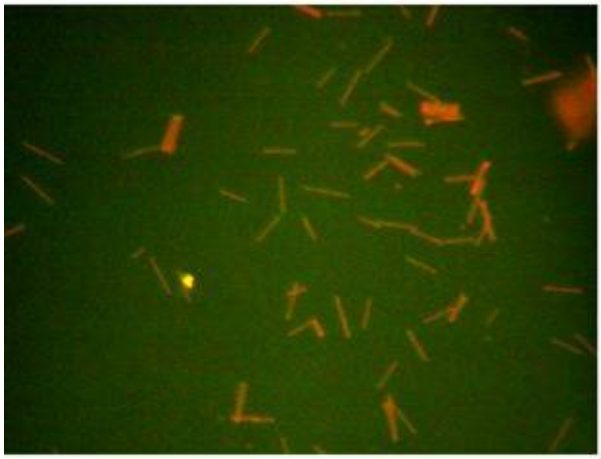
< Fluorescent microscope image>

Fig. 5 Optical and Fluorescent microscope image of polymer nanorod.

The oprical and fluorescent microscope image of the nanorods was shown in figure 5. Could not confirm a fluorescence in the pure polypyrrole nanorod. Figure 5 show the Polypyrrole nanorod is observed without the CdSe nanoparticle.



<Optical microscope image>



< Fluorescent microscope image>

Fig. 6 Optical and Fluorescent microscope image of CdSe particle embedded polymer nanorods.

Figure 6 show the Polypyrrole nanorod is observed the CdSe nanoparticle. Confirmed the fluorescence of the NEP-rod. In contrast,

3 CONCLUSION

In conclusion, we have described a powerful method for producing nanoparticle/polymer composite nanorod. The concept is versatile and could be extended to diverse composite nanorod with a variety of properties, based on different polymers and nanoparticle. The electropolymerization routes permit the incorporation of additional material within the nanoparticle/polymer composite.

In summary, CdSe/polypyrrole composite nanorod with

embedded structure have been prepared through a electro-polymerization process., and the optical properties.

The transmission electron microscope and near-field scanning fluorescence microscopic measurement showed that NEP-rod are homogeneously dispersed in the polypyrrole nanorod with diameters and length of 230 ~ 250 nm and 5 μm respectively. This structure can be applied in the applications of solar cell, light-emitting diode, and sensors.

4 ACKNOWLEDGNENTS

This research was supported by the Ministry of Commerce, Industry and Energy of the Korean Government and BK21 Program of the Ministry of Education and Human Resources Development for the Molecular Science and Technology in Ajou University, Republic of Korea.

REFERENCES

[1] J. Ouyang, C. Chu, D. Sieves, and Y. Yang, Appl. Phys. Lett. 86, 123507, 2005.
[2] S. R. Sershen, S. L. Westcott, N. J. Halas, and J. L. West, Appl. Phys. Lett. 80, 4609, 2002.
[3] N. Cioffi, L. Torsi, N. Ditaranto, L. Sabbatini, P. G. Zambonin, L. Ghibelli, M. D' 'Alessio, T. Bleve-Zacheo, and E. Traversa, Appl. Phys. Lett. 85, 2417, 2004.
[4] N. Cioffi, I. Farella, L. Torsi, A. Valentini, and A. Tafuri, Sens. Actuators B 84, 49, 2002.
[5] C. R. Martin, Acc. Chem. Res. 28, 61, 1995
[6] C. B. Murray, D. J. Norris, M. G. Bawendi, J. Am. Chem. Soc, 115, 8706, 1993