



Electrical Conductivity of Cadmium Oxide Nanoparticles Embedded Polyaniline Nanocomposites

Subhash Kondawar*, Ritu Mahore, Ajay Dahegaonkar, Shikha Agrawal

Department of Physics, RTM Nagpur University, Nagpur, India

ABSTRACT

Cadmium Oxide (CdO) nanoparticles have been synthesized by simple approach of sol-gel method at room temperature using cadmium acetate (precursor) and starch as stabilizing agent. The precipitate of cadmium hydroxide after hydrolysis by using ammonia was heated overnight and then sintered upto 600°C in steps so as to get the reddish brown colour of CdO nanoparticles. Nanocomposites of polyaniline with CdO nanoparticles have been synthesized by in-situ chemical oxidation polymerization method using ammonium persulphate (APS) as oxidant and HCl as dopant. The synthesized nanocomposites were subjected for spectroscopic and structural characterization using FTIR, UV-VIS and SEM, XRD respectively. The structure of CdO was found to be cubic with lattice parameter 4.689 Å which was confirmed from XRD. The average crystallite size was found to be 56 nm which was supported by SEM images. Structural changes have been observed with different weight % of CdO in composite in UV and IR spectra. Nanocomposites show high electrical conductivity compared to pure PANI. The conductivity of nanocomposites increases with increasing of CdO content because of the new conductivity passageways formed by embedded nanoparticles of CdO.

Keywords: polyaniline; conducting polymers; nanocomposites; CdO nanoparticles; electrical conductivity.

INTRODUCTION

Conducting polymers have been the subject of continuous research and development due to their potential applications in many technological areas. Conducting polymers offered the promise of achieving a new generation of polymers; materials which exhibit the electrical and optical properties of metals or semiconductors and which retain the attractive mechanical properties and processing advantages of polymer leading to wide range of technological applications [1-4]. Amongst the family of conducting polymers, polyaniline (PANI) is unique due to its ease of

synthesis, environmental stability, and simple doping/dedoping chemistry. Because of its rich chemistry, polyaniline has been one of the most studied conducting polymers of the past 20 years. Polyaniline (PANI) is a promising material because of its intrinsic electrical conductivity by doping with organic dopants [5]. The highly ordered structures such as crystalline or self-assembled structures of ideal conducting polymer with π -conjugated structure is expected to have metal-like electrical conductivity [6]. To induce an ordered structure, other materials acting as filler for the composite are required [7-14]. Nanostructurization of conducting polymers and their composites emerged as a new field of research and development, directed to creation of new materials for use in modern and future technologies. Recently, conducting polymer/metal oxide nanoparticle composites have been considered as a new class of materials due to their improved properties when compared with those of pure conducting polymer and metal oxide [15-17].

Cadmium oxide (CdO) is n-type semiconductor used as a transparent conductive material prepared as a transparent conducting film back. Cadmium oxide has been used in applications such as photodiodes, phototransistors, photovoltaic cells, transparent electrodes, liquid crystal displays, IR detectors, and anti reflection coat. CdO micro particles undergo band gap excitation when exposed to UV-A light and is also selective in phenol photo degradation. With this background of multifunctionality CdO, it was thought worthwhile to use the nano-sized CdO as an inorganic counter part in the composite preparation.

In present context, we are introducing a conducting polymer polyaniline in which nano scale filler of cadmium oxides are embedded in the polymer matrix. Appropriate addition of nano particulates or nanoscale fillers to the polymer matrix and good dispersion of these fillers not only enhances its performance but also introduces new physical properties and novel behaviour to the original polymer matrix. It also observed that electrical conductivity of polyaniline vary as the concentration percentage varies. In this paper we report FTIR, UV-VIS, XRD, SEM and electrical conductivity studies of polyaniline-CdO nanocomposites.

MATERIALS AND METHODS

All the chemicals used in this investigation were of analytical reagent grade and used as received except aniline which was distilled prior to use. Nanostructure CdO was synthesized by sol – gel method using respective metal precursor cadmium acetate [18]. Cadmium acetate was added slowly in 500 ml clear solution of starch and distilled water and the solution was stirred. While stirring, equimolar ammonia in aqueous solution was added drop by drop. Then stirring was carried for another two hours and the solution was kept overnight. Next day the solution was filtered and precipitate of CdO was obtained which was heated overnight at 80°C. Next day crystalline form of CdO was sintered up to 600°C. At 80°C the colour of CdO was light red and at 600°C, it was reddish brown. PANI-CdO nanocomposite was obtained by in-situ polymerization. Initially polymerization of monomer aniline was initiated by drop wise addition of ammonium peroxodisulphate in acidic medium in which specific quantity of synthesized CdO powder was added. The stirring was continued for 2 hours and then solution was kept overnight. Next day, the mixture was filtered, washed with distilled water and the methanol and then dried at 80°C for overnight. By changing the weight percentage of CdO with aniline monomer (5%.10%, 20%) a series of PANI-CdO nanocomposites was obtained [19].

The UV-Vis spectra of synthesized composites were recorded by using UV-1800 Shimadzu automatic recording double beam spectrophotometer in the range of 200-1100 nm. The FTIR spectra were taken on Shimadzu FTIR-8101A spectrophotometer between 450 cm^{-1} to 4600 cm^{-1} . X-ray diffraction patterns were recorded on Philips PW1710 automatic X-ray diffractometer. The morphology analysis was carried out using scanning electron microscope JSM-6380A. The electrical conductivity was measured by using four point probe method.

RESULTS AND DISCUSSION

The XRD patterns of pure CdO and PANI-CdO nanocomposite (20%) are shown in figure 1(a) and (b) respectively. The XRD pattern of pure CdO has been matched with standard JCPDS data (file No.11049). According to that data, structure of sample is cubic where atoms are arranged in octahedral position. The particle size of CdO was determined from the width of the XRD peak by using Scherrer's formula. The particle size of pure CdO was found to be 56 nm. While comparing the XRD pattern of PANI reported earlier [20] and PANI-CdO nanocomposite (20%), it can be concluded that CdO has been uniformly mixed in the chain of polyaniline as the peak at 26° of polyaniline became well intense and the peak at 21° of polyaniline became diminished in case of nanocomposite shown in figure 1 (b).

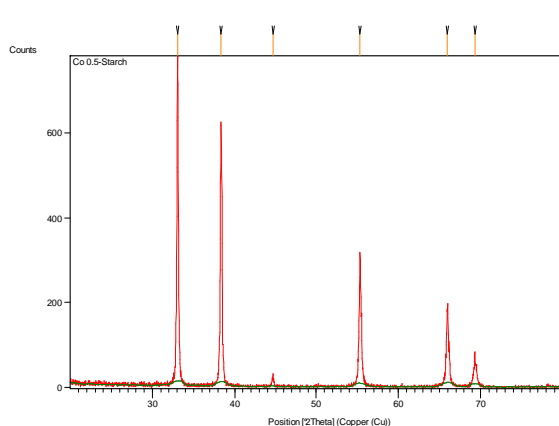


Fig 1(a): XRD pattern of CdO nanoparticles

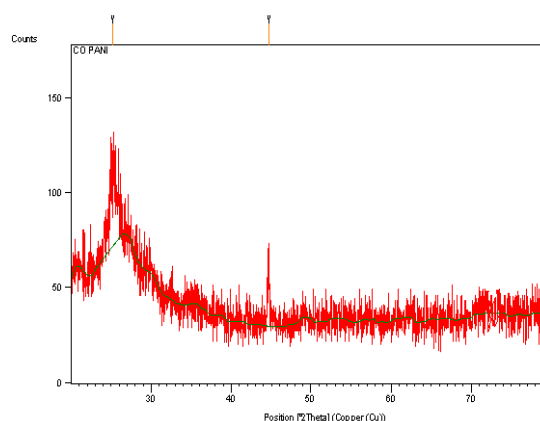


Fig 1(b): XRD pattern of nanocomposite (20%)

The SEM image of PANI-CdO nanocomposite (20%) is shown in figure 2. It can be seen from the image that the particle size is in the range of nanometer and having spherical and porous structure [21]. The FTIR spectra of PANI-CdO nanocomposite (20%) is shown in figure 3. It is clearly seen from the figure that the characteristic peaks at 3450 , 1600 , 1554 , 1491 , 1207 , 1160 , 823 cm^{-1} attributed to N-H stretching of secondary amine, benzenoid ring, C-N stretching band vibrating of the dopant anion and paradisubstituted benzene ring respectively. The decrease in peak area with respect to the PANI indicates the structural change in polymer due to presence of CdO nanoparticles which has been uniformly mixed in the polymer matrix as supported from its SEM..

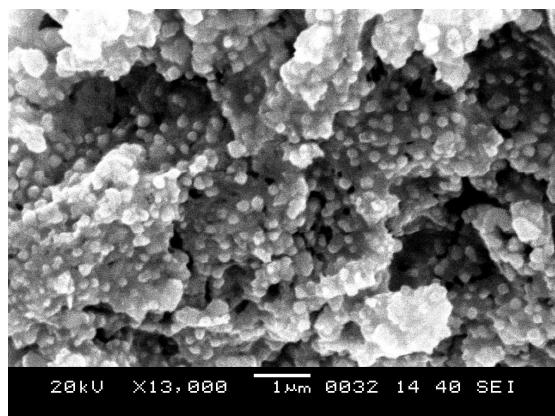


Fig 2: SEM image of CdO nanoparticles

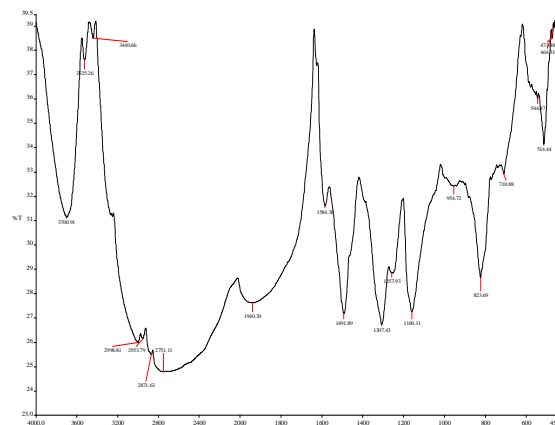


Fig 3: FTIR spectra of nanocomposite (20%)

UV-VIS spectra of nanocomposites are shown in figure 4. From the spectra, it can be seen that pure CdO shows maximum absorption at 400nm indicating blue shift which is due to particle size in nano regime [22]. The changes in peak position of PANI- CdO composites of 5% and 20% shows the enhanced absorption as compared to 10% around 389-390nm indicating the polaronic bands have been formed in the composites which are responsible to increase the electrical conductivity of these composites due to specific amount of CdO incorporation in polymer matrix as compared to that of pure polyaniline [23,24].

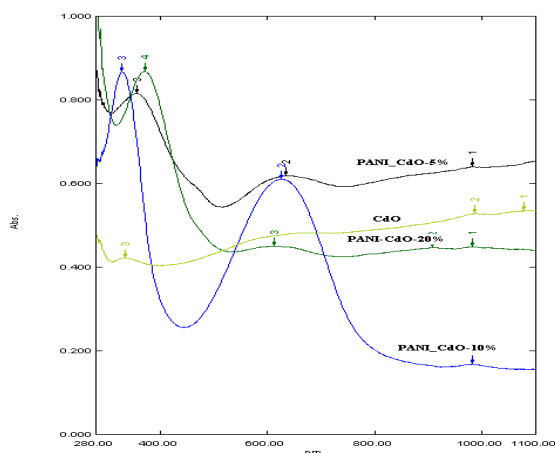


Fig 4: UV -VIS Spectra of CdO and nanocomposites

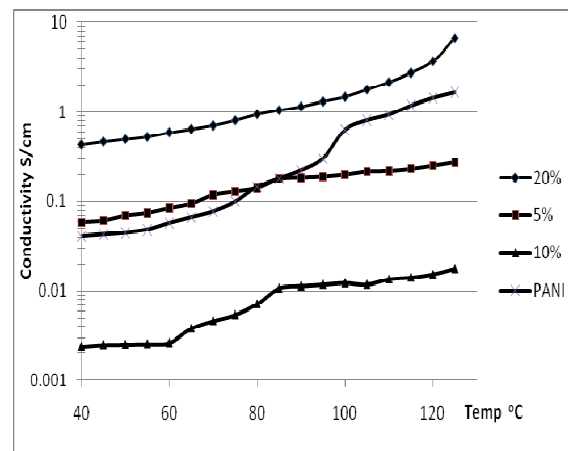


Fig 5: Electrical conductivity of pure PANI and nanocomposites

The variation of conductivity with temperature for PANI-CdO nanocomposites are shown in figure 5. The increase in conductivity for the nanocomposites containing 5% and 20% filler particles may be due to the formation of more number of polarons in the widen band gap which is also confirmed from the UV-vis spectra. Hence for the particular amount of filler nanomaterial, the surface of PANI would be modified to have high conductivity and have much active surface. The change in the conductivity of the composites indicates a change in the doping state of the polymer. Though the composite having 5% and 20% of CdO shows the higher conductivity than pure PANI but the formation of 3-D conduction network is not likely and thus

such enhancement of DC conductivity values can be attributed to the uncoiling of polymeric chains due to strong interfacial interaction between CdO nanocrystallites with PANI caused by their composition [25].

CONCLUSION

CdO nanoparticles were prepared successfully by sol-gel simple approach. A series of PANI-CdO nanocomposites have been synthesized by chemical oxidation polymerization method. PANI-CdO nanocomposites show enhanced polaronic bands as observed from UV-VIS spectra. This also reveals the well incorporation of the nanosized CdO in the PANI matrix and effect of nanoparticles on the structural and optical properties of polyaniline. The enhanced electrical conductivity for the composites of 5% and 20% with ordered structure compared to pure PANI may be applicable in the nanoelectronic devices which have the dual advantages of low dimension and organic conductor.

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REFERENCES

- [1] Sexena, V, Malhotra, B D, *Curr. Appl. Phys.*, **3**, 293-305 (2003)
- [2] Srinivasan, S, Pramanik, P, *Synth. Met.*, **63**, 199-204 (1994)
- [3] Jing, X, Wang, Y, Zhang, B, *J. Appl. Polym. Sci.*, **98** (5), 2149-2156 (2005)
- [4] Cai, Z, Geng, M, Tang, Z, *J. Mater. Sci.*, **39** (12) 4001-4003 (2004)
- [5] Jang, J, Ha, J., Kim, S., *Macromol. Res.*, **15**, 154-159 (2007).
- [6] Luzny, W., Banka, E., *Macromolecules*, **33**, 425-432, (2000).
- [7] Kim, D. K., Oh, K. W., Kim, S. H., *J. Polym. Sci. Part B*, **46**, 2255-2266 (2008).
- [8] Pud, A., Ogurtsov, N., Korzhenko, A., Shapova, I. G., *Prog. Polym. Sci.*, **28**, 1701-1707, (2003).
- [9] Gangopadhyay, R., De, A., *Chem. Mater.*, **12**, 608-613, (2000).
- [10] Mittal, H., Kaith B., Jindal R, *Advances in Applied Science Research*, **1** (3) 56-66, (2010)
- [11] Ramaswamy, V, Vimalathithan, R M., Ponnusamy, V., *Advances in Applied Science Research*, **1** (3) 197-204, (2010)
- [12] Igwe, H.U., Ugwu, E.I., *Advances in Applied Science Research*, **1** (3) 240-246, (2010)
- [13] Tomar, A.K., Mahendia, S., Kumar, S., *Advances in Applied Science Research*, **2** (3) 327-333, (2011)
- [14] Lanje, A.S., Sharma, S.J., Pode, R.B., Ningthoujam, R.S., *Advances in Applied Science Research*, **1** (2) 36-40, (2010)
- [15] Kondawar, S. B., Thakare, S. R., Khati, V., Bompilwar, S., *J. Modern. Phys. B*, **23** (15) 3297-3304, (2009).
- [16] Chaudhari, S, Mandate, AB, Patil, KR, Sainkar, SR, Patil, PP, *J. Appl. Polym. Sci.*, **106**, 220-229 (2007)
- [17] Novak, BM, *Adv. Mater.*, **5**, 422-433 (1993)
- [18] Bolto, B.A., Weiss, D.E., Willis, D., *Australian Journal of Chemistry* **18**, 487-495 (1965)

- [19] Bompilwar, S D, Kondawar, S B, Tabhane, V A, Kargirwar, S R, *Advances in Applied Science Research*, **1** (1) 166-173, (2010)
- [20] Kondawar, S B, Bompilwar, S D, Khati, V S, Thakare, S R, Tabhane, V A, Burghate, D K, *Archives of Applied Science Research*, **2**(1) 247-253, 2010,
- [21] Yang, C H, Yang, T C, Chih, Y K, *J Electrochem Soc.* **152** (2005)
- [22] Ma, X. Y., Lu, G. X., Yang, B. J., *Applied Surface Science*, **187**, 235-238, (2002)
- [23] Godowsky, D. Y., Varfolomeev, A. E., Zaretsky, D. F., *J. Mater. Chem*, **11**, 2465-2469, (2001).
- [24] Raji, P., Sanjeeviraja, C., Ramchandran, K., *Cryst. Res. Technol.*, **39**, 621, (2004).
- [25] Pant, H. C., Patra, M. K., Nagi, S. C., Bhatia, A., Vadera, S. R., Kumar, N., *Bull. Mater. Sci.* **29**(4), 379, 2006.