Published: 09 January 2019

Ferromagnetism in Cu^{2+} doped ZnO nanoparticles and their physical properties

Pallavi G. Undre, Prashant B. Kharat, R. V. Kathare & K. M. Jadhav

Journal of Materials Science: Materials in Electronics **30**, 4014–4025 (2019)

Abstract

Cu^{2+} doped ZnO nanoparticles designated as $Zn_{1-x}Cu_xO$ (x = 0.00, 0.02, 0.04, 0.06, 0.08 and 0.10) were prepared by sol–gel auto combustion technique. The modifications in structure, morphology, band gap, electrical, dielectric and magnetic properties due to Cu^{2+} doping were investigated through XRD, FE-SEM/EDAX, TEM/SAED, Raman, FT-IR, UV–Vis and VSM respectively. The analysis of XRD pattern reveals the incorporation of the dopants Cu^{2+} into ZnO lattice. The XRD spectra show that all the synthesized nanoparticles are a single crystalline phase with hexagonal wurtzite structure. The analysis of FE-SEM indicates that Cu^{2+} doping affects the surface morphology of ZnO. The compositional study performed by EDAX confirmed the presence of Zn, O, and Cu in stoichiometric proportion. TEM micrographs show the spherical shape of

nanocrystals with small agglomeration. SAED patterns confirm the crystalline nature with hexagonal wurtzite structure. Raman spectra show the strongest peak at 437 cm^{-1} related to vibration of oxygen atoms in ZnO and also confirms optical phonon modes. FTIR result confirms the successful accompanying of Cu^{2+} ions into ZnO crystal lattice without changing its original structure. From DC electrical resistivity measurements it was found that electrical resistivity enhanced with increase in Cu^{2+} content. The measured dielectric parameters decreased with increase in Cu^{2+} content. An optical study revealed that the energy band gap decreased with

doping of Cu^{2+} ions into ZnO nanoparticles. The VSM analysis shows the transformation of paramagnetic to superparamagnetic and superparamgnetic to ferromagnetic at room temperature due to Cu^{2+} doping in ZnO nanoparticles. The enhanced physical properties revealed that the prepared Cu^{2+} doped ZnO nanoparticles are the potential candidate for high-frequency devices, optoelectronic devices and spintronics devices application.

References

1. S.M. Hosseinpour-Mashkani, A. Sobhani-Nasab, M. Mehrzad, J. Mater. Sci. Mater. Electron. **27**, 5758–5763 (2016)

2. M. Rahimi-Nasrabadi, M. Behpour, A. Sobhani-Nasab, S.M. Hosseinpour-Mashkani, J. Mater. Sci. Mater. Electron. **26**, 9776–9781 (2015)

3. M. Rahimi-Nasrabadi, M. Behpour, A. Sobhani-Nasab, M.R. Jeddy, J. Mater. Sci. Mater. Electron. **27**, 11691–11697 (2016)

4. W. Lee, Y.S. Lim, S. Kim, J. Jung, Y.-K. Han, S. Yoon, L. Piao, S.-H. Kim, J. Mater. Chem. **21**, 6928–6933 (2011)

5. M.S. Park, G.X. Wang, Y.M. Kang, D. Wexler, S.X. Dou, H.K. Liu, Angew. Chem. **119**, 764–767 (2007)

6. A. Jaroenworaluck, W. Sunsaneeyametha, N. Kosachan, R. Stevens, Surf. Interface Anal. **38**, 473–477 (2006)

7. R. Saravanan, K. Santhi, N. Sivakumar, V. Narayanan, A. Stephen, Mater. Charact. **67**, 10–16 (2012)

8. A. Javidan, M. Ramezani, A. Sobhani-Nasab, S.M. Hosseinpour-Mashkani, J. Mater. Sci. Mater. Electron. **26**, 3813–3818 (2015)

9. M. Mansournia, S. Rafizadeh, S.M. Hosseinpour-Mashkani, Ceram. Int. **42**, 907–916 (2016)

10. C.B. Ong, L.Y. Ng, A.W. Mohammad, Renew. Sustain. Energy Rev. **81**, 536–551 (2018)

11. N.A. Hammed, A.A. Aziz, A.I. Usman, M. Qaeed, Ultrason. Sonochem. **50**, 172–181 (2019)

12. M. Arshad, A. Azam, A.S. Ahmed, S. Mollah, A.H. Naqvi, J Alloys Compd. **509**, 8378–8381 (2011)

13. S. Kant, A. Kumar, Adv. Mater. Lett. **3**, 350–354 (2012)

14. B. Straumal, B. Baretzky, A. Mazilkin, S. Protasova, A. Myatiev, Straumal P., J. Eur. Ceram. Soc. **29**, 1963–1970 (2009)

15. M.M. Hassan, W. Khan, A. Azam, A. Naqvi, J. Lumin. **145**, 160–166 (2014)

16. Z. Zhang, J.B. Yi, J. Ding, L.M. Wong, H.L. Seng, S.J.

Wang, J.G. Tao, G.P. Li, G.Z. Xing, T.C. Sum, J. Phys. Chem. C **112**, 9579–9585 (2008)

17. N. Kouklin, Adv. Mater. **20**, 2190–2194 (2008)

18. B.K. Das, T. Das, K. Parashar, A. Thirumurugan, S. Parashar, J. Mater. Sci. Mater. Electron. **28**, 15127–15134 (2017)

19. K. Omri, A. Bettaibi, K. Khirouni, L. El Mir, Physica B **537**, 167–175 (2018)

20. V. Vaiano, G. Iervolino, L. Rizzo, Appl. Catal. B **238**, 471–479 (2018)

21. R.-C. Wang, H.-Y. Lin, Mater. Chem. Phys. **125**, 263–266 (2011)

22. M. Zhu, Z. Zhang, M. Zhong, M. Tariq, Y. Li, W. Li, H. Jin, K. Skotnicova, Y. Li, Ceram. Int. **43**, 3166–3170 (2017)

23. S. Muthukumaran, R. Gopalakrishnan, Opt. Mater. **34**, 1946–1953 (2012)

24. P. Dhamodharan, R. Gobi, N. Shanmugam, N. Kannadasan, R. Poonguzhali, S. Ramya, Spectrochim. Acta A **131**, 125–131 (2014)

25. Z.-P. Sun, L. Liu, L. Zhang, D.-Z. Jia, Nanotechnology **17**, 2266 (2006)

26. R. Kripal, A.K. Gupta, R.K. Srivastava, S.K. Mishra, Spectrochim. Acta A **79**, 1605–1612 (2011)

27. A.N.P. Madathil, K. Vanaja, M. Jayaraj, *Nanophotonic Materials IV* (International Society for Optics and Photonics, San Diego, 2007), p. 66390J

28. A.K. Zak, M.E. Abrishami, W.A. Majid, R. Yousefi, S. Hosseini, Ceram. Int. **37**, 393–398 (2011)

29. S.M. Hosseinpour-Mashkani, M. Ramezani, Mater. Lett. **130**, 259–262 (2014)

30. A. Sobhani-Nasab, M. Maddahfar, S.M. Hosseinpour-Mashkani, J. Mol. Liq. **216**, 1–5 (2016)

31. S.M. Hosseinpour-Mashkani, M. Maddahfar, A. Sobhani-Nasab, J. Mater. Sci. Mater. Electron. **27**, 474–480 (2016)

32. H. Mirzaei, M. Darroudi, Ceram. Int. **43**, 907–914 (2017)

33. M. Vafaee, M.S. Ghamsari, Mater. Lett. **61**, 3265–3268 (2007)

---

34. A. Sobhani-Nasab, A. Ziarati, M. Rahimi-Nasrabadi, M.R. Ganjali, A. Badiei, Res. Chem. Intermed. **43**, 6155–6165 (2017)

---

35. L. Shen, N. Bao, K. Yanagisawa, K. Domen, C.A. Grimes, A. Gupta, J. Phys. Chem. C **111**, 7280–7287 (2007)

---

36. D. Raoufi, J. Lumin. **134**, 213–219 (2013)

---

37. R. Elilarassi, P.S. Rao, G. Chandrasekaran, J. Sol-Gel Sci. Technol. **57**, 101–108 (2011)

38. K. Raja, P. Ramesh, D. Geetha, Spectrochim. Acta A **131**, 183–188 (2014)

39. A. Ziarati, A. Sobhani-Nasab, M. Rahimi-Nasrabadi, M.R. Ganjali, A. Badiei, J. Rare Earth **35**, 374–381 (2017)

40. L.-H. Ye, A. Freeman, B. Delley, Phys. Rev. B **73**, 033203 (2006)

41. K. Raja, P.S. Ramesh, D. Geetha, Spectrochim. Acta A

120, 19–24 (2014)

42. D. Theyvaraju, S. Muthukumaran, Physica E **74**, 93–100 (2015)

43. M. Ashokkumar, S. Muthukumaran, J. Lumin. **162**, 97–103 (2015)

44. M. Ahmad, E. Ahmed, Y. Zhang, N. Khalid, J. Xu, M. Ullah, Z. Hong, Curr. Appl. Phys. **13**, 697–704 (2013)

45. S. Singhal, J. Kaur, T. Namgyal, R. Sharma, Physica B **407**, 1223–1226 (2012)

46. S.D. Birajdar, P.P. Khirade, T.S. Saraf, R. Alange, K. Jadhav, J. Alloys Compd. **691**, 355–363 (2017)

47. J. Wang, G. Huang, X. Zhong, L. Sun, Y. Zhou, E. Liu, Appl. Phys. Lett. **88**, 252502 (2006)

48. P. Labhane, V. Huse, L. Patle, A. Chaudhari, G. Sonawane, J. Mater. Sci. Chem. Eng. **3**, 39 (2015)

49. U. Gahlaut, V. Kumar, R. Pandey, Y. Goswami, Optik **127**, 4292–4295 (2016)

50. A.S. Lanje, S.J. Sharma, R.S. Ningthoujam, J.-S. Ahn,

R.B. Pode, Adv. Powder Technol. **24**, 331–335 (2013)

51. M. Iwamoto, in *Encyclopedia of Nanotechnology*, ed. by B. Bhushan. Maxwell–Wagner effect (Springer, New York, 2012), pp. 1276–1285

52. I. Gul, A. Abbasi, F. Amin, M. Anis-ur-Rehman, A. Maqsood, J. Magn. Magn. Mater. **311**, 494–499 (2007)

53. A. Ghosh, N. Kumari, A. Bhattacharjee, Pramana **84**, 621–635 (2015)

54. P. Capper, S. Kasap, A. Willoughby, *Zinc Oxide Materials for Electronic and Optoelectronic Device Applications* (Wiley, Hoboken, 2011)

55. A.J. Reddy, M. Kokila, H. Nagabhushana, R. Chakradhar, C. Shivakumara, J. Rao, B. Nagabhushana, J Alloys Compd. **509**, 5349–5355 (2011)

56. K. Noipa, S. Rujirawat, R. Yimnirun, V. Promarak, S. Maensiri, Appl. Phys. A **117**, 927–935 (2014)

57. C. Xia, C. Hu, Y. Tian, P. Chen, B. Wan, J. Xu, Solid State Sci. **13**, 388–393 (2011)

58. S. Riaz, S. Naseem, Y. Xu, J. Sol-Gel Sci. Technol. **59**, 584–590 (2011)

59. M. El-Hilo, A. Dakhel, A. Ali-Mohamed, J. Magn. Magn. Mater. **321**, 2279–2283 (2009)

60. R. Elilarassi, G. Chandrasekaran, J. Mater. Sci. Mater. Electron. **21**, 1168–1173 (2010)

61. D. Gao, Y. Xu, Z. Zhang, H. Gao, D. Xue, J. Appl. Phys.

105, 063903 (2009)

62. N. Khare, M.J. Kappers, M. Wei, M.G. Blamire, J.L. MacManus-Driscoll, Adv. Mater. **18**, 1449–1452 (2006)

63. T.M. Hammad, J.K. Salem, R.G. Harrison, R. Hempelmann, N.K. Hejazy, J. Mater. Sci. Mater. Electron. **24**, 2846–2852 (2013)

Acknowledgements

One of the authors (PGU) is thankful to UGC-DAE Consortium for Scientific

Research for providing TEM and VSM facility.

Author information

Authors and Affiliations

Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, MS, India

Pallavi G. Undre, Prashant B. Kharat & K. M. Jadhav

Department of Physics, Karmaveer Mamasaheb Jagdale Mahavidyalaya, Washi, Osmanabad, MS, India

Pallavi G. Undre & R. V. Kathare

Corresponding author

Correspondence to K. M. Jadhav.

Ethics declarations

Conflict of interest

The authors declare that they have no conflict of interest.

Rights and permissions

[Reprints and Permissions](#)

About this article

Cite this article

Undre, P.G., Kharat, P.B., Kathare, R.V. *et al.* Ferromagnetism in Cu^{2+} doped ZnO nanoparticles and their physical properties. *J Mater Sci: Mater Electron* **30**, 4014–4025 (2019). https://doi.org/10.1007/s10854-019-00688-4

Received	Accepted	Published
11 October 2018	03 January 2019	09 January 2019

Issue Date

28

February

2019

DOI

https://doi.org/10.1007/s10854-019-00688-4