My Scientific Journey in Nanotechnology

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Abstract

This article is a historical review of my encounter with Nanotechnology in DAVIET, Jallandhar. The methodology used for fabrication of nanowires and nanoflowers is briefly discussed. A passing reference is made to the contribution of my collaborators. The article is illustrated with images of nanoflowers and copper nanocrystals obtained as a by product of nanowires. The list of our publications in the area of nanotechnology is given at the end.

Keywords: *Nanowires, Nanocrystals, Nanoflowers, Anodic alumina and polymer templates*

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At the time of my retirement on June 30, 2002, Nanotechnology has not yet become a fashionable area of research in the Indian universities. During 2005, Department of Science and Technology (DST), Govt. of India issued a circular letter to all Universities to send proposals for setting up teaching and research departments in Nanotechnology. Almost fifty universities started this course, including Guru Nanak Dev University (GNDU), Amritsar. Nanotechnology was not yet a current topic of research in India but it was considered to be an upcoming technology of future worldwide. After my retirement, I moved to Canada to join my sons and their families. However, I returned to India after two months to make India my centre of future activities. I was not inclined to get re-employment but thought of keeping myself busy in my writing project and publication work.

During 2002, Dmitri Zagorski, a Russian scientist from Moscow, participated in 21st International Conference on Nuclear Tracks in Solids (ICNTS-21) held in New Delhi. He again visited India in 2007 on my personal invitation. He fell in love with India and asked me to collaborate in his research project under Indo-Russian exchange program to be funded by DST, New Delhi. In order to participate in this project, I had to join some University in Punjab. I met Dr N.P. Singh, Dean Punjab Technical University (PTU), Jallandhar, who was interested in this project but there was no research laboratory in PTU. Hence, this proposal remained in the cold store for lack of any research facility in PTU. Ultimately, I got the offer from DAVIET (DAV Institute of Engineering & Technology), Jallandhar in 2008 to create a research centre in Nanotechnology. It was a timely offer and I seized upon this opportunity to fulfil my mission.

Before retirement, I started fabrication of microstructures during 1990s using mica and plastic sheets exposed to heavy ion beams at the accelerator in GSI, Darmstadt (Germany). Ion Track Filters prepared in our laboratory in GNDU were used for water purification from bacteria and virus contamination, cancer blood cell separation and fabrication of microstructures. Our limitation was the pore size of filters which we could achieve up to a diameter limit of 1 micron by chemical etching. The experimental technique to reach nanometer size of pores was not available in India and we had to import the templates from UK and USA.

It took me six months to set up facilities in DAVIET Jallandhar. Our major equipment was Russian make ND-MDT Atomic Force Microscope (AFM) costing us four million rupees and vacuum coating unit. We imported anodic alumina and polymer membranes from UK and USA, respectively, with pore diameters from 20 to 200 nanometers to be used as templates for fabrication of Nanowires. In DAVIET Research Centre, our funding was provided by DAV Managing

Committee with Rs. 5 million as equipment grant and three posts, two of research scholars and one of a research scientist. Vishal Balouria from NIT Jallandhar joined as research scholar and Poonam Sharma, Ph.D. in Chemistry from GNDU Amritsar, joined as Scientist. I made a mistake in proposing low salaries for our research staff as I was not aware of revised grades for researchers by UGC and other funding agencies after my retirement.

Our first experiment was fabrication of Nanowires by electro-deposition technique. A prototype of electrochemical cell was provided by Ranjit Singh who had recently finished his Ph.D. thesis in K.U. Kurukshetra. Kamal Kishore, an Assistant Professor of Physics in DAVIET, assembled all the components required for my experiment. We were not sure of success as it was a topsy-turvy arrangement made in a haphazard manner. I took up the anodic alumina template after electro-deposition of nanowires to Punjab University, Chandigarh to liberate nanowires from the template and record SEM images. To my surprise, Nanowires of copper of highest quality were produced in our hit and trial experiment.

Poonam proved to be a great asset for preparation of nanomaterials in DAVIET. She prepared various types of nanocrytals, namely, Barium carbonate/oxalate, Barium hexaferrite, Cadmium sulphide, Zinc oxide and Silver oxide, using reverse micelle, microemulsion and co-precipitation techniques. During 2009-11, our laboratory was involved in creating nanocrystals, quantum dots, nanorods and nanowires of various dimensions. Nanoflower fabrication was not on our agenda. This interesting phenomenon was a by-product of our Nanowire fabrication. When our experimental set up failed to produce Nanowires, due to some uncalled for and unintended discrepancy, we were rewarded by exquisite and exotic patterns of Copper appearing as nanoflowers (Figures 1-3).

In recent years, nanowires and nanorods of metallic and semi-conducting materials have drawn a lot of research interest because of their potential applications in diverse fields, for example, nanoelectronics, optoelectronics and sensors. The special features of nanowires are defined by two quantum-confined dimensions allowing free flow of current in one dimension only. In nanowires, electronic conduction takes place both by bulk conduction and through tunnelling mechanism. It has been discovered recently that nanoflowers have great potential for possible applications in nanotechnology.

Electro-deposition technique used in our experiment is similar in principle to that used for the electroplating process. Commercial anodic alumina membranes (Anodisc 25, Whatman, U.K.) having an average pore diameter of 200 nm, a nominal thickness of 60 μm and pore density of 10^9 pores/cm^2, were used as templates. A second set of polymer membranes was selected for sake of comparison. Commercially available polycarbonate membranes (Sterlitech, USA) of 25 mm diameter with pore density of 10^8 pores/cm^2 and pore diameter of 100 nm were selected for this experiment. Electrochemical cell used for growth of Nanowires was fabricated in our workshop. The details of electro-deposition technique used in our experiments has been given in our publications listed at the end of this Chapter.

There is as yet no specific theory to explain exotic patterns developed during electro-deposition of copper in anodic alumina or polymer templates. A speculative explanation is provided on the basis of over-deposition. During the growth of copper nanowires in the template pores, the current remains nearly stable until the wires arrive at the template surface. If the electro-deposition process is not stopped at this stage, the current keeps on rising very gradually leading to over-deposition of copper. The exotic patterns in the form of micro-flowers having their petals in nanometer dimension, copper buds leading to mushroom effect and double pyramid shaped copper crystals (Figure 4) have been observed [26]. Our investigations reveal that chance plays a predominant role in growth of nanoflowers. One may conclude that fabrication of nanoflowers is an art and lacks scientific explanation. However, there is one satisfaction that all these exotic patterns find some analogue in nature.

In addition to Nanowires, we fabricated Cu-Se hetero-junctions using anodic alumina membrane, Cadmium oxide quantum dots by quenching method, and studied the effect of CTAB surfactant on structural and magnetic properties of Barium hexaferrite. Rajshree Jotania of G.U. Ahmedabad motivated our group to study hexaferrites during her visit to DAVIET in 2009. During our collaboration, a Review Paper " *Y-type hexaferrites: Structural, Dielectric and Magnetic properties*" was published in a special volume "Ferroics and Multiferroics" published by Trans Tech Switzerland in 2012. It has gained lot of popularity on Researchgate recording 2500 downloads.

During my Editorship of Trans Tech Publications, Switzerland (2011-2016), I edited twelve volumes under two series: Solid State Phenomena and Defect and Diffusion series. I developed a cordial relationship with many authors ending up in collaborations and in writing joint Review papers in a wider number of areas under Nanotechnology. The list of Review Papers is given at the end [21-38]. K.V.R. Murthy from Applied Physics Department of MS University of Baroda,a well known author in the field of Luminescence, joined me as a research collaborator. Our Review paper "*Luminescence Phenomena: An Introduction*" has been highly cited and downloaded on Researchgate.

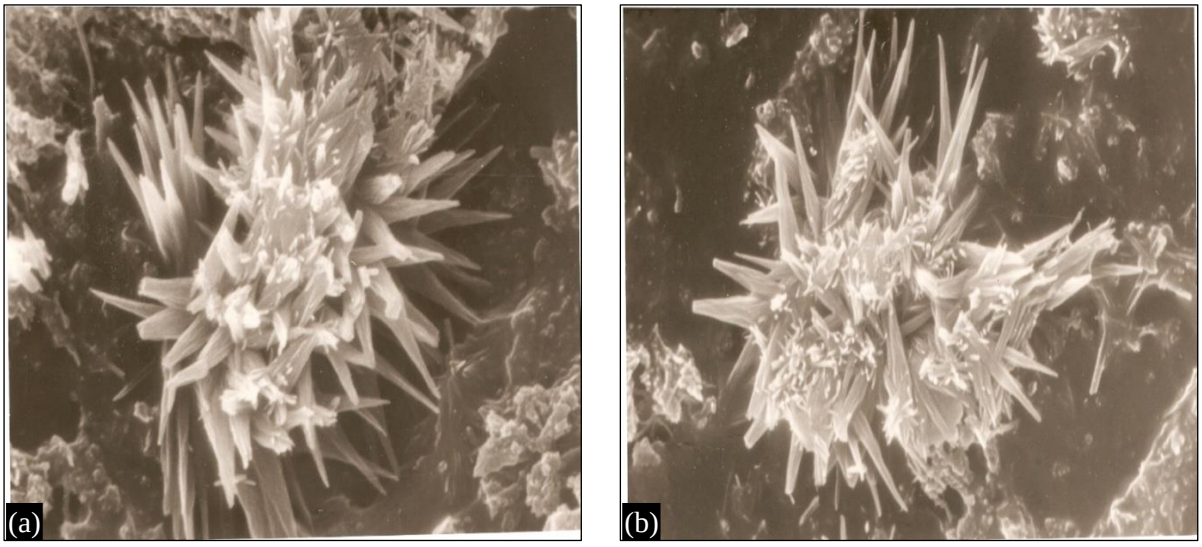

Fig. 1 (a, b): *SEM micrographs show identical patterns of Copper nanoflowers grown in polymer template (100 nm pore dia.).*

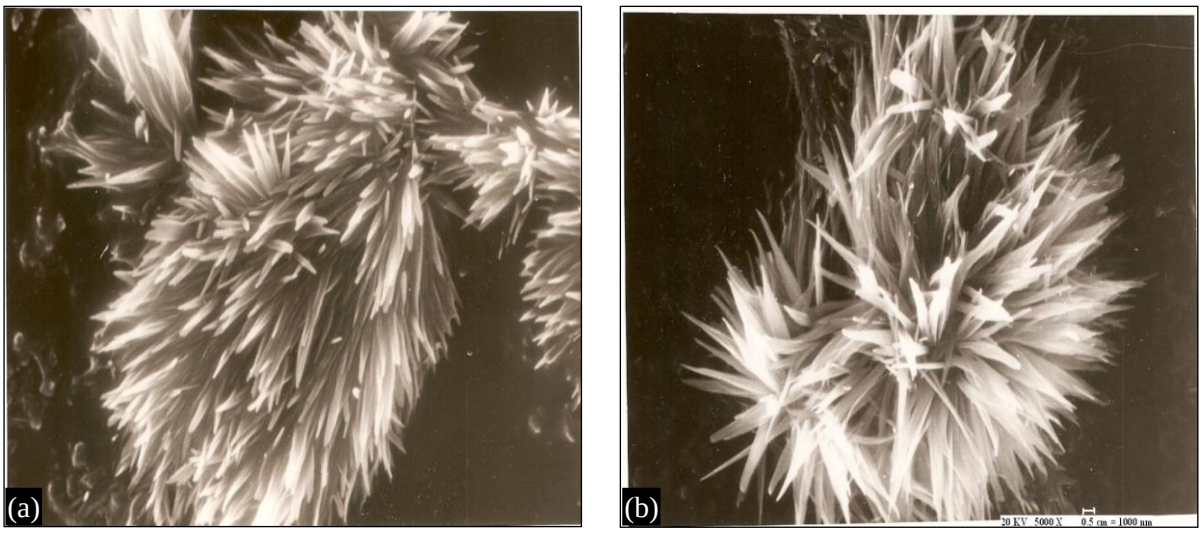

Fig. 2 (a, b). *SEM micrographs of lily-like copper nanoflowers grown in polymer template (100 nm pore dia.).*

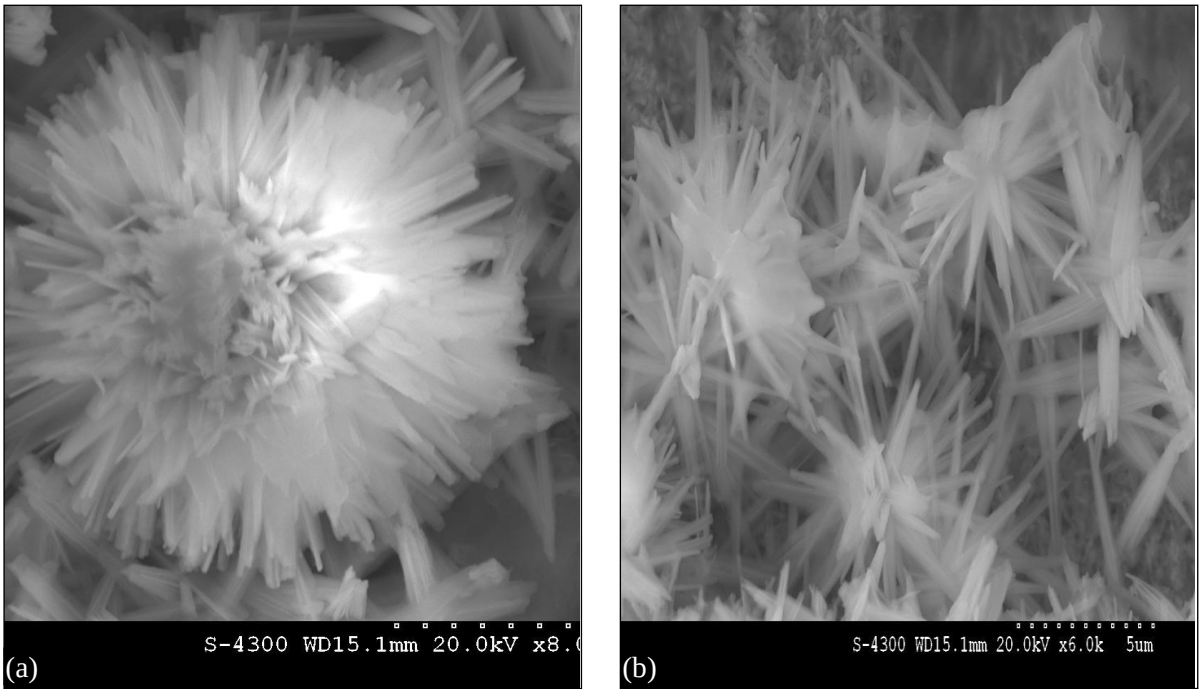

Fig. 3: (a, b). *SEM micrographs of marigold copper nanoflowers grown in polymer template.*

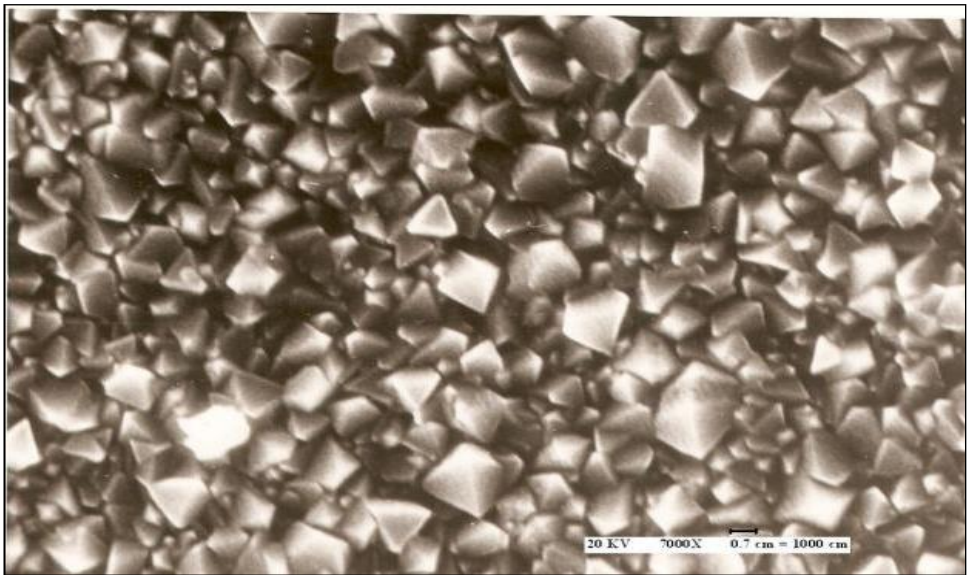

Fig. 4: *SEM micrograph of double pyramid shaped Copper nanocrystals grown in anodic alumina membrane of 20 nm diameter.*

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REFERENCES

1. Virk HS. Heavy ion track route to nanotechnology. *Advanced Materials Research*. 2009; 67, 115–120p.

2. Poonam Sharma, Virk HS. Fabrication of nanoparticles of Barium carbonate/oxalate using Reverse Micelle technique. *The Open Surface Science Journal*. 2009; 1: 23–28p.
3. Virk HS, Baloria V, Poonam Sharma. An overview of nanotechnology research at DAV Institute of Engineering and Technology (DAVIET), Jalandhar, India. *Indian Science Cruiser*. 2009; 23(4), 29–34p.
4. Virk HS, Kishore K, Baloria V. Fabrication of Copper Nanowires by Electrodeposition using Anodic Alumina and Polymer Templates. *Journal of Nano Research*. 2010; 10: 63–67p.
5. Virk HS, Poonam Sharma. Heavy ion irradiation effects on Cadmium oxide (CdO) quantum dots prepared by quenching method. *Journal of Nano Research*. 2010; 10: 69–76p.
6. Virk HS, Poonam Sharma. Fabrication of nanoparticles and nanowires using reverse micelle and template synthesis techniques. Noida: Tata McGraw Hill Professional Publication; 2010. pp. 37–41.
7. Virk HS. Template synthesis of Cu-Se hetero-junctions using anodic alumina membrane and their characterization. *Digest J. of Nanomater & Nanostructures*. 2010; 5(3): 593–598p.
8. Virk HS. Quantum dots and nanowires: fabrication and characterization. *International Journal of Advanced Engineering Technology*. 2010;1(2): 55–60p.
9. Virk HS, Poonam Sharma. Chemical route to nanotechnology. *International Journal of Advanced Engineering Technology*. 2010;1(3): 114–129p.
10. Virk HS, Poonam Sharma. Synthesis, characterization and clustering phenomenon of zinc oxide nanocrystals. *Int. J. of Nanosci. & Tech*. 2010; 1(1), 11–16p.
11. Virk Hardev Singh. Fabrication of polycrystalline copper nanowires by electrodeposition in anodic alumina membrane and their characterization. *Nano Trends*. 2010; 9(1): 1–9p.
12. Poonam Sharma, Virk HS. Effect of co-surfactant and water to surfactant molar ratio on the CdS nanoparticles in microemulsion. *Nano Trends*. 2010;9(3): 1–12p.
13. Virk HS, Poonam Sharma, Rajshree Jotania. Comparative study of Ba-M hexaferrite particles prepared using microemulsion processing and co-precipitation techniques. *International Journal of Advanced Engineering Technology*. 2011;2(1): 131–143p.
14. Virk Hardev Singh. Fabrication and Characterization of Copper Nanowires: An Overview. *Journal of NanoScience, NanoEngineering & Applications*. 2011;1(1): 1–16p.
15. Jotania R, Poonam Sharma, Virk HS. Effect of CTAB surfactant on the microstructural and magnetic properties of Barium hexaferrite. *J. Nanoscience Letters*. 2011;1(1): 63–71p.
16. Hardev Singh Virk. Template synthesis and morphology of CdS nanowire arrays using anodic alumina membranes. *Nano Trends*. 2011;10 (2): 17–24p.
17. Virk HS. Template growth of copper nanowires and exotic patterns of metallic copper using electrodeposition technique. *International Journal of Advanced Engineering Technology*. 2011;2(3), 64–68p.
18. Virk HS. Effects of 90 MeV Carbon ion irradiation on Cadmium oxide quantum dots. *Current Science*. 2011;100(10): 1540–1542p.
19. Virk HS. Fabrication and characterization of metallic Copper and Copper Oxide nanoflowers. *Pakistan J. of Chemistry*. 2011;1(4), 1–7p.
20. Hardev Singh Virk. Fabrication and characterization of copper nanowires. In: Abbass Hashim (editor). *Nanowires - Implementations and Applications*. London: IntechOpen Limited; 2011.
21. Rajshree B Jotania, Hardev Singh Virk. Y-type hexaferrites: Structural, Dielectric and Magnetic properties. In: Virk HS, Kleemann W (editors). *Ferroics and Multiferroics*. Switzerland: Trans Tech Publications; 2012. pp. 209–232.
22. Hardev Singh Virk. Synthesis of metallic Copper nanoflowers, nanocrystals and nanorods using electrodeposition and hydrothermal techniques. *Journal of NanoScience, NanoEngineering & Applications*. 2012;2 (1): 23–37p.

23. Hardev Singh Virk. Our fabrication routes to nanotechnology. In: Singh NL (editor). *Solid State Nuclear Track Detectors and their Applications Proc. of 17th National SSNTD Conference held in MSU Baroda, Vadodra, Oct. 25-27, 2011*. New Delhi: Narosa Publishing House; 2013. pp. 109–114.
24. Hardev Singh Virk. Synthesis and Characterization of Metal and Semiconductor Nanowires. In*:* Hardev Singh Virk (editor). *Functional Nanomaterials and their Applications, Solid State Phenomena Series*, Switzerland: Trans Tech Publications; 2013. pp. 21–64.
25. Ravi Chand Singh, Manmeet Pal Singh, Hardev Singh Virk. Applications of nanostructured materials as gas sensors. In: Hardev Singh Virk (editor). *Functional Nanomaterials and their Applications*, Solid State Phenomena Series. Switzerland: Trans Tech Publications; 2013. pp. 131–158.
26. Hardev Singh Virk. Fabrication of nanoflowers and other exotic patterns. In: Hardev Singh Virk (editor). *Functional Nanomaterials and their Applications. Solid State Phenomena Series*. Switzerland: Trans Tech Publications; 2013. pp. 159–180.
27. Murthy KVR, Virk HS. Luminescence phenomena: an introduction. In: Hardev Singh Virk (editor). *Luminescence Related Phenomena and their Applications. Defect and Diffusion Forum Series*. Switzerland: Trans Tech Publications; 2013. pp. 1–34.
28. Omanwar SK, Koparkar KA, Virk HS. Recent Advances and Opportunities in TLD Materials: A Review. In: Hardev Singh Virk (editor). *Luminescence Related Phenomena and their Applications. Defect and Diffusion Forum Series.* Switzerland: Trans Tech Publications; 2013. pp. 75–110.
29. Hardev Singh Virk. History of luminescence from ancient to modern times. In: Hardev Singh Virk (editor). *Luminescent Materials and their Applications. Defect and Diffusion Forum Series*, vol. 361. Switzerland: TransTech Publications; 2014. pp. 1–13.
30. Bajpai PK, Yadav S, Tiwari A, Virk HS. Recent Advances in the synthesis and characterization of chalcogenide nanoparticles. In: Hardev Singh Virk (editor). *Nanomaterials: Basic Concepts and Applications. Solid State Phenomena Series.* Switzerland: Trans Tech Publications; 2015. pp. 187–233.
31. Praveena K, Sadhana K, Virk HS. Structural and Magnetic Properties of Mn-Zn Ferrites Synthesized by Microwave-Hydrothermal Process. In: Hardev Singh Virk (editor). *Ferroics Materials: Synthesis and Applications, Solid State Phenomena Series*. Switzerland: Trans Tech Publications; 2015. pp. 45–64.
32. Dewan PK, Virk HS. heavy ion range measurements in SSNTD materials: A Review. In: Hardev Singh Virk (editor). *Solid State Nuclear Track Detectors and their Applications, Solid State Phenomena Series*, vol. 238. Switzerland: TransTech Publications; 2015. pp. 174–195.
33. Rani B, Sharma K, Anupam Neetu, Kumar S, Virk HS. Energy loss for swift heavy ions in different elemental absorbers: a different approach for effective charge parameterization. In: Hardev Singh Virk (editor). *Solid State Nuclear Track Detectors and their Applications, Solid State Phenomena Series*, vol. 238. Switzerland: Trans Tech Publications; 2015. pp. 196–205.
34. Singh D, Mudahar GS, Thind KS, Virk HS. Structural investigations of gamma-irradiated PbO glasses. In: Hardev Singh Virk (editor). *Radiation Induced Modification of Materials, Solid State Phenomena Series*, vol. 239. Switzerland: Trans Tech Publications; 2015. pp. 98–109.
35. Singh D, Bhattacharya B, Virk HS. Conductivity modulation in polymer electrolytes and their composites due to ion-beam irradiation. In: Hardev Singh Virk (editor). *Radiation Induced Modification of Materials, Solid State Phenomena Series*, vol. 239. Switzerland: Trans Tech Publications; 2015. pp. 110–148.
36. Sajó-Bohus L, Vega-Carrillo HR, Virk HS. SSNTD Technique in photo-neutron applications. In: Hardev Singh Virk

(editor). *Radiation Induced Modification of Materials, Solid State Phenomena Series*, vol. 239. Switzerland: Trans Tech Publications; 2015. pp. 180–214.

37. Sharma JK, Pratibha Srivastava, Gurdip Singh, Virk HS. Nanoferrites of transition metals and their catalytic activity. In: Rajshree Jotania, Hardev Singh Virk (editor). *Ferrites and Ceramics II. Solid State Phenomena Series*, vol. 241. Switzerland: Trans Tech Publications; 2016. pp. 126–138.
38. Varalaxmi N, Sivakumar KV, Virk HS. Studies on internal friction and curie-temperature of NiMgCuZn spinel ferrites for micro-inductor applications. In: Rajshree Jotania, Hardev Singh Virk (editor). *Ferrites and Ceramics II, Solid State Phenomena Series*, vol. 241. Switzerland: Trans Tech Publications; 2016. pp. 202–225.

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