

<b>Name</b>	<b>Dr. Smrutisikha Bal</b>
<b>Designation</b>	<b>Senior Scientific Officer, Central Instruments Facility, NIT Rourkela.</b>
<b>Area of Specialization</b>	Polymer nanocomposites (CNT/CNF based), Materials Characterization including Small Angle X-ray Scattering (SAXS)
<b>Mailing Address</b>	<p>B/17, NIT Campus, Rourkela-8, NIT Rourkela, Orissa. , PIN-769008</p> <p><b>E-mail:</b> <a href="mailto:balss@nitrkl.ac.in">balss@nitrkl.ac.in</a>, <a href="mailto:smrutisikha_bal@yahoo.com">smrutisikha_bal@yahoo.com</a></p> <p><b>Ph #</b> 91-661-2462572 (O), 91-661-2463454 (R), 91-8763115908 (M).</p>

### Educational Qualification

**M.Sc. (Physics): REC (NIT) Rourkela Sambalpur University (1992)**

**Ph. D.: REC (NIT) Rourkela, Sambalpur University (2002)**

### Details of Work Experience:

- ❖ Senior Scientific Officer in CIF, NITR: May 2017 – till date
- ❖ Senior Scientific Officer in Metallurgical & Material Engineering Department, NIT Rourkela: 9<sup>th</sup> May, 2013 – April 2017
- ❖ Assistant Professor, Physics department, NIT Silchar, ASSAM: 5<sup>th</sup> May, 2010 - 6<sup>th</sup> May, 2013
- ❖ Principal Investigator/Scientist, DST Project, NIT Rourkela: Sept. 2006 - April 2010.
- ❖ Guest faculty, Physics dept., NIT Rourkela: 2001 May - April 2006.
- ❖ Research Scholar, Physics Department, NIT Rourkela: 1996 - 2001
- ❖ Part time faculty, Purusottam Engg. College, Rourkela: 2000-2001
- ❖ PGT, Central school, Rourkela: 1995-96
- ❖ Part time lecturer, Ispat college, Rourkela: 1994-95

## Present Research Activity

- Synthesis of Carbon Nanotube (CNT)/ Carbon Nanofiber (CNF) Polymer Composite
- Characterization of these nanocomposites

## R & D Projects

1. Title: **Fabrication & characterization of polymer nanocomposite**

Funding Agency: **Department of Science and Technology (DST), India.**

2. Title: **Development of carbon nanotube reinforced polymer composites for naval application**

Funding Agency: **Naval Research Board (NRB), DRDO, India.**

## Research lab developed

Procured and installed instruments thro project: Ultrasonic processor, Vacuum oven, LCR meter, Digital precision weighing machine, Humidity chamber, Cryogenic chamber

Experience on instruments: XRD, SEM, DSC, FTIR, INSTRON, DMA (NITR)

Outside NITR: SAXS, TEM, MicroRaman Spectroscopy, VNA

## Publication Details:

Total: 71

**Journals: 18 (Thirteen International and Five Indian)**

International & national Conference: 50

Communicated to Journals: 3 (Two International and One National)

Publication in the last 5 years: 50

Articles of general interest: 3

## Research Supervision:

M. Sc. Dissertation: 3 (2 students in 2004 and one in 2006)

**Ph. D. supervision: 2**

1. Name: Yogojyoti Nayak

Status: Degree awarded in November 2011

Title: **Processing and Characterization of Hydroxyapatite-Ceramic Composites**

2. Name: Sunirmal Saha

Status: Degree awarded in November 2018

Title: **Investigations of electrical, mechanical and thermal characteristics of polymer nanocomposites using various nanofillers for marine applications**

### **Project coordinator of ‘Darshini: A Scanning Electron Microscope’**

This project is an innovative attempt by students of NIT Rourkela in the direction of product development. It is a small yet novel initiative and aims at inculcating a trend of fabrication of sophisticated scientific instruments indigenously with the help of available resources.

### **Achievements and Awards**

- Received ‘**Young Scientist Award**’ for best research paper “***Structural investigation of normal and treated polyester fiber by SAXS and other techniques***” in physical Sciences Division at 91st ISCA, Chandigarh in 2004.
- Received ‘**Best poster presentation award**’ for the research paper “***Influence of nanomodification on physical properties of polymer nanocomposite***” in the Physical Sciences Division at 93rd ISCA, Hyderabad in 2006.
- **DST Women scientist** fellowship award in 2006.
- Received ‘**Best Research Paper Award**’ for paper “***Study of Mechanical and Morphological Properties of Aligned and Randomly Oriented Carbon Nanotube Composites***” in International Conference on Emerging Scenarios in Space Technology & Applications-2008, 13<sup>th</sup>-15<sup>th</sup> November (Advanced Materials & Reliability) ISRO, Bangalore.

### **.Memberships:**

- Indian Science Congress Association [Life member (L19309)]
- Orissa Physical Society
- Polymer Processing Society
- American Nano Society
- Electron Microscopy Society of India

## LIST OF PUBLICATIONS

### (a) Papers published in journals:

- I. ***Influence of nanotube content on the mechanical and thermo-mechanical behaviour of –COOH functionalized MWNTs/epoxy composites***, Sunirmal Saha and Smrutisikha Bal, Bulletin of Materials Science, Springer, 2017. Volume 40, Issue 5, pp 945–956, <https://link.springer.com/article/10.1007/s12034-017-1433-x>
- II. ***Long term hydrothermal effect on mechanical and thermo-mechanical properties of carbon nanofiber doped epoxy composites***, Sunirmal Saha and Smrutisikha Bal, Journal of Polymer Engineering, Degruyter, 2017, <https://doi.org/10.1515/polyeng-2017-0037>
- III. ***Effect of sea and distilled water conditioning on the overall mechanical properties of CNT/ epoxy composites***, Smrutisikha Bal and Sunirmal Saha, International Journal of Damage Mechanics, SAGE, 2017, Vol. 26(5), 758–770, DOI: 10.1177/1056789515615184.
- IV. ***Mechanical performances of hygrothermally conditioned CNT/epoxy composites using seawater***, Smrutisikha Bal and Sunirmal Saha, Journal of Polymer Engineering, De Gruyter, 2016, DOI: 10.1515/polyeng-2016-0121.
- V. ***Comparison and analysis of physical properties of carbon nanomaterial doped polymer composites*** - Smrutisikha Bal and Sunirmal Saha, High Performance Polymer, SAGE, 2014, vol.26 (8), pp.953-960. DOI: <http://dx.doi.org/10.1177/0954008314535823>
- VI. ***Mechanical and Microstructural Analysis of Carbon nanotube Composites Pretreated at Different Temperatures*** - S. Bal, S.S. Samal and U.K. Mohanty, American Journal of Material science, 1(1), 2011, pp. 1-7.
- VII. ***Experimental study of mechanical and electrical properties of carbon nanofiber/epoxy composites*** – Smrutisikha Bal, Materials & Design, Elsevier, vol.31, 2010, pp. 2406-2413.
- VIII. ***Dispersion and reinforcing mechanism of carbon nanotubes in epoxy nanocomposites*** - Smrutisikha Bal, Bulletin of Material Science, Springer, vol.33, no.1, February 2010, pp. 1-5.
- IX. ***Preparation and characterization of carbon nanotube filled epoxy composites*** - Smrutisikha Bal, International Journal of Nano Science, Nano Engineering & Nanotechnology, Research Science Press, vol.1, No.1-2, 2009, pp. 17-21.

- X. ***Carbon Nanotube Reinforced Ceramic Matrix Composites- A Review*** - Subhranhsu Sekhar Samal and **Smrutisikha Bal**, Journal of Minerals and Materials Characterization and Engineering, jmmce.org (USA), vol.7, No.4, 2008, pp 355-370.
- XI. ***Effect of mechanical properties on fracture surfaces of carbon nanotube composites pre- treated at different temperatures*** - **S. Bal**, S.S Samal and U.K.Mohanty, NICE Journal of Emerging Technologies, ISSN No.: 0973-2993, vol-3, no.1, June 2008, pp 7-13.
- XII. ***Influence of dispersion states of carbon nanotubes on mechanical and electrical properties of epoxy nanocomposites*** - **S. Bal**, Journal of Scientific and Industrial Research (JSIR), NISCAIR, Vol.66, No.9, Sep.2007, 752.
- XIII. ***Carbon nanotube reinforced polymer composites*** – A state of the art – **S. Bal** & S. S. Samal, Bulletin of material science, Springer, Vol. 30, No.4, Aug. 2007, 379-386.
- XIV. Analysis of structural parameters of acid and alkali treated polyester fibers using SAXS and other techniques - **S. Bal** and R.C. Behera - Indian journal of Engineering and Material Science (IJEMS), NISCAIR, Vol. 14, No. 3, June 2007, 240. <http://nopr.niscair.res.in/handle/123456789/193>
- XV. Effect of changing environments on microstructure of hdpe polymer - **S. Bal**, D. Mahesh, T.K. Sen and B.C. Ray: Journal of Minerals and Materials Characterization and Engineering, jmmce.org (USA), vol.6, No.1, 2007, pp 1-16. [www.scirp.org/Journal/PaperInformation.aspx?PaperID=20488](http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=20488)
- XVI. Structural investigation of chemical treated polyester fibers using SAXS and other techniques–**S. Bal** and R.C. Behera, Journal of Minerals and Materials Characterization and Engineering, jmmce.org (USA), vol 5, No.2, 2006, pp.179-198. [www.scirp.org/JOURNAL/PaperInformation.aspx?paperID=20487&](http://www.scirp.org/JOURNAL/PaperInformation.aspx?paperID=20487&)
- XVII. Comparative study of structural parameters of normal and alkali treated polyester fiber by SAXS, SEM and Instron – T.Patel & **S.Bal.**, Polymer Journal, The society of polymer science, Japan, Vol-33, No-2, 2001, pp. 121-127.
- XVIII. Fine structural analysis of alkali treated polyester by SAXS technique using correlation function – T.Patel & **S.Bal.**, Bulletin of Orissa Physical Society, Vol-VIII, February, 2000, pp-74-84.

**(b) Book Chapter:**

- ❖ ***Microscopic analysis of mechanical properties of aligned carbon nanotube/epoxy composite*** – **S. Bal**, J.P. Borah and C. Bergheim, Advanced Nanomaterials and Nanotechnology, Springer Proceedings in Physics, Vol. 143, 2013, pp 347-366.

- ❖ ***Fabrication and characterization of carbon nanofiber (CNF) based epoxy composites*** – **S Bal** and S Saha, IOP Conf. Series: Materials Science and Engineering 75 (2015) 012018, IOP Publishing.
- ❖ ***Micro graphical analysis and comparison of MWNT and CNF reinforced polymer composite*** - **Smrutisikha Bal**, Springer Proceedings Phys., Vol. 186, Ahmet Yavuz Oral and Zehra Banu Bahsi (Eds): 3rd International Multidisciplinary Microscopy and Microanalysis Congress (InterM), Proceedings, Oludeniz, Turkey, 19-23 October 2015, 978-3-319-46600-2,
- ❖ ***Scheming of microwave shielding effectiveness for X band considering functionalized MWNTs/epoxy composites*** - **S Bal** and S Saha, 2016 IOP Conf. Ser.: Mater. Sci. Eng. 115 012027.

**Popular Science Magazine: CARBON NANOTUBES: DREAM TO REALITY**, Smrutisikha Bal, Science Vision, Orissa Bigyan Academy, 2nd issue, Feb 2011, pg 11-14.

**(c) Papers presented in conferences**

- I. ***Field Emission Display using Multiwalled carbonnanotube - a state of the art*** - **S. Bal**, G. Panda and K. K. Mahapatra - National conference on Physics of materials and Devices (PEMD-2005), Jyotivihar, Burla, Feb. 10 - 12, pp. 37-38.
- II. ***Influence of nanomodification on physical properties of polymer nanocomposite*** – **S.Bal** & Y. Nayak, 93<sup>rd</sup> Indian Science Congress Association, Hyderabad, Jan 3-7, 2006.
- III. ***Polymeric Nanocomposites – An advanced material*** - **S. Bal** and S.S. Samal, Recent Advanced Materials, Dalmia college, Rajgangpur. Feb.4&5, 2006.
- IV. ***Carbon Nanotube Based Polymer Composites- A physicist's view point*** – **S. Bal**, National conference on Emerging Trends In Nano Technology And Innovations In Design And Manufacturing (Etnmd-2006), NIT Rourkela, February 18-19, 2006.
- V. ***Polymer based CNT composites*** - S.Bal & S.S Samal, Indo-Australian symposium of Nanoscience and Nanotechnology, IISc Bangalore, 31 march-01 April, 2006.
- VI. ***Influence of dispersion states of carbon nanotubes on mechanical properties of epoxy nanocomposites*** - **S. Bal** and S.S. Samal, Recent Trends in Mechatronics Nanotechnology and Robotics (*RTMNR 2006*), NIT Rourkela, 15-16 April, 2006.
- VII. ***Nanotube dispersion in nanotube composites*** - **S.Bal** & S.S Samal, Self-assembly Routes for Nanotech Materials (SARNaM-06), BARC, Mumbai, 26-28 April, 2006.

- VIII. ***Polymer Carbon Nanocomposites - A big leap in material science*** – S. Bal & S. S Samal, International Conference on NANO TECHNOLOGY - MATERIALS AND METHODS, CIT, Coimbatore, Tamilnadu, 23<sup>rd</sup> - 25<sup>th</sup> June 2006.
- IX. ***Effect of dispersion of nanotube composites*** – S. Bal & S. S Samal, International Conference on NANOTECHNOLOGY - MATERIALS AND METHODS, CIT, Coimbatore, Tamilnadu, 23<sup>rd</sup> - 25<sup>th</sup> June, 2006.
- X. ***Carbon Nanotube Reinforced Polymer Composite*** - S.Bal & S.S Samal, Eighth International Conference on Nanostructured Materials, [Department of Metallurgy](#), IISc Bangalore, August 20-25, 2006.
- XI. ***Nanotube dispersion in polymeric nanocomposites*** - S. Bal & S.S Samal, Eighth International Conference on Nanostructured Materials, [Department of Metallurgy](#), IISc Bangalore, Aug. 20-25, 2006.
- XII. ***Sonicated low volume fraction Carbon Nanotube Reinforced Epoxy nanocomposites and the role of dispersion on its mechanical properties*** – S. Bal & S. Samal, National Review and coordination meeting on Nanoscience and Nanotechnology, ARCI Hyderabad -2007, Feb.21-23.
- XIII. ***Physical And Morphological Characterization Of Microwave Cured Multiwalled Nanotube Reinforced Smart Polymer Nanocomposites***- Smrutisikha Bal & Mr. Subhranshu Sekhar samal, National Conference on Smart Materials and Recent Technologies (SMART-2007), Department of Physics, Sri Venkateswara University, Tirupati.
- XIV. ***Effect of mechanical properties on fracture surfaces of carbon nanotube composites pre-treated at different temperatures*** – S.Bal, S.S.Samal & U.K.Mohanty, Proceedings of second International Conference on Emerging Adaptive Systems and Technologies (EAST-2007), 25<sup>th</sup>-27<sup>th</sup> Oct., NICE, Kumaracoil, Tamilnadu.
- XV. ***Role of Dispersion for Enhancement of Mechanical and Electrical Parameters of Multiwalled Carbon Nanotube Reinforced Epoxy composites***- Subhranshu S. Samal, S Bal, & U.K Mohanty. ICAMC- 2007, 26<sup>th</sup>-28<sup>th</sup> Oct., RRL Trivendrum.
- XVI. ***Mechanical and microstructural analysis of carbon nanotube reinforced polymer composites*** - S.Bal, Proceedings of International and INCCOM-6 Conference, Future Trends in Composite Materials and Processing, Dec. 12-14, 2007, Indian Institute of Technology, Kanpur.
- XVII. ***Effect of process parameters on the mechanical and electrical properties of the multiwalled carbon nanotube based polymer composites treated at different conditions*** – S.S. Samal & Smrutisikha Bal, Poster and R.I.C.H. document, Bangalore Nano, 6<sup>th</sup> & 7<sup>th</sup> Dec., 2007, pp.27.
- XVIII. ***CNT based Ceramic Matrix Composites*** – S S Samal & S Bal, International conference on Nanoscopic, Mesoscopic and Microscopic

object (INWNMM), 2nd-4th January, 2008, Institute of Material Science, Bhubaneswar.

- XIX. ***Effect of Temperature on Mechanical & Micro Structural Properties of Fracture Surfaces of Carbon Nanotube Reinforced Polymer Composites*** - Subhranshu S. Samal & **S Bal**, IndoSwiss Bonding (2008), International symposium on Bonding & Adhesions (Feb 14-16).
- XX. ***Effect of process parameters on the mechanical & electrical properties of the multiwalled carbon nanotube based polymer composites post cured at different environmental conditions-*** Subhranshu S. Samal & **S Bal**, ICONSAT-2008 (Feb.17-29), Chennai.
- XXI. ***Study of Mechanical and Morphological Properties of Aligned and Randomly Oriented Carbon Nanotube Composites-*** Subhranshu Sekhar Samal & **Smrutisikha Bal**, International Conference on Emerging Scenarios in Space Technology & Applications-2008, 13<sup>th</sup>-15<sup>th</sup> November (Advanced Materials & Reliability) ISRO, Bangalore. **(Received Best Research Paper Award)**
- XXII. ***Carbon nanotube reinforced epoxy nanocomposites and analysis of their properties,*** **S. Bal**, 25th Annual meeting of polymer processing society (PPS-25), 1st-5th March, 2009, Goa.
- XXIII. ***Carbon nanotube and Carbon nanofiber polymer composites: A comparative assessment,*** **Smrutisikha Bal**, First International Conference on Composites and Nanocomposites (ICNC 2011): January 7, 8 and 9, 2011, Kottayam, Kerala, India.
- XXIV. ***Mechanical characterization of epoxy composite doped aligned carbon nanotubes,*** **Smrutisikha Bal**, National conference on processing and characterization of materials (NCPCN 2011), 2-3 Dec, 2011, NIT Roukela.
- XXV. ***Microscopic analysis of mechanical properties of aligned carbon nanotube/epoxy composite*** – **S. Bal**, J.P. Borah and C. Bergheim, ICANN 2011, DEC 8-10, IIT GUWAHATI.
- XXVI. ***Carbon nanotube dispersed liquid crystal medium: a state of the art-*** S. P. Choudhury, A. Bhattacharjee and **S. Bal**, ICNANO 2011, DEC 18-21, NEW DELHI.
- XXVII. ***Comparison and analysis of physical properties of Carbon nanomaterial doped polymer Fabrication and Characterization of Aligned and Functionalized Nanotube Polymer Composites*** - **Smrutisikha Bal**, Snigdha Bhattacharjee and Sunirmal Saha, INTERNATIONAL SYMPOSIUM ON MACRO- AND SUPRAMOLECULAR ARCHITECTURES AND MATERIALS (MAM-12), Nov 21-25, 2012, Centre for Nano Science and Technology, K.S. Rangasamy College of Technology, Tamil Nadu, India.
- XXVIII. ***Microscopic analysis of mechanical properties of functionalised carbon nanotube/epoxy composite-*** **Smrutisikha Bal**, Sunirmal Saha & Snigdha Bhattacharjee, International Symposium for Research Scholars on



- Metallurgy, Materials Science and Engineering (ISRS-12), December 13-15, 2012, Indian Institute of Technology Madras, Chennai.
- XXIX. ***Fabrication and Characterization of Aligned and Functionalized Nanotube Polymer Composites*** - Smrutisikha Bal, Snigdha Bhattacharjee and Sunirmal Saha, Twenty first International Symposium on Processing and Fabrication of Advanced Materials(PFAM XXI), Dec 10-13, 2012, Dept. of Mechanical Engineering, IIT Guwahati.
- XXX. ***Assessment of Electrical and Mechanical Properties of Carbon nanomaterial Doped Polymer Composites*** – Smrutisikha Bal & Sunirmal Saha, 2nd International Conference on Advances in Energy Conversion Technologies (ICAECT 2014), pp. 109-113, Jan 23-25, 2014, Manipal Institute of Technology, Manipal.
- XXXI. ***Multiwall Carbon Nanotube reinforced polymer composites: A comparative study*** - Smrutisikha Bal, International Conference on Nanoscience + Technology (ICNT' 2014), Vail, Colorado, USA, July 20-25, 2014.
- XXXII. ***Mechanical and microscopical investigation of sea water conditioned CNT/epoxy composites*** – Smrutisikha Bal and Sunirmal Saha, 7th National symposium for Materials Research scholars, IIT Bombay, pg. no. 64, May 20-22, 2015.
- XXXIII. ***Emerging Technology for Shielding of Electromagnetic Radiation Using Composite Materials-*** S Bal and S Saha, International Conference on Emerging Trends in Engineering and Technology (ICET-15), Mangalore, 23 Aug, 2015. pg. no. 46-50.
- XXXIV. ***Micro graphical analysis and comparison of MWNT and CNF reinforced polymer composite*** - Smrutisikha Bal, 3<sup>rd</sup> International Multidisciplinary Microscopy and Microanalysis Congress & Exhibition (InterM), October 19-23, 2015 in Oludeniz, Fethiye / Mugla-TURKEY.
- XXXV. ***Fabrication and characterization of carbon nanofiber (CNF) based epoxy composites***, S. Bal and S. Saha, IOP Conference Series Materials Science and Engineering 2015, DOI: 10.1088/1757-899X/75/1/012018
- XXXVI. ***Scheming of microwave shielding effectiveness for X band considering functionalized MWNT/epoxy composites***, S. Bal and S. Saha, IOP Conference Series Materials Science and Engineering, 2016, DOI: 10.1088/1757-899X/115/1/012027
- XXXVII. ***Investigation of adverse effect of CNT' functionalization on the long term water conditioned CNT/epoxy composites***, S. Bal and S. Saha, 9th International Conference on Materials for Advanced Technologies (ICMAT 2017), Materials Research Society, Suntec, Singapore, June 18 – 23, 2017
- XXXVIII. ***Degradation in Mechanical and Thermal Properties of Partially Aligned CNT/Epoxy Composites due to Seawater Absorption***, S. Bal and S. Saha, IOP Conference Series: Materials Science and Engineering, vol. 178, no. 1, pp. -, 2017,

- XXXIX. ***Analysis and comparison of CNF and ACNT reinforced epoxy composite using microscopic technique***, Smrutisikha Bal, International Conference on Microscope and XXXIX Annual Meeting of Electron Microscope Society of India (EMSI 2018), 18 - 20 July, 2018 at Mayfair Convention Center, Bhubaneswar.
- XL. Comparative study of structural parameters of normal and acid treated polyester fiber by SAXS, XRD, SEM and Instron – T.Patel, **S.Bal.** & B.Mallick-p16.12.001, IUCR 99-International conference on SAXS, Brookhaven national lab, Long Island, Uptown, New york, 1999.
- XLI. Investigation of physical and macromolecular parameters of normal and alkali treated polyester fibers by SAXS, XRD, SEM and Instron- T.Patel, **S.Bal.** & B.Mallick- A comparative study-XI International conference on Small-angle scattering (SAS-99, May 18, 1999), Polymer processing session program.
- XLII. Structural analysis of Polyester by Small-angle X-ray Scattering- T.Patel, **S.Bal.** & B.Mallick-Indian Science Congress Association-Jan99.
- XLIII. Small Angle X-ray scattering investigation of graft Co-polymer of Methyl Methacrylate on to Nylon-6 fiber using correlation function- T.Patel, S. S. Khuntia, D. Nayak, **S. Bal.** & Rita Patel, ISCA, Jan. 1998.
- XLIV. X-ray investigation of Polyester and surf treated Polyester (PET) fibers- T.Patel, **S.Bal.** & B.Mallick, ISCA, Jan. 1998.
- XLV. Small Angle X-ray scattering study of normal and acid treated high tech polyester fiber- T.Patel & **S.Bal.**, National seminar on “Advanced materials”, Govt. college, Rourkela, p40, 2002.
- XLVI. Structural investigation of normal and treated polyester fiber by SAXS and other techniques - T.Patel & **S.Bal.**, Indian Science Congress Association, 2004.
- XLVII. Effect of changing environments on microstructure of HDPE polymer- **S. Bal**, D. Mahesh, T.K. Sen & B.C. Ray, National conference on PMIP, 20-21 November, 2004, NITR, 2004, pp-44-49
- XLVIII. Effect of changing environment on mechanical behaviour of HDPE & LDPE polymer – **S.Bal**, D.Mahesh, T.K.Sen & B.C.Ray, 92<sup>nd</sup> Indian Science Congress Association, Ahmedabad, Jan 3-7, 2005.
- XLIX. Under-representation of Women And Strategies To Encourage Them In Science and Technology:An Analysis – **S. Bal**, National seminar in ‘Women in Science and Technology: issues and Concerns (WISTIP-2005), Jan-8-9, pp-121-131.
- L. Crystalline Behaviour And Properties Of Chemical Treated Polyester Fibers – **S. Bal**, Y. Nayak and R.C. Behera, NSPAET-2005, VNIT, Nagpur, 3<sup>rd</sup>-5<sup>th</sup> March, 2005.