Biodata of

Dr. Laxmidhar Besra

1. Name : **Dr. LAXMIDHAR BESRA**
2. Date of Birth : **16 May 1969**
3. Current Position and Address :

Senior Principal Scientist, &
Professor- Academy of Scientific & Innovative Research (AcSIR)
CSIR-Institute of Minerals & Materials Technology (IMMT)
Bhubaneswar 751 -13, Odisha, INDIA

4. Educational Qualification

Sl No.	Degree/ Certificate	Year of Passing	University Institute	Subjects
1	PhD	2003	Indian Institute of Technology (IIT) Kharagpur, India	Metallurgical & Materials Engineering
2	Master of Engineering	1993	Indian Institute of Science (IISc), Bangalore, India	Metallurgical Engineering
3	Bachelor of Engineering	1991	National Institute of Technology (NIT), Rourkela, India	Metallurgical Engineering

5. Academic/Research Experience/Employment

Sl No.	From	To	Name of Organization	Position held
1	Feb 2011	Till date	Institute of Minerals and Material Technology (IMMT), Bhubaneswar, Odisha, India	Senior Principal Scientist & Professor AcSIR
2	Feb 2007	Jan 2011	Institute of Minerals and Material Technology (IMMT), Bhubaneswar, Odisha, India	Principal Scientist & Associate Professor AcSIR
3	Sept 2008	Nov 2008	National Institute for Materials Science (NIMS), Tsukuba, Japan	NIMS Invitation Fellow
4	June 2007	May 2008	National Institute for Materials Science (NIMS), Tsukuba, Japan	NIMS Post-doctoral fellow
5	Jan 2004	Jan 2005	Georgia Institute of Technology, USA	Post-doctoral Fellow
6	Feb 2003	Jan 2007	Institute of Minerals and Material Technology (IMMT), Bhubaneswar, Odisha, India	Scientist E-I
7	Oct 1998	Dec 1999	Brandenburgische Technishe Universitaet, Cottbus, Germany	Guest Researcher
8	Feb 1998	Jan 2003	Regional Research Laboratory (RRL) Bhubaneswar, Odisha, India	Scientist –C

9	Feb 1993	Jan 1998	Regional Research Laboratory (RRL) Bhubaneswar, Odisha, India	Scientist-B

6. Area of Specialization
   Broad subject area: Metallurgical and Materials Engineering

   Specific areas of interest are:

   1. Advanced materials processing and coatings by Electrophoretic deposition (EPD)
   2. Colloidal processing of ceramics- Gelcasting, slipcasting, tapecasting etc.
   3. Solid oxide fuel cells (SOFC)
   4. Interfacial phenomena of particle suspensions
   5. Mineral Processing- size reduction, flotation, gravity separation
   6. Solid-liquid separation including flocculation and dewatering of industrial sludges
   7. Dispersion and stability of suspensions.

7. Honors/Awards received

Awards:

1. **Advanced Research Award**-2012. Japan Society for Powder & Powder Metallurgy
2. **NASA Technology Brief Award**-2007 for the technology titled "Electrophoretic deposition on non-conducting substrates".
3. **NIMS Postdoctoral Fellowship** of National Institute for Materials Science (NIMS), Tsukuba, Japan, 2007.
4. **IIME Best Paper published Award** on Environment Issues related to Mineral Processing for the year 2007 -for the paper titled "Flocculation improves uptake of ^{90}Sr and ^{137}Cs from radioactive effluents" by Tapan K. Rout, Dilip K. Sengupta and Laxmidhar Besra, published in Int. J. Miner. Process. 79, 2006, pp. 225-234. The Award is instituted by Indian Institute of Mineral Engineers
5. **IIME Best paper award on Beneficiation** for year 2004 – for the paper titled "Effect of additives on electro-kinetic properties of colloidal alumina suspension" published in J. colloid & Interface Science, 254, pp.95-100 (2002), instituted by Indian Institute of Mineral Engineers.
6. **Fellowship under "Better Opportunities for Young Scientists in Chosen areas of Science and Technology (BOYSCAST)",** Department of Science and Technology, Govt of India, 2003-04.
7. **German Academic Exchange Service (DAAD) Fellowship** (Sandwich Model), 1998-99.
8. **GATE Scholarship**, 1991-92.
9. **2nd prize in Students Technical Quiz**- Indian Institute of Metals, Rourkela Chapter, 1989-90.

Honors:

Invited to deliver the following Keynote lectures and Invited talks in International Conferences:

Sl No	Type of presentation (Keynote/ Invited)	Authors	Title of the paper	Details of the Conference

1	Keynote	**L.Besra**	Electrophoretic Deposition as a Versatile Coating Technique for Corrosion Prevention	4th International Conference for Advanced Materials and Materials Processing (ICAMMP-IV), IIT Kharagpur. INDIA. 5-7 Nov 2016.
2	Keynote	**L.Besra**	Electrophoretic Deposition as a Versatile Technique for Advanced Materials and Coatings: Interfacial Phenomena	67th Annual Meeting of the International Society of Electrochemistry. The Hague, THE NETHELANDS. 21-26 August 2016. S-14, 53
3	Invited	S. Dey, S. Bhattacharjee, T. K. Rout, D. K. Sengupta, T. Uchikoshi and **L. Besra**	Effect of Electrode Reactions during Aqueous Electrophoretic Deposition on Bulk Suspension Properties and Deposition Quality	5th International Conference on Electrophoretic deposition: Fundamentals and Applications (EPD-2014), 9-10 October, AUSTRIA
4	Keynote	**L. Besra**.	Electrophoretic deposition: A versatile technique for advanced functional materials and coatings.	6th International conference on Science & Technology of Advanced Ceramics (STAC), June 26-28, 2012, Yokohama, JAPAN
5	Invited	**L. Besra**, C. Compson, S. M.Majhi, S. Bhattacharjee, B. P. Singh, M. Liu	Electrophoretic deposition on non-conducting substrates for Solid oxide fuel cell application.	4th International conference on Electrophoretic deposition: Fundamentals & Applications, 2-7th October 2011, Puerto Vallarta, MEXICO

<u>Journal Editor:</u>
Guest edited a special issue on “Electrophoretic Deposition” in the journal **“Coatings**” in 2017 along with Prof. Aldo R. Boccaccini Institute of Biomaterials, Department of Materials Science and Engineering, University of Erlangen-Nuremberg, Erlangen, Germany and Prof. Dr. Begoña Ferrari Instituto de Cerámica y Vidrio, CSIC, Madrid, Spain.

8. Professional Affiliations

Membership of professional Societies:

(i) Indian Institute of Mineral Engineers (IIME)
(ii) Indian Institute of Metals (IIM)
(iii) Indian Institute of Chemical Engineers (IIChE)
(iv) Institution of Engineers (India) Ltd
(v) International Society of Electrochemistry (ISE)

Peer reviewer of Journals:

(i) Journal of the European ceramic Society
(ii) Journal of the American Ceramic Society
(iii) International Journal of Applied Ceramic Technology
(iv) Journal of Alloy and Compounds
(v) Portugalia Electrochemica Acta
(vi) International Journal of Hydrogen Energy
(vii) Applied Clay Science
(viii) Journal of Materials Chemistry
(ix) Environmental Science and Technology
(x) Journal of Colloid & Interface Science
(xi) International journal of Mineral processing
(xii) Separation and Purification Technology
(xiii) Industrial & Engineering Chemistry
(xiv) Materials Science & Engineering B
(xv) Materials Letters

9. Research Projects (ongoing and completed)

Sl. No	**Project title**	**Project Category**	**Funding agency**	**Role played**
1	Electrophoretic deposition for Industrial applications	Fast-track translational project	CSIR. New Delhi	Principal Investigator
2	Scale up of Electrophoretic Deposition (EPD) and Colloidal-based Coating for Industrial Application	Translational project	CSIR. New Delhi	Principal Investigator
3	Biogas utilization through fuel flexible SOFC	Grant-in aid Indo-UK project	DST (India) RCUK (UK)	Principal Investigator
4	High temperature diffusion conducting ceramic coatings on steel/high strength steel by Electrophoretic deposition (EPD) for active corrosion protection	Industry Sponsored	M/s TATA Steel Europe, Nederland	Principal Investigator
5	Design and development of functional hybrid nanostructure for photoelectrochemical water splitting.	Grant-in aid	Ministry of New & Renewable Energy (MNRE), New Delhi	Co- Principal Investigator

6	Graphene reinforced polymer nanocomposite as environment barrier coating.	Grant-in aid	BRNS, DAE Mumbai	Team Member
7	Development of oxide based thermoelectric material	Grant-in aid	BRNS, DAE Mumbai	Team Member
8	Development of platinum free hybrid electrocatalyst based on nanostructured metal particles and graphene for fuel cell applications.	Grant-in aid	MNRE, New Delhi	Team Member
9	Development of high performance Intermediate temperature Solid oxide fuel cells (IT-SOFC) by low-cost ceramic processing techniques.	Grant-in aid	MNRE, New Delhi	Principal Investigator
10	Nano-material & Nanodevices for Applications in Health & Diseases (CSIR Network project)	CSIR Network project	CSIR, New Delhi	Co- Principal Investigator
11	Cost-effective diamond coating on industrial polishing wheels by Electrophoretic deposition (EPD)	Industry Sponsored	M/s. Mesacon Enterprise, Mumbai	Principal Investigator
12	Template assisted Electrophoretic & Electrolytic deposition for preparation of ordered nanostructured arrays for advanced functional materials	Grant-in aid	BRNS, DAE Mumbai	Principal Investigator
13	Development of Planar Solid oxide Fuel cell (SOFC) system by Electrophoretic deposition (EPD)	Collaborative	NMRL, Ambernath	Co- Principal Investigator
14	Dispersion of nano particles colloidal suspensions for shaping process	Grant-in aid	DST, New Delhi	Team Member
15	Characterization and Optimization of Process Parameters to Prepare Slurry suitable for Tapecasting using YSZ	Collaborative	NMRL, Ambernath	Co- Principal Investigator
16	Nanostructured ceramic coatings by electrophoretic deposition	Grant-in aid	DST, New Delhi	Principal Investigator
17	Development of Low Toxicity Environment Friendly Gel-	Grant-in aid	Ministry of Environment &	Team Member

	casting System for Industrial Application		Forest (MOEF), Gov. of India	
18	Development of Innovative process for Selection of Flotation Collectors in Mineral Industry	Grant-in aid	DST, New Delhi	Co- Principal Investigator
19	Coal preparation and quality enhancement	CSIR Network project	CSIR, New Delhi	Team Member
20	Development of Porous Bio-implant	Grant-in aid	Department of Biotechnology (DBT), New Delhi	Team Member
21	Improvement in dewaterability of Industrial sludges by Flocculation	Grant-in aid	BRNS, DAE Mumbai	Team Member
22	Development of a process for recycling coal-washery waste water by clarification flocculation	Inhouse exploratory	CSIR, New Delhi	Principal Investigator
23	Improvement on performance of Spiral concentrators by statistical analysis and Computer aided methods	Industry Sponsored	M/s. Indian Rare Earths Limited (IREL), Chhatrapur	Co- Principal Investigator
24	Dewaterability study to suggest suitable system for Joda iron ore fines	Industry Sponsored	M/s. Tata Steel, Jamshedpur	Co- Principal Investigator
25	Beneficiation of sillimanite using flotation column	Industry Sponsored	M/s. Indian Rare Earths Limited (IREL), Bombay	Team Member
26	Coal beneficiation and slurry combustion	CSIR Mission programme	CSIR, New Delhi	Team Member
27	Upgradation of low grade bauxite for refractory and ceramic application	Grant-in aid	DST, New Delhi	Team Member

10. Books authored/edited: 3 Book chapters
    (i) Partho Sarkar, Debnath De, Tetsuo Uchikoshi, **Laxmidhar Besra**. Electrophoretic Deposition (EPD): Fundamentals and Novel Applications in Fabrication of Advanced Ceramic Microstructures. In *Electrophoretic Deposition of Nanomaterials, Nanostructure Science and Technology*. J. H. Dickerson, A. R. Boccaccini (eds.), **Springer Science, LLC**, 2012.
    (ii) Maria Cannio, Sasa Novak, **Laxmidhar Besra**, Aldo R. Boccaccini. Electrophoretic deposition. In *Processing Approaches for Ceramics and Composites*. Narottam Bansal and Aldo Boccaccini (eds). **John Wiley & Sons**, Inc, NJ. 2012
    (iii) **Laxmidhar Besra**. An Introduction to Zeta Potential: Basic Concepts, Applications, Measurements and recent techniques. MIneral Characterization and Processing, edited by Vibhuti N. Misra, P. S. R. Reddy, B. K. Mohapatra, Allied Publishers New Delhi, 2004

11. (a) Patents granted /applied

(i) Sarama Bhattacharjee, Purna C. Rath, Yatendra S. Chaudhary, Bimal P. Singh**, Laxmidhar Besra**. An Improved Process for Producing Adhere Synthetic Apatite Coating on Titanium/ Titanium Alloy Surfaces. Ref. No: CSIR Ref. No. -167NF2010, Date: 26 October 2010, Year: 01/2010

(ii) B.R. Reddy, G.N. Banerjee, R.B. Rao, **L. Besra**, S.K. Mishra, D.K. Dey, H.S. Ray. A process for the production of refractory grade bauxite from ferrugineous bauxite. CSIR Ref No.- 0366NF1997, date: 12 January 1999. Application No. 0057DEL1999, Patent No. 226573

(b) Technologies developed, Licenced and /or commercialized with details.
Please see Annexure-IV

12. Dissertations supervised

(a) PhD:
Guiding 1 Ph. D student: Sanjukta Dey , AcSIR; Topic: Electrophoretic deposition of ceramics on metals for active corrosion protection.

(b) Post-Graduation projects:

Guided 2 students (M.Tech) for their projects

1. Deepak Joshi, M.Tech, IIT Bhubaneswar- 2014. Sulphur tolerant anode material for Solid oxide fuel cells
2. Ashwani Pandey, M.Tech, IIT Bhubaneswar- 2015. Identification of phase in-homogeneities in Na doped $SrSiO_3$ electrolytes for low temperature SOFCs.

(c) Under-graduation summer projects guided: 5

ANNEXURE-I

LIST OF RESEARCH PUBLICATIONS IN REFEREED JOURNALS

(Average Impact Factor: 2.398)

Sl No	Authors	Year	Title of the paper	Journal, volume, year and page
77	S. Dey, S. Chatterjee, B.P.Singh, S.Bhattacharjee, T. K. Rout, D. K.Sengupta, **L. Besra**	2018	Development of Superhydrophobic Corrosion Resistance Coating on Mild Steel by Electrophoretic Deposition	*Surface & Coatings Technology.* 2018, 341, 24-30 **IF. 2.589**
76	N. Usha Kiran, S. Dey, B. P. Singh and **L. Besra.**	2017	Graphene Coating on Copper by Electrophoretic Deposition for Corrosion Prevention.	*Coatings. 2017, 7(12), 214; doi:10.3390/coatings7120214* **IF: 2.175**
75	S. C. Sahu, B. Satpati, **L. Besra** and Bikash Kumar Jena	2015	A Bifunctional Nanoelectrocatalyst Based on Flower-like Au/Pd Bimetallic Alloy Nanostructure and Its Graphene Hybrid	*ChemCatChem*, 2015, 7, 4042–4049 **IF =4.724**
74	K.K.Nanda, S.Swain, B.Satpati, **L.Besra**, B.Mishra, Y.S.Chaudhary.	2015	Enhanced photocatalytic activity and charge carrier dynamics of hetero-structured organic-inorganic nano-photocatalysts	*ACS Applied Materials & Interfaces*, *2015,* ***7*** *(15), 7970–7978.* **IF =7.145**
73	S. Dey, S. Bhattacharjee1, T. K. Rout, D. K. Sengupta, T. Uchikoshi, and **L. Besra**	2015	Effect of Electrode Reactions during Aqueous Electrophoretic Deposition on Bulk Suspension Properties and Deposition Quality	*Key Engineering Materials, 2015, 654, 3-9.* **IF =0.39**
72	S. K.Ojha, S. Mishra, V. K. Malesu, P. K. Singh, K. Naik, S. Panda, **L.Besra**, M. Suar	2014	In situ Physicochemical and Microbial Changes During Kitchen Refuse Biogasification	*Journal of Advanced Microbiology, 2014, 1 (6), 338 – 349* **IF =0.00**
71	K. K. Nanda, S. Swain, B. Satpati, **L.Besra** and Y.S. Chaudhary.	2014	Facile synthesis and the photo-catalytic behavior of core–shell nanorods	*RSC Adv., 2014, 4, 10928–10934.* **IF =3.289**
70	T. Uchikoshi, L. Kreethawate, C. Matsunaga, S. Larpkiattaworn, S. Jiemsirilers, **L. Besra**	2014	Fabrication of ceramic membranes on porous ceramic supports by electrophoretic deposition	*Advances in Applied Ceramics. 2014, 113(1), 3-7* **IF =1.163**
69	BP Singh, BK Jena, S Bhattacharjee, **L**	2013	Development of oxidation and corrosion resistance hydrophobic graphene oxide-	*Surface and Coatings Technology*, 2013, 232, pp. 475–481

	Besra		polymer composite coating on copper	**IF =1.998**
68	S Panigrahi, RC Biswal, S Anwar, **L Besra**, S Bhattacharjee	2013	Temperature Dependence of Ionic Conductivity of Ceria Electrolyte at Concentrated Range of Multiple Doping	*Journal of the American Ceramic Society. 2013,96(9), 2846–2851* **IF =2.787**
67	B. P. Singh, S.Nayak, K.K. Nanda, B.K.Jena, S.Bhattacharjee, **L. Besra**	2013	The production of a corrosion resistant graphene reinforced composite coating on copper by electrophoretic deposition	*Carbon. 61 (2013) 47–56.* **IF =6.196**
66	P. C. Ratha, S. Nayaka, S. Bhattacharjee, **L. Besra**, B. P. Singh.	2013	Nanotitania-coated multi-walled carbon nanotube composite by facile colloidal processing route for photocatalytic applications	*Composite Interfaces,2013, 21(3), 251–262.* **IF =1.046**
65	P.C. Rath, B.P. Singh, **L.Besra**, S. Bhattacharjee	2012	Multi-walled carbon nanotube reinforced hydroxyapatite – chitosan composite coating on Ti metal: Corrosion and mechanical properties	*Journal of the American Ceramic Society*, 2012, 25(9), 2725-2731 **IF =2.787**
64	M Mishra, Y Sakka, C Hu, TS Suzuki, T Uchikoshi, **L Besra**	2012	Electrophoretic Deposition of Ti3SiC2 and Texture Development in a Strong Magnetic Field	*Journal of the American Ceramic Society,* 2012 (in press). **IF =2.787**
63	Y Sakka, TS Suzuki, T Uchikoshi, CF Hu, M Mishra, **L Besra**	2012	Textured Ti3SiC2 by EPD in a Strong Magnetic Field	Key Engineering Materials, 2012, 507, 15-19 **IF =0.39**
62	P.C.Rath, **L. Besra**, B.P. Singh, S. Bhattacharjee	2012	Titania/hydroxyapatite bi-layer coating on Ti metal by electrophoretic deposition: Characterization and corrosion studies	*Ceramics International, 2012, 38 (4), 3209-3216.* **IF =2.605**
61	B. P. Singh, S. Nayak, S. Samal, S. Bhattacharjee, **L. Besra**	2012	Characterization and dispersion of multi-walled carbon nanotubes (MWCNT) in aqueous suspension: surface chemistry aspect.	*Journal of Dispersion Science & Technology, 2012, 33 (7), 1021-1029.* **IF =0.795**
60	B. P. Singh, S. Nayak, S. Samal, S. Bhattacharjee, **L. Besra**	2012	The role of poly(methacrylic acid) conformation on dispersion behavior of nano TiO_2 powder	*Applied Surface Sci,. 2012, 258, 3524-3531.* **IF =2.711**
59	B.P. Singh, S. Samal, S. Nayak, S.M. Majhi, **L. Besra**, S. Bhattacharjee	2011	The production of a multi-walled carbon nanotube/hexamethylene diisocyanate nanocomposite coating on copper by electrophoretic deposition	*Surface and Coatings Technology, 2011, 206 (6), 1319-1326.* **IF =1.998**
58	S.Nayak, B.P. Singh, **L. Besra**, T.K. Chongdar,	2011	Aqueous tape casting using organic binder: A case study with YSZ	*Journal of the American Ceramic Society, 2011, 94 (11), 3742-3747.* **IF =2.787**

	N.M.Gokhale, S. Bhattacharjee			
57	S. M. Majhi, S. K. Behura, S. Bhattacharjee, B.P. Singh, T.K. Chongdar, N.M. Gokhale, **L. Besra.**	2011	Anode supported solid oxide fuel cells (SOFC) by Electrophoretic deposition	*International Journal of Hydrogen Energy, 2011*, 36 (22), 14930-14935. **IF =3.313**
56	S. Panigrahi, **L. Besra**, B. P.Singh, S. P. Sinha, S. Bhattacharjee	2011	Electrophoretic Deposition of Doped Ceria in Antigravity Set-up.	*Adv. Powder Technology, 2011, 22(5), 570-575.* **IF =2.478**
55	L. Kreethawate, S. Larpkiattaworn, S. Jiemsirilers, **L. Besra**, T. Uchikoshi	2010	Application of Electrophoretic deposition for inner surface coating of porous ceramic tubes	*Surface & Coatings Technology*, 205(7), 1922-1928, 2010. **IF =1.998**
54	M. Mishra, S. Bhattacharjee, **L.Besra**, H.S. Sharma, T.Uchikoshi, Y. Sakka	2010	Effect of pH localization on microstructure evolution of deposits during aqueous electrophoretic deposition (EPD)	*Journal of the European ceramic Society*, 30(12), 2010, 2467-2473. **IF =2.933**
53	**L. Besra**, T. Uchikoshi, T.S. Suzuki, Y. Sakka	2010	Experimental verification of pH localization mechanism of particle consolidation at the electrode/solution interface and its application to pulsed DC Electrophoretic deposition (EPD)	*J. European Ceramic Society*, 30, 2010, 1187-1193 **IF =2.933**
52	S. Panigrahi, S. Bhattacharjee, **L. Besra,** B. P. Singh, S.P. Sinha	2010	Electrophoretic deposition of doped ceria: Effect of solvents on deposition microstructure	*J. European Ceramic Society*, 30, 2010, 1097-1103. **IF =2.933**
51	**L. Besra**, T. Uchikoshi, T.S. Suzuku, Y. Sakka.	2009	Pulsed-DC electrophoretic deposition (EPD) of aqueous alumina suspension for controlling bubble incorporation and deposit microstructure	*Key Engineering Materials*, 412, 2009, 39-44. **IF =0.39**
50	**L. Besra**, T. Uchikoshi, T.S. Suzuki, Y. Sakka	2009	Application of constant current pulse to suppress bubble incorporation and control deposit morphology during aqueous Electrophoretic deposition (EPD).	*Journal of European Ceramic Society*, 29(10) 2009, 1837-1845. **IF =2.933**
49	M. Kawakita, T. Uchikoshi**, L. Besra**, T. S. Suzuki, J. Kawakita, Y. Sakka	2009	Formation of crystalline-oriented titania thin films on ITO glass electrodes by electrophoretic deposition in a strong magnetic field	*Key Engineering Materials*, 412, 2009, 143-148 **IF =0.39**

48	**L. Besra**, T. Uchikoshi, T.S. Suzuki, Y. Sakka.	2008	Bubble-free aqueous electrophoretic deposition (EPD) by pulse potential application	*Journal of the American ceramic Society*, 91(10), 2008, 3154-3159. **IF =2.787**
47	G. Mohanty, **L.Besra**, S. Bhattacharjee, and B.P. Singh	2008	Optimisation of Electrophoretic deposition of alumina onto steel substrates from its suspension in iso-propanol using statistical design of experiments	*Materials Research Bulletin.* 43 (7),2008,1814-1828 **IF =2.435**
46	**L. Besra** and M. Liu	2007	A review on fundamental and applications of Electrophoretic deposition	*Progress in Materials Science*, 52 (1), 2007, 1-61 **IF =31.083**
45	**L. Besra** and M. Liu	2007	Electrophoretic deposition on non conducting substrates: The case of YSZ film on NiO-YSZ composite substrates for Solid oxide fuel cell application	*Journal of Power Sources,* 173(1), 2007, pp. 130-136 **IF =6.333**
44	**L. Besra**, P. Samantaray, S. Bhattacharjee, and B.P. Singh	2007	Electrophoretic deposition of alumina on stainless steel from non-aqueous suspension	*Journal of Materials Science,42(14),* 2007, pp.5714-5721 **IF =2.302**
43	S. Bhattacharjee, **L. Besra,** B. P.Singh	2007	Effect of additives on the microstructure of porous alumina	*J. European. Ceram. Soc, 2007,* 27(1) , 47-52. **IF =2.933**
42	C. Compson, **L. Besra** and M. Liu	2006	Modeling Electrophoretic Deposition on Porous Non-conducting Substrates using Statistical Design of Experiment	*J. Am Ceram. Soc*, 89(9), 2006, 2787-2795. **IF =2.787**
41	**L. Besra** , C. Compson and M. Liu	2006	Electrophoretic deposition of YSZ particles on porous non-conducting NiO-YSZ for solid oxide fuel cell (SOFC) applications	*J. Am Ceram.Soc*. 89 (10), 2006, pp. 3003-3009 **IF =2.787**
40	**L.Besra**, S. Zha and M. Liu	2006	Preparation of NiO-YSZ/YSZ Bi-layers for Solid Oxide Fuel Cells by Electrophoretic Deposition	*J. Power Sources*. 160, 2006, 207-214 **IF =6.333**
39	T.K. Rout, **L. Besra**, D.K. Sengupta and P.S.R. Reddy	2006	Flocculation improves uptake of ^{90}Sr and ^{137}Cs from radioactive effluents	*International Journal of Mineral Processing,* 79(4), 2006, 225-234. **IF =1.617**
38	**L.Besra,** D.K. Sengupta and S.K. Roy	2006	Influence of unadsorbed and weakly adsorbed flocculants on separation properties of kaolin suspensions	*International Journal of Mineral Processing,* 78, 2006, 101-109. **IF =1.617**
37	B.P. Singh, S.Bhattacharjee, **L.Besra**, D. K.Sengupta**.**	2005	Electrokinetics and adsorption studies of alumina suspensions using Darvan C as dispersant.	*J.Colloid & Interface Science, 289 (2) (2005) 592-596.* **IF =3.782**
36	S. Bhattacharjee, B.P. Singh, **L. Besra** & D. K.Sengupta	2005	Performance evaluation of dispersants through streaming potential measurements	*J.Dispersion Science & Technology*, 26 (3) 2005, 234-240. **IF =0.97**
35	**L. Besra,** D.K. Sengupta, B. P.	2005	A novel method based on Capillary Suction Time (CST)	*J. Am Ceram.Soc*. 88[1], 109-113(2005).

	Singh and S. Bhattacharjee		for assessment of dispersion characteristics of suspensions	**IF =2.787**
34	**L.Besra,**, D.K.Sengupta, S.K. Roy and P. Ay	2004	Influence of polymer adsorption and conformation on flocculation and dewatering of kaolin suspension.	*Separation and Purification Technology*, 37, 2004, pp.231-146. **IF =3.299**
33	B.P. Singh, S.Bhattacharjee, **L.Besra**, D. K.Sengupta	2004	Comparison between techniques based on Charge characterisation and Capillary Suction Time (CST) for assessing the dispersion characteristics of concentrated slurry	*Journal of Material Science,* 39, 2004, pp.2437-2442. **IF =2.302**
32	B.P. Singh, S.Bhattacharjee, **L.Besra**, D. K.Sengupta	2004	Evaluation of dispersibility of aqueous alumina suspension in presence of Darvan C	*Ceramic International***,** 30, 2004, pp.939-946 **IF =2.758**
31	B.P. Singh, S.Bhattacharjee, **L.Besra**, D. K.Sengupta	2004	Use of polymeric and other organic additives in ceramic slurry processing for casting: a review	*Trans. Indian Ceramic Society*, 63(1) Jan-March (2004) 1-11. **IF =0.548**
30	B P.Singh, S. Bhattacharjee and **L. Besra**, D.K. Sengupta and V.N. Misra	2003	Raw materials and processing techniques for advanced ceramics and Indian scenario	*Trans. Indian Inst. Metals,* 56 (2) 2003, pp.141-154. **IF =0.502**
29	B. P Singh, **L. Besra** and D. K. Sengupta	2003	The economics of coal utilization challenges and solutions.	*Mines, Metal and Fuels*. Vol. XLVIII (1) (2003) 16-21. **IF =0.19**
28	**L.Besra,**, D.K.Sengupta, S.K. Roy and P. Ay	2003	Influence of surfactants on flocculation and dewatering of kaolin suspensions by cationic polyacrylamide (PAM-C) flocculant	*Separation and Purification Technology* , 30, 2003, pp. 251-264. **IF =3.299**
27	S. Bhattacharjee, B.P. Singh and **L.Besra**	2002	Effect of additives on Electrokinetic properties of colloidal alumina suspension.	*Journal of colloid and interface science* 254, 2002, pp. 95-100. **IF =3.782**
26	B. P. Singh, S. Bhattacharjee and **L.Besra**	2002	Influence of Surface Charge on Maximizing Solids Loading in Colloidal Processing of Alumina	*Materials Letters*. Vol. 56 No. 5 (2002) 475-480. **IF =2.437**
25	**L.Besra**, D.K.Sengupta, S.K. Roy and P. Ay	2002	Polymer adsorption: Its correlation with flocculation and dewatering of kaolin suspensions in presence and absence of surfactants	*International Journal of Mineral Processing*, 66 (1-4), 2002**,** pp.183-202 **IF =1.617**
24	B. P. Singh, S. Bhattacharjee and **L.Besra**	2002	Optimisation of performance of dispersants in aqueous plasma dissociated zircon suspension.	*Ceramic International*. 28 (4), 2002, pp.413-417. **IF =2.758**
23	**L.Besra**, D.K.Sengupta, S.K. Roy and P. Ay	2002	Flocculation and dewatering of kaolin suspensions in the presence of polyacrylamide and surfactants	*International Journal of Mineral Processing*, 66 (1-4), 2002, pp.203-232. **IF =1.617**

22	B.P.Singh, **L.Besra,** and S. Bhattacharjee	2002	Factorial design of experiments on the effect of surface charge on stability of aqueous colloidal ceramic suspension.	*Colloids and Surfaces A: Physicochemical and Engineering aspects*. 204 (1-3), 2002, pp.175-181. **IF =2.760**
21	**L.Besra**, D.K.Sengupta, S.K. Roy and P. Ay	2002	Studies on flocculation and dewatering of kaolin suspensions by anionic polyacrylamide flocculant in the presence of some surfactants	*International Journal of Mineral Procesing* , 66 (1-4), 2002, pp.1-28 **IF =1.617**
19	**L.Besra**, D.K. Sengupta and S.K. Roy	2000	Particle characteristics and its influence on dewatering of kaolin, calcite and quartz suspensions	*International Journal of Mineral Processing*, 59 (2), 2000, pp.89-112. **IF =1.617**
18	P.K.Banerjee, P.V.T.Rao, B. P. Singh, and **L.Besra**	2000	Dewatering characteristics of Joda iron ore slimes	*Tata Search*, Vol. 11 2000, 7-13. **IF =0.00**
17	**L.Besra,** and P. Ay	1999	Flocculation and dewatering of kaolin suspensions with the help of combination of polymeric flocculants and surface active substances	*Forum der forschung*, 9, 1999, pp.68-74. **IF =0.00**
16	S.K. Bhaumik, S.K. Biswal, **L.Besra**, P.S.R. Reddy, S.K. Das, and G.V. Rao	1999	Beneficiation of sillimanite using 220 mm dia Column.	*Trans. Ind. Inst. Metals, 52(1),* 1999, pp.1-6 **IF =0.502**
15	T.K Rout, **L.Besra**, B.P. Singh, A.R. Prasad, P.S.R. Reddy, and D.K. Sengupta	1999	Improved dewatering characteristics of leach pulp from Uranium industry by flocculants and surfactants	*Minerals and Metallurgical Processing*, 16(4) 1999, pp.706-710. **IF =0.612**
14	B.P. Singh, **L.Besra** and A.R. Prasad.	1999	Role of surface effects in the improved dewatering of alumina trihydrate	*Trans. Instn. Min.Metall (Section C: Mineral process. Extr. Metall*), 108, 1999, pp. C27-C32. **IF =0.52**
13	B.P.Singh, **L.Besra** and A.R. Prasad	1999	Coagulation and flocculation studies of iron ore fines	*Separation Science and Technology*. 34(5), 1999. pp-743-753. **IF =1.083**
12	B.P.Singh and **L.Besra.**	1999	Scope of energy conservation for solid-liquid separation in coal preparation plant, the role of surfactant dewatering aids	*Jl. Ins. Engineers (India*), 79CH, 1999, pp.10-15. **IF =0.00**
11	G.V. Rao, and **L.Besra**	1998	Enhancement of Cu, Ni, Mo recoveries in the byproduct recovery plant of UCIL Jaduguda, India	*J. Metals, Materials and Processes*, 102 (2), 1998, pp.127-134. **IF =1.798**
10	B.P.Singh, **L.Besra,** P.S.R.Reddy and D.K.Sengupta	1998	Use of surfactants to aid the dewatering of fine clean coal	*Fuel*, 77 (2), 1998, pp.1349-1356. **IF =4.49**

9	**L. Besra**, D.K.Sengupta and S.K.Roy	1998	Flocculant and Surfactant aided dewatering of fine particle suspensions: A review	*Mineral Processing and Extractive Metallurgical Review,* vol 18, 1998, pp.67-102. **IF =1.06**
8	**L.Besra**, B.P.Singh, P.S.R. Reddy and D.K.Sengupta	1998	Influence of surfactants on filter cake parameter during vacuum filtration of flocculated iron ore sludge	*Powder Technology*. vol 96, No.3, 1998, pp.240-247. **IF =2.759**
7	B.P. Singh and **L.Besra**	1997	Effect of flocculant and surfactants on the filtration dewatering of iron ore fines	*Separation Science and Technology*, 32(13), 1997, pp.2181-2199. **IF =1.083**
6	R. B.Rao, **L.Besra** and B.R.Reddy and G.N. Banerjee	1997	Effect of pretreatment on magnetic separation of ferrugenous minerals in bauxite	*Jl. of Magnetic and Electrical separation*, vol. 8, 1997, pp.115-123. **IF =0.59**
5	**L. Besra**, B.P.Singh, P.S.R. Reddy, D. K.Sengupta and S. K. Bhaumik	1996	Effect of flocculant on settling and filtration of iron ore sludge	*Minerals & Metallurgical Processing.* Nov 1996, pp.402-405. **IF =0.612**
4	**L.Besra** and R. Bhima Rao	1996	Low Temperature ashing; A method to assess the effect of additives in grinding of coal-mineral matter	*Fuel Science & Technology International,* 14 (10), 1996, pp.1405-1413 **IF =0.307**
3	B.P. Singh, **L. Besra** and M.I. Ansari	1995	Clean Coal Technology- Present trends and Future outlook	*Indian Jl. of Environmental Protection*, 15(15), 1995, pp.359-366. **IF =0.18**
2	**L. Besra**, S.K. Biswal, S.Prakash, B.Das, P.S.R.Reddy, D.K.Sengupta, S.K.Bhaumik and M.I.ansari	1995	Some aspects of Non-coking coal flotation	*Mines, Metals and Fuels*, vol.XLIII, No.7, 1995, pp.173-176. **IF =0.19**
1	**L.Besra** and R.Bhima Rao	1995	Liberation Enhancement by Grinding aids for Clean Coal	Jl. Of Institution of Engineers (India), Mining Engineering Division, Vol.76, 1995, pp.56-59. **IF =0.00**

ANNEXURE-II

HIGHLIGHTS OF SCIENTIFIC CONTRIBUTIONS

I have over 24 years of research experience and made significant contributions in the area of Mineral processing, solid-liquid separation (flocculation and dewatering of industrial sludges), colloidal processing of ceramics, electrophoretic deposition (EPD), clean energy generation by solid oxide fuel cells (SOFC), etc. My notable contributions are in the field of Electrophoretic deposition (EPD) as a versatile coating technology for various applications. Some of the highlights of the contributions are summarized below:

Electrophoretic deposition (EPD) for advanced materials processing and coatings.

We have developed an advanced coating technology based on electrophoretic deposition (EPD) at IMMT Bhubaneswar, which has the potential for application in a variety of industries. This process works on the principle of electrophoretic mobility. When an electric field is applied to a stable suspension of charged particles in a liquid, they migrate towards the electrode of opposite polarity and gets deposited there. So, depending on the type of charge present on the particles, both cathodic as well as anodic EPD is possible.

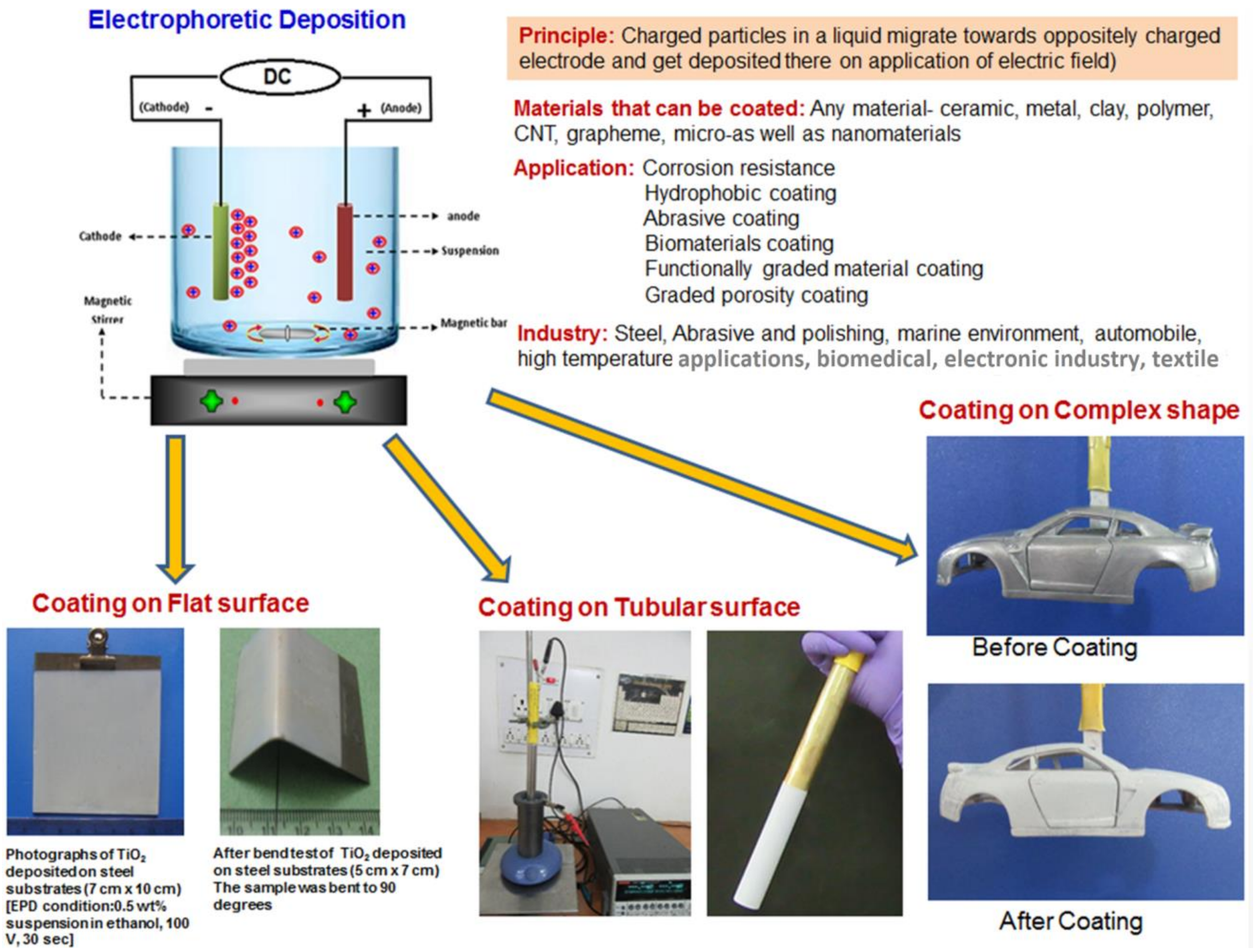
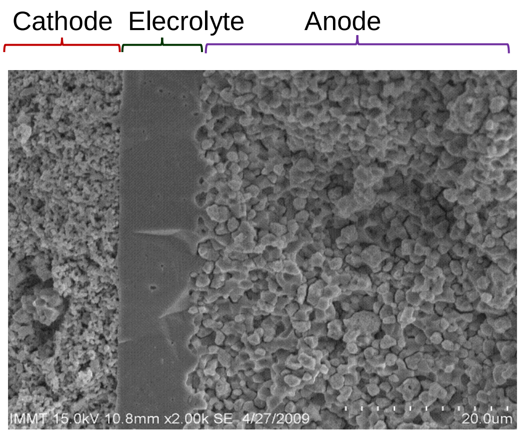


Fig 1. Electrophoretic deposition process and its capabilities to coat on any shape of surfaces (flat, tubular or complex shapes).

The process can be controlled easily by suitably controlling the process variables, such as applied voltage, deposition time, powder concentration and inter-electrode distance. Dr. Besra has pioneered in applying this technique for several applications, including, ceramic coating on steel, carbon nanotube coating, graphene polymer nanocomposite coating on copper for active corrosion protection, hydrophobic coating, diamond coating on copper disc for application in diamond cutting and polishing industry, biocompatible materials coating on metal implants, thin and dense electrolyte layer for solid oxide fuel cells, ordered array of nanoparticles for advanced functional materials, etc. The process, has the potential to be applied for many other applications, both in macro as well as in micro and nano-scale. The process is simple, and is suitable for mass production. Both single component, as well as binary or multicomponent coating is possible by suitable adjustment of critical parameters, such as surface charge. The process is very versatile as coating can be done on any shape of surfaces, whether flat, tubular or complex shapes. It is also easy to scale up. Therefore, industries can easily adopt this technology for their specific coating needs by suitably custom designing the electrode setup for their applications. Some of the fields for which I have applied EPD technology at CSIR-IMMT is depicted below:

Example-1: Development of Solid Oxide fuel cells (SOFC) for clean energy generation

Conventionally, the electrolyte membrane in solid oxide fuel cell (SOFC) is deposited on the electrodes by expensive chemical vapour deposition (CVD) and physical vapour deposition (PVD). It is desirable to develop a low cost technique for this purpose. I contributed significantly in using EPD for preparation of thin (10 micron) and dense YSZ film on porous non-conducting NiO-YSZ substrate for SOFC application. The green YSZ films deposited by EPD were densified by co-sintering the bi-layer at high temperatures. The NiO and NiO-YSZ substrates are made either by uniaxial dry pressing or by tapecasting. The cathode material, mainly $La_{0.85}Sr_{0.15}MnO_3$ (LSM), is then deposited on the YSZ film by slurry painting followed by sintering as 1200 ^oC. A planar SOFC prepared in this manner consistently exhibited an open circuit voltage (OCV) of about 1.03 V and a peak power density of more than 624 mW/cm^2 at 850 ^oC when tested using H_2 as fuel.



LSM:YSZ (50:50)/YSZ/NiO-GNP:YSZ (60:40); EPD: 50V, 180 sec, from suspension in Acetylacetone; Sintering:1450 ^oC, 5h

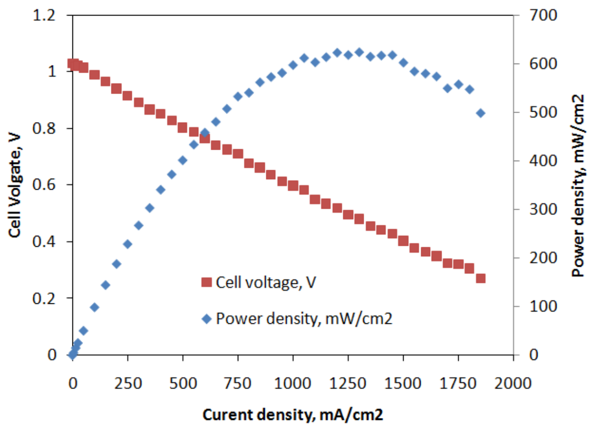
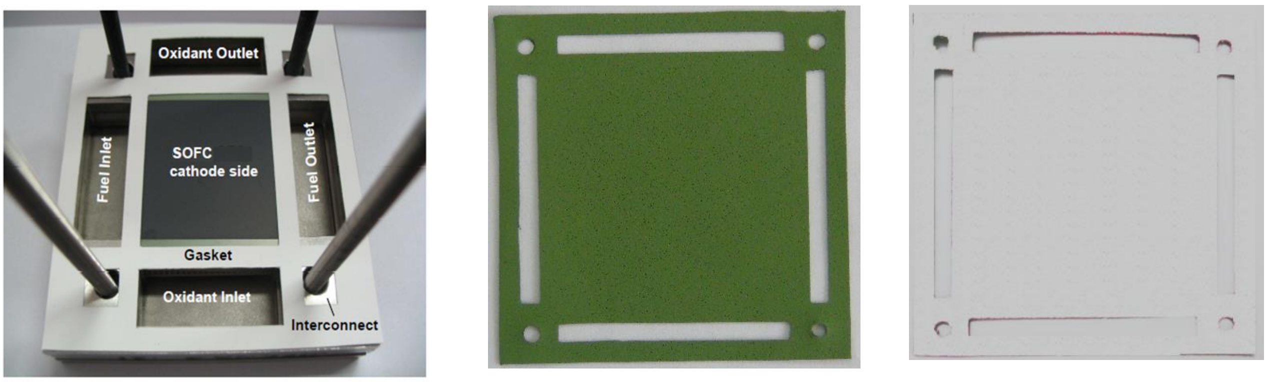


Fig 2. (a)Cross-sectional SEM image of a single SOFC cell; (b) Performance of single SOFC cell with configuration NiO:YSZ (60:40)/YSZ/ LSM:YSZ (50:50) tested with H_2 gas as fuel and O_2 from ambient air as oxidant. [Ref: S. M. Majhi, S. K. Behura, S. Bhattacharjee, B.P. Singh, T.K. Chongdar, N.M. Gokhale, L. Besra. *International Journal of Hydrogen Energy, 2011*, 36 (22), 14930-14935]

Since H_2 is expensive, hazardous and has problems of storage, it is required to feed other hydrocarbon fuels like biogas in SOFC for power generation. But the inherent presence of sulphur in hydrocarbon fuels causes sulphur poisoning of SOFC and consequent degradation in its performance. Therefore, I also developed new sulphur tolerant SOFC anode materials by incorporation of Gd doped ceria (GDC) and copper (Cu) in the NiO anode. Ceria and Cu are known to be sulphur tolerant. In order to get the desired power output, the single SOFC cells need to be connected in series to make stacks. However, gas sealing is a serious problem in stack making. Non-hermetic sealing will lead to intermixing of oxidizing and reducing gases which can result in short circuiting and also may cause fire hazard. I have designed a novel concept where the single cell components are fabricated in a unique geometry (as shown in Fig 3), in which when the single cells are stacked one above the other, it builds up the gas manifold channel, thus eliminating the necessity of gas manifolding and decreasing gas leakage to provide hermetic sealing.

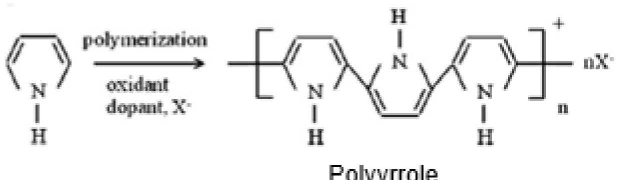


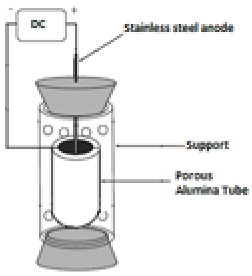
(a) SOFC stack module (b) Anode design (c) Electrolyte deposited on anode by EPD

Fig 3. SOFC stack fabrication

Example -2: Nanosized Al_2O_3 coating on inner surface of non-conducting porous Al_2O_3 tube for filter application

Generally an electrically conductive substrate is necessary for Electrophoretic deposition (EPD). Here, I effected EPD of nanosized Al_2O_3 on inner surface of non-conducting porous Al_2O_3 tube by pre-coating the substrate with very thin layer of conductive polymer like polypyrrole (Ppy) and using a rod counterelectrode at the center enabling formatiomn of graded porous tube suitable for filter application.





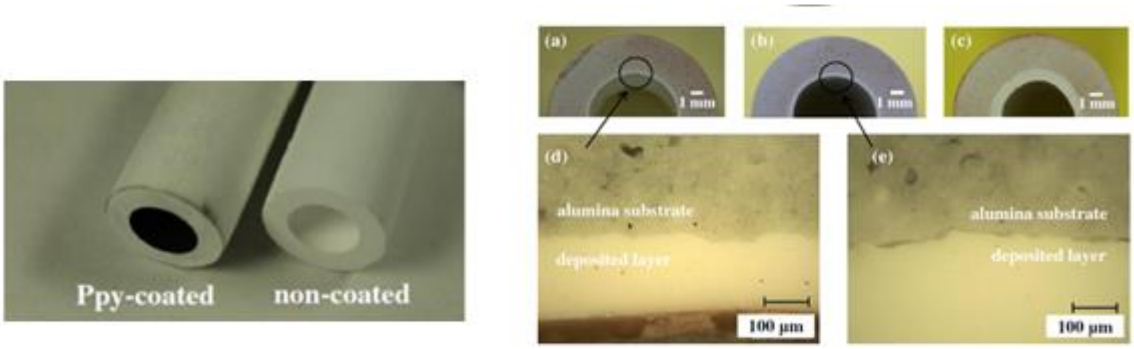


Fig 4. Nanosize Al_2O_3 coated on inner surface of non-conducting porous Al_2O_3 tube for filter application

Example- 3: Highly adherent corrosion resistant Ceramic coating (TiO_2, Al_2O_3 and Al_2O_3-Ni core-shell particles) on mild steel by electrophoretic deposition

Ceramic coating on metal generally exhibit poor adhesion to the substrate leading to coating failure on drying and sintering owing to their mismatch in thermal expansion coefficients. We used tri-methyl hydrosiloxane (trade name KF-99) both in the EPD bath (0.5 wt%) as well as a post-deposition dipping solution to produce highly adherent and corrosion resistant coating on mild steel. In particular the TiO2 coating obtained by EPD at 100 V for 30 sec from its suspension (5wt % in ethanol) and treated with KF-99 post deposition was highly adherent at 500 oC, withstood 1200 hr salt spray test in 3.5% NaCl solution, withstood 500 °C, and 90 deg bend test.

Highly adhered TiO2 on steel by EPD

TiO_2 coating on steel withstood 1200 hr salt spray test, withstood 500 °C, and 90 deg bend test

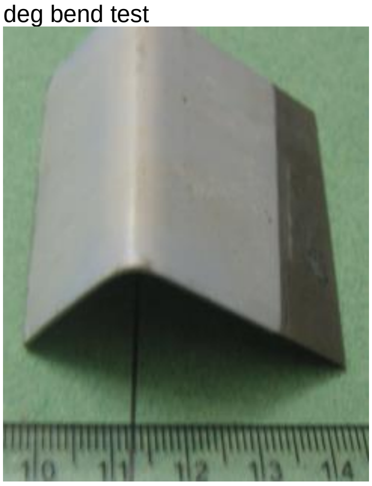


Fig 5a. TiO_2 coating on mild steel by electrophoretic deposition

To further improve adhesion of ceramic coating at high temperature, we prepared coating of Al_2O_3-Ni core-shell particle on mild steel by electrophoretic deposition. The coating can withstand a temperature of up to 850 ^{o}C without delamination from the surface. The core-shell particles were prepared by a heterogeneous precipitation method. Here, 1 g Al_2O_3 powder was first ball milled with 0.3 g nickel nitrate [$Ni(NO_3)_2$.$6H_2O$] for 24 h, followed by ultrasonication at 1000 W intensity for 1 h. The pH was adjusted to 7.8 by addition of 1M ammonium bicarbonate (NH_4HCO_3) and stirring for 30 min. This was followed by addition of 0.1 g sodium citrate and stirring for 10 min. It was kept in in ice bath and purged with Ar gas for 30 min. This resulted in a continuous amorphous film of $NiCO_3 .2Ni(OH)_2.2H_2O$ uniformly coated on the Al_2O_3 particles surface. The amorphous film was reduced to metallic Ni by addition of 0.05 g sodium borohydrate (NH_4HCO_3) (dissolved in 1 ml water), leading to formation of discontinuous (discrete) Ni particle of about 25 nm as shell on Al_2O_3 surface. The Ni-coated Al_2O_3 powder was washed with distilled water and ethanol once each and dried at room temperature in vacuum to prevent spontaneous oxidation of Ni to NiO.

The Al_2O_3-Ni core-shell particle thus prepared was electrophoretically deposited on mild steel from its suspension (1 wt%) in ethanol at natural pH 7.8 at an optimized condition of 100 V for 30 sec. It was then treated with methylhydroxy siloxane (Trade name KF 99) as binder to enhance binding as well as to prevent spontaneous oxidation of mild steel initiated from uncoated parts, followed by overnight drying and curing at 140 ^oC for 2 h before subjecting it to high temperature sintering in vacuum at 650,750 and 850 ^oC for 1 h at a heating rate of 2 degree/min.

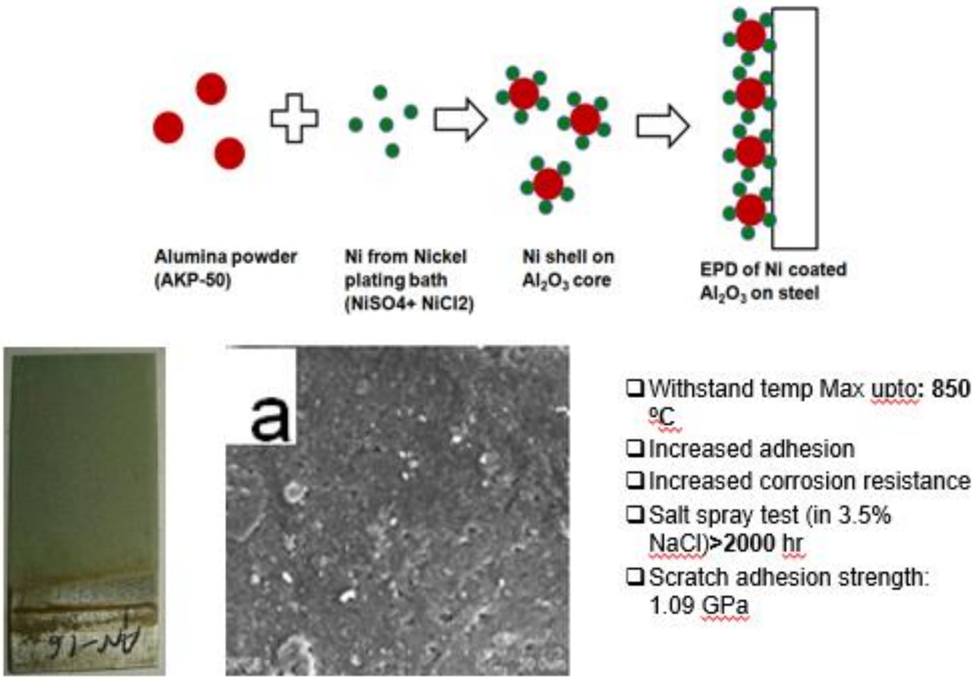


Fig 5b. Al_2O_3-Ni core-shell particle coating on mild steel by electrophoretic deposition

The coating was highly adherent because of comparable thermal expansion coefficients of Ni and Fe and diffusion of Si to the diffuse zone between metal and coating forming silicates. Micro-crack if any developed during sintering was masked by dipping in 20 wt% solution of KF 99 in ethanol and final curing at 140 ^oC. The coating sintered at 850 ^oC showed hardness of 1.17 GPa determined using Nano indentation test at 30 mN load. Corrosion resistance of the coating was evaluated using electrochemical measurements in 3.5 wt% NaCl solution. The corrosion potential (E_{corr}) and the corrosion current ($I_{corr)}$ as determined from the Tafel curve for bare steel was – 1.0906 V and 6.3255 µA/cm^2 , respectively. The E_{corr} and I_{corr} values for coated samples sintered at 850 ^oC were -0.5854 V and 0.8445 µA/cm^2, respectively, suggesting significant improvement in corrosion resistance. The corresponding corrosion rate improved from 63.0304 x 10^{-6} mm/year for bare steel to 8.4150 x 10^{-6} mm/year for Al_2O_3-Ni core-shell particle coated samples sintered at 850 ^oC.

Example 4: Electrophoretic deposition of diamond powder on copper disc for diamond cutting and polishing industry

Diamond being the hardest material, diamond coated copper disc is used in diamond cutting and polishing industries in Gujarat area. I applied Electrophoretic deposition (EPD) to coat diamond powders on copper discs for this application. For this, first a stable suspension of diamond particles in water and isopropyl alcohol (IPA) was prepared using charging agent $AlCl_3$ in isopropyl alcohol (IPA). The use of water soluble dispersants such as Darvan-C (ammonium salt of polyacrylate), polyethyleneimine (PEI) and binders such as hexamethylene diisocyanate (HDI) for effecting better adhesion of the coating on the substrate has been studied. Presence of impurities on diamond powder surface lead to unstable suspension and hindered deposition. Significantly improved stability and deposition was obtained by repeated washing of the impurities before preparing the EPD suspension. The deposited diamond was cured at 160 oC for use in cutting and polishing industry.

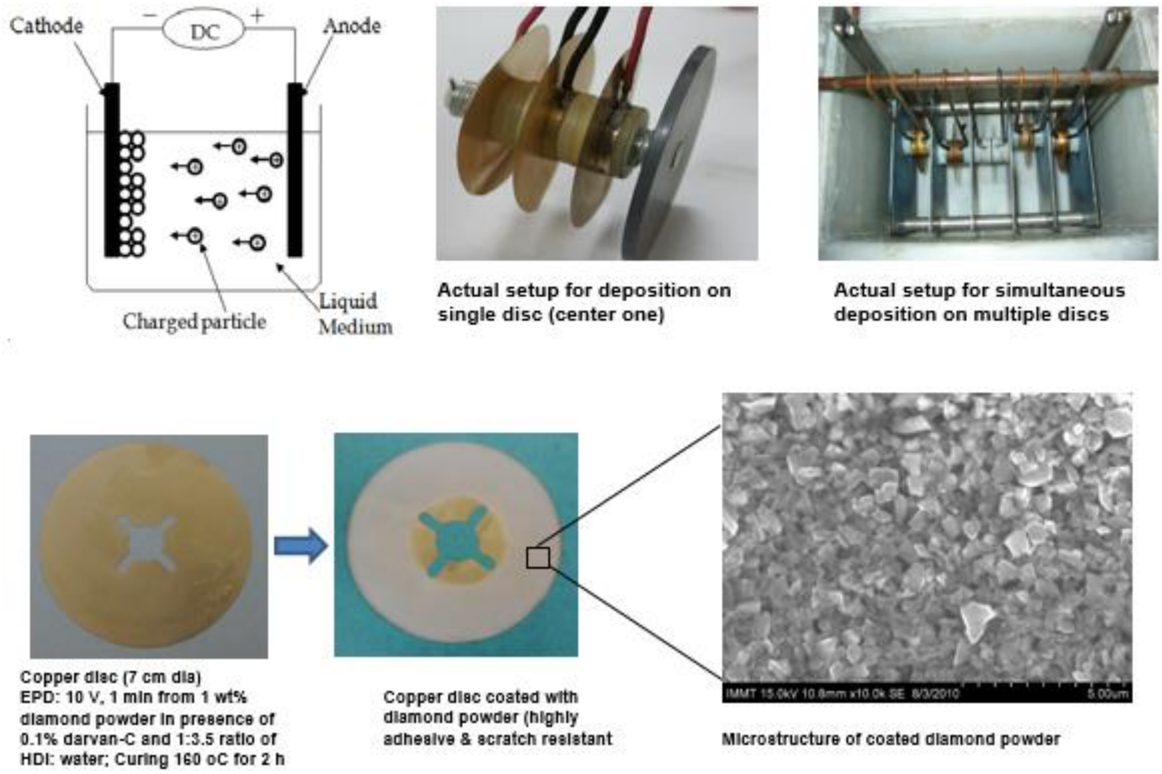


Fig 6. Diamond powder coated on copper discs for diamond cutting and polishing industry

Example 5: Aqueous Electrophoretic deposition by pulse DC

In electrophoretic deposition, charged particles suspended in a liquid medium are attracted on application of an electric field and get deposited on the oppositely charged electrode to form a homogeneous coating within 1-3 min. The electrophoretic deposition (EPD) process generally uses non-polar organic solvents as suspending medium. The preference of organic liquids is due to their higher density, good chemical stability and low conductivity.

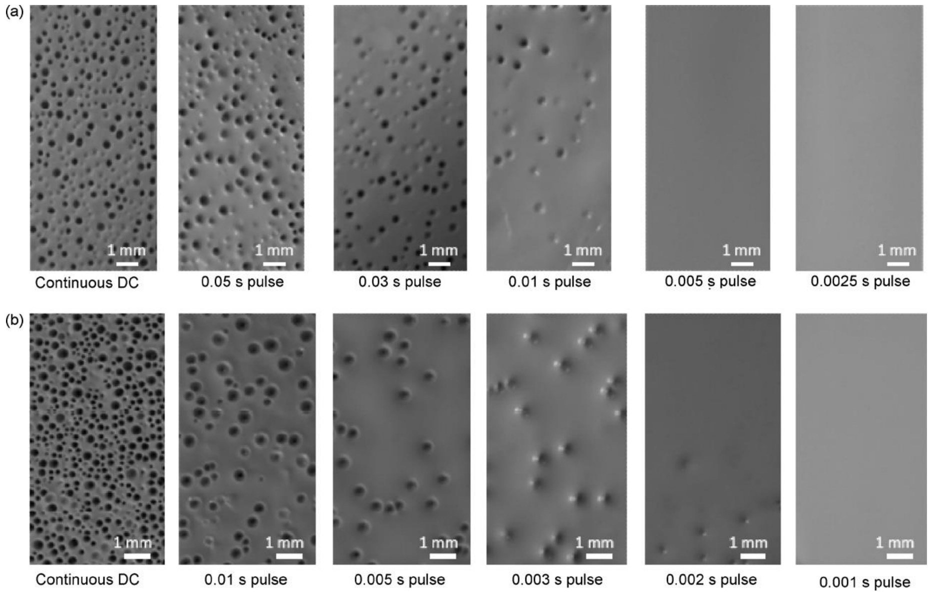


Fig 6. Surface morphology of deposits of Al2O3 obtained on steel by pulsed DC EPD in constant current mode (a) applied current: 0.004 A, (b) applied current: 0.006A (suspension: 5 vol%, pH 4.5, substrate: stainless steel (316 L), pulse ON time: 3 min, pulse duty cycle: 50%, inter-electrode distance: 20 mm). *[L. Besra, T. Uchikoshi, T.S. Suzuki, Y. Sakka. Journal of European Ceramic Society, 29(10) 2009, 1837-1845]*

But the use of aqueous system has important advantages since they need much lower voltage to be applied and the environmental problems associated with organics are avoided. But the use of water as suspending medium in EPD was not possible because of electrolysis of water on application of DC electric field during EPD, and gas evolution at the electrodes (H_2 at cathode and O_2 at anode). This resulted in incorporation of bubbles in the deposits. I developed a simple technique of controlling and minimizing the bubble incorporation in deposits and also obtain bubble-free deposits by use of pulsed DC instead of continuous DC of suitable pulse size for both cathodic as well as anodic EPD. He demonstrated that the use of pulse DC is generic and applicable for EPD process in both constant voltage as well as constant current mode. He showed that by suitable choice of pulse size and duty cycle, the extent of bubble incorporation can be controlled or eliminated.

Example 6: Fundamental understanding on mechanism of particle coagulation at the electrode

We have also developed the fundamental understanding of the mechanism of particle coagulation at the electrode during EPD. Although EPD is used extensively for various applications over the years and several mechanisms have been proposed to explain experimental results of EPD, a full understanding is still lacking. The main question that remains to be answered pertains to the particle coagulation mechanism during EPD. It is now recognized that EPD is a two step process: (i) first the particles in the suspension must migrate to the deposition electrode, and (ii) the particles must be destabilized to form the deposit on the electrode surface. The mechanism of particle stabilization and electrophoretic migration is now well established in the literature. However a general consensus pertaining to particle destabilization near the electrode has not yet been reached. We demonstrated experimentally that a pH localization phenomena (i.e., increase in pH at cathode and decrease in pH at anode compared to the bulk) occurs at the electrode on application of electric field during EPD, which is responsible for taking the pH of suspension near cathode towards its isoelectric point (i.e.p) leading to coagulation of particles for deposition at the electrode. The pH localization mechanism is applicable for both continuous DC EPD as well as pulsed DC EPD. The salient findings are published in Journal of the American ceramic Society and Journal of the European Ceramic Society.

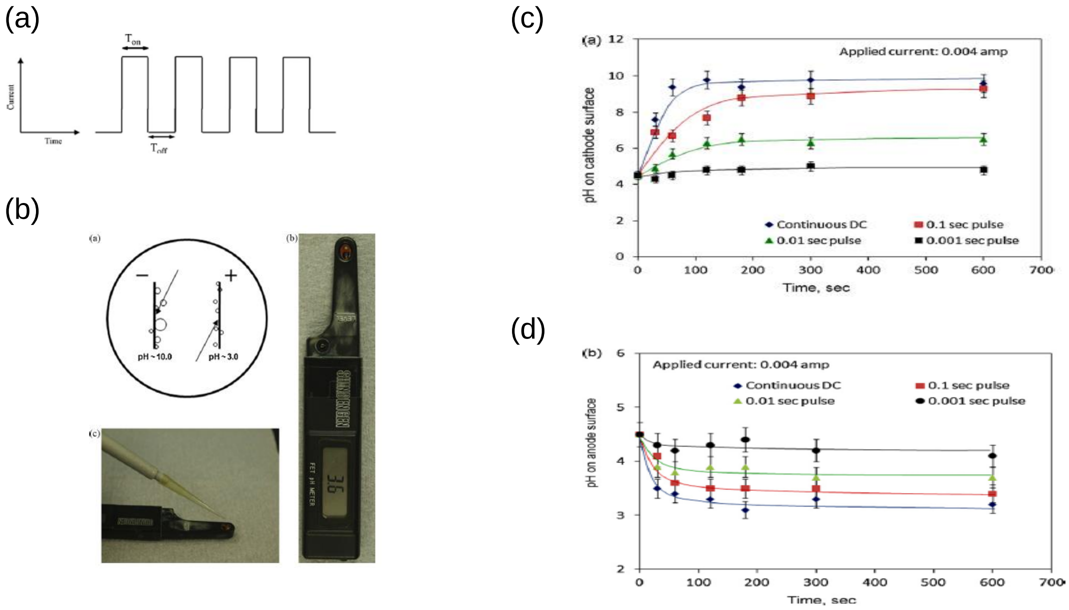


Fig 7 (a). Typical current pulse of 50% duty cycle, (b) Experimental setup to measure pH at the electrode surface using Micropipette, (c) pH at cathode surface for varying pulse size, (d) (c) pH at anode surface for varying pulse size. *[L. Besra, T. Uchikoshi, T.S. Suzuki, Y. Sakka. J. European Ceramic Society, 30, 2010, 1187-1193]*

ANNEXURE-III

TECHNOLOGIES WITH TRANSLATIONAL POTENTIAL

1. Electrophoretic deposition as a versatile coating technology for Industrial Application

As detailed in Annexure-III, I have developed an advanced coating technology based on electrophoretic deposition (EPD) at IMMT Bhubaneswar, which has the potential for application in a variety of industries. This process works on the principle of electrophoretic mobility. When an electric field is applied to a stable suspension of charged particles in a liquid, they migrate towards the electrode of opposite polarity and gets deposited there. So, depending on the type of charge present on the particles, both cathodic as well as anodic EPD is possible.

The process can be controlled easily by suitably controlling the process variables, such as applied voltage, deposition time, powder concentration and inter-electrode distance. I have applied this technique for several applications, including, ceramic coating on steel, carbon nanotube coating, graphene polymer nanocomposite coating on copper for active corrosion protection, hydrophobic coating, diamond coating on copper disc for application in diamond cutting and polishing industry, biocompatible materials coating on metal implants, thin and dense electrolyte layer for solid oxide fuel cells, ordered array of nanoparticles for advanced functional materials, etc. The process, has the potential to be applied for many other applications, both in macro as well as in micro and nano-scale. The process is simple, and is suitable for mass production. Both single component, as well as binary or multicomponent coating is possible by suitable adjustment of critical parameters, such as surface charge. The process is very versatile as coating can be done on any shape of surfaces, whether flat, tubular or complex shapes. It is also easy to scale up. Therefore, industries can easily adopt this technology for their specific coating needs by suitably custom designing the electrode setup for their applications.

Since this technology is at an advanced stage of development (technology readiness level between TRL-4 to TRL-5) with translational potential, I have taken up a Fast Track Translational (FTT) project on “Electrophoretic deposition for Industrial application”, where the objective is to enhance the technology readiness level (TRL) of the EPD technology from the present TRL-4 to TRL-8 to be in a position to transfer the technology to different industries for their specific coating needs. Already several industries including M/s reliance Refineries, Gujarat; M/s. Metal Alloys Corporation, Jamnager, Gujarat; M/s. Pratibha Medinox, Solapur, Maharashtra, TATA Steel Jamshedpur have shown interest to adopt this technology for their specific coating needs.

2. Terafil Add-on technology for zero bacteria drinking water

As an exploratory work, I am leading a team of young scientist to develop an Add-on technology to the existing Terafil filter of CSIR-IMMT to provide zero bacteria drinking water satisfying the WHO standard. The existing Terafil filter of IMMT is proven cost-effective water purification technology for both, house-hold and community level scale. It has been propagated all over the country at house-hold, community scale and in the natural calamity affected areas. It removes iron and other impurities responsible for turbidity, but does not remove the dissolved bacterial/microorganism contamination completely. Hence development of this add-on technology to remove all kind of bacteria/microorganism contamination completely will find wider acceptability and dissemination in all sections of the society. This will have a big societal impact in the country.

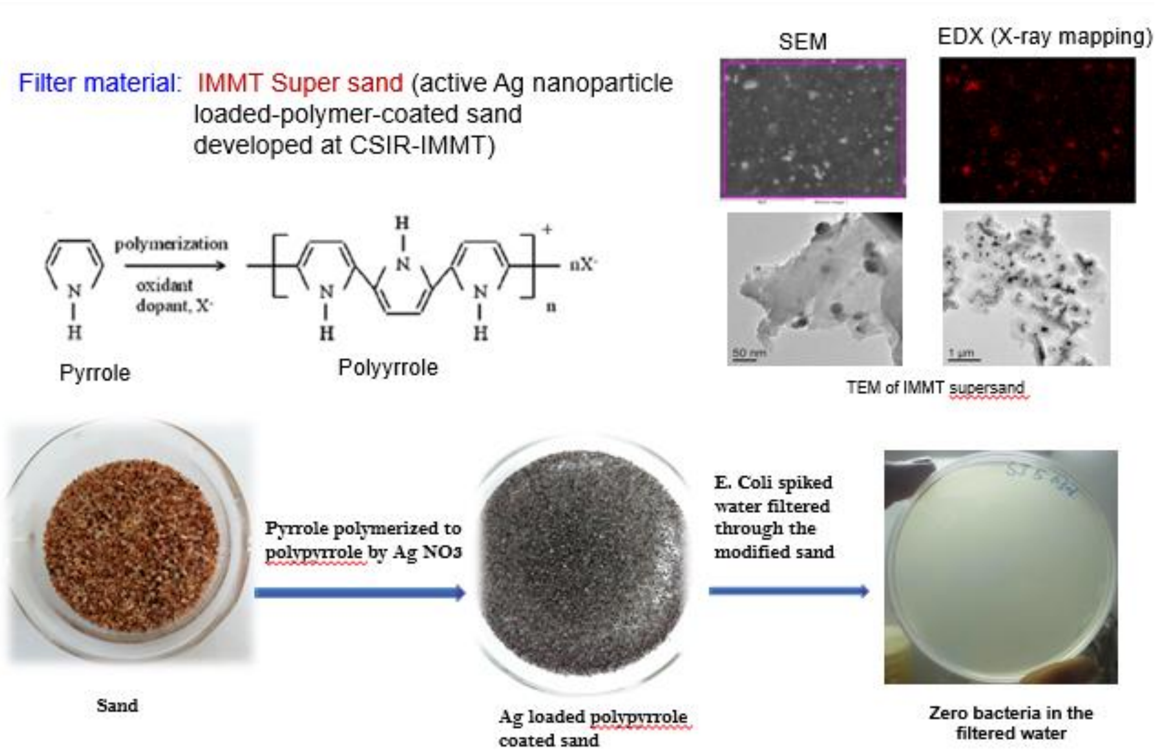
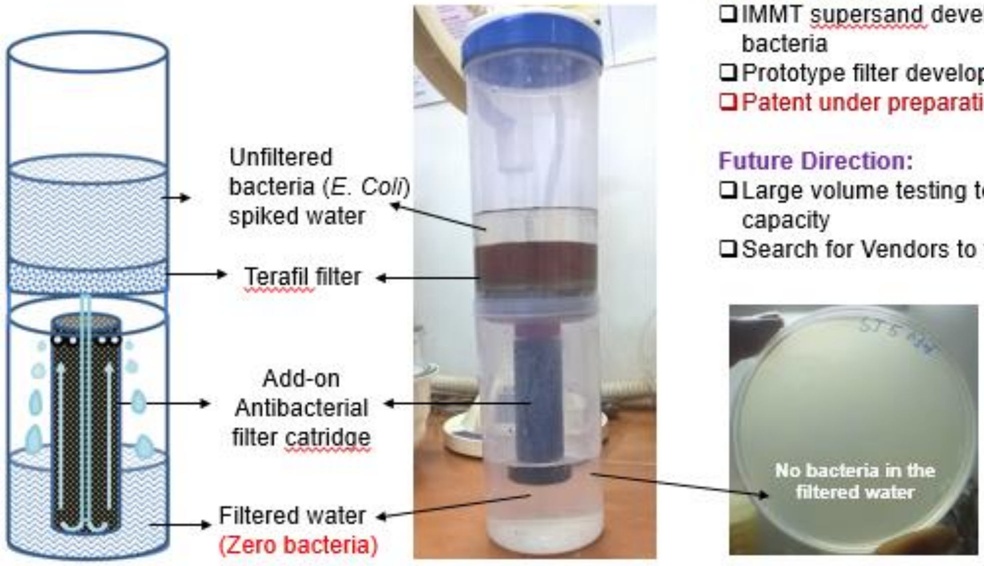


Fig 8. Ag loaded polypyrrole coated sand developed at IMMT

Filter module:

- ❑ Catridge filled with IMMT Super sand (active Ag nanoparticle loaded-polymer-coated sand) is attached at the bottom of IMMT Terafil filter.
- ❑ Filtrate from IMMT Terafil is the feed to the Add-on catridge
- ❑ Flow rate : 1.5 lit/hr
- ❑ Residence time required: 3 min



Present Status:

- ❑ IMMT supersand developed for zero bacteria
- ❑ Prototype filter developed and tested
- ❑ Patent under preparation

Future Direction:

- ❑ Large volume testing to determine filter capacity
- ❑ Search for Vendors to fabricate

Fig 9. Terafil Add-on filter prototype developed at IMMT

We have developed a composite material consisting of Ag-loaded polypyrrole coated on sand (Ppy-Ag- SiO_2) [SIPAG] by oxidation polymerization of pyrrole monomer using Ag^+ from $AgNO_3$ as oxidant in presence of a substrate (sand) on which it gets coated during polymerization. This material has shown excellent antibacterial property, evaluated using Escherichia Coli (*E.Coli*) bacteria spiked water under stationary condition. In a batch of 100 g of this material, residence time of 3 min was sufficient to ensure bacteria-free water.

We have developed a prototype of an Add-on filter to Terafil filter to produce zero bacteria drinking water. The Ppy-Ag- SiO_2 composite material thus developed was packed into a tubular catridge and fitted to the underside of the IMMT-Terafil filter to receive the filtrate from IMMT-Terafil as feed water. The preliminary results were very promising in obtaining zero bacteria water, which has opened up the possibility of deploying it on a mass scale.

3. Dewatering of radioactive sludge by flocculation

The most significant work that I did is on flocculation and dewatering to enhance solid-liquid separation problem of waste water of fuel processing plant of Bhabha Atomic Research Center. This technology is not licensed, but BARC is using it now for dewatering of radioactive sludges. The waste water from the fuel processing plant contains dissolved radioactive elements like CS^{137} and Sr^{90} . They cannot be discharged directly into any water body. These dissolved species are typically co-precipitated onto chemical sludges like copper ferrocyanide, barium sulphate of ferric chloride. However the suspension is very stable and it does not settle. It is essential to increase sedimentation of these sludge and reduce sludge volume so that it can be compacted and encapsulated in containers and buried in the soil for radioactive decay. In this project, I incorporated suitable indigeneous polyacrylamide based flocculants, which not only improved flocculation (increased settling rate and reduced sludge volume) but also adsorbed CS^{137} and Sr^{90} ions which was an added benefit. The process is currently being adopted in BARC.