Curriculum Vitae

Dr. Sunder Lal Pal

Assistant Professor
Department of Chemical Engineering
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Personal Data:

Date of Birth **:** June 09, 1975

Research Interest and Expertise:

Heterogeneous Catalysis and Reaction Engineering, Fuel Cell, Nanocatalysis, Fuel Cell Petroleum Engineering, and Biofuels

Educational Qualification:

April 25, 2012 : Ph.D. in Chemical Engineering, Indian Institute of Technology Kanpur

April 08, 2001 : M.Tech in Chemical Engineering, HBTI Kanpur

May 10, 1998 **:** B.Tech in Chemical Engineering, HBTI Kanpur

Professional Career:

2010-Present : Assistant Professor of Chemical Engineering, MANIT Bhopal

2007-2010 : Teaching Assistant of Department of Chemical Engineering, I.I.T. Kanpur

2001-2007 : Project Engineer, Department of Chemical Engineering, I.I.T. Kanpur

1998-1999 : Worked as Graduate Trainee in Jay Shri Industry Sonepat Hariyana

Administrative Experience:

1. Examination Coordinator since 2010
2. Warden since 2012
3. Member of DPRC since 2012

Awards and Honors:

1. SRF from CSIR New Delhi, during 2002-2003

2. **SHELL India fellowship Banglore,** during 2007-2009

3. MHRD Fellowship during 2009-2010

Other Professional Activities: Delivered expert lectures at various institutes of national importance

Short Term Training Programme Conducted on:

1. Green Catalysis for Industrial Application

2. Advances in Heat and Mass Transfer

3. Processing and Characterization of Smart Materials

4. Advancement of Materials

Expert Lecture delivered on following topics:

1. Green Catalysis in Chemical Industries, Department of Chemical Engineering MANIT Bhopal. Year 2012

2. Fundamentals of Heat and Mass Transfer, Department of Mechanical Engineering, MANIT Bhopal. Year 2013

3. Fundamentals of Catalysis, at Department of Chemistry MANIT Bhopal Year 2015

4. Various Characterization techniques for the Study of smart materials, Department of Mechanical Engineering MANIT Bhopal Year 2015

5. Importance of Chemical Engineering in our society, at SATI Vidisha Year 2014

6. Solid catalyst for the transesterification of Oils, National Conference on Environment and Renewable Energy, at NIT Rourkela Year 2012

7. Heterogeneous Catalyst for Biofuel Production, National Conference on Bioenegy and Biotechnology at Government Science College Reewa Year 2013

Courses Attended:

Seven courses on different areas have been completed at IISc Banglore, IIT Kanpur, and IIT Delhi

LIST OF PROJECTS HANDLED (during 2001-2007 in IIT Kanpur and MANIT Bhopal from 2012 onwards) by Dr. Sunder Lal (with Professor Anil Kumar and Professor Deepak Kunzru, Department of Chemical Engineering IIT Kanpur):

1. Isomerization of Pinane, Hindustan lever Limited Mumbai, 2001-2002, Rs. 10 Lakhs (with Professor Deepak Kunzru)

2. Development of Endothermic Fuels, DRDL, 2002-2003, 30 Lakhs (With Professor Deepak Kunzru)

3. Degradation of Polymer through Heterogeneous Catalytic Depolymerization in Presence of Molecular Oxygen, CSIR, 2002-2005, Rs. 12 Lakhs (with Prof. Anil Kumar)

4. Development and Characterization of Functional Polymers, MHRD, 2001-2004, Rs. 10 Lakhs (with Prof. Anil Kumar)

5. Gas Phase Nitration Scheme for Organic and inorganic substances and their applications, Jubilant Organosys, Noida, 2003-2005, 26 lakhs (with Prof. Anil Kumar)

6. High Temperature Adhesives for Railway track Welding, Thermit India, Kanpur, 2007, 1Lakh (with Prof. Anil Kumar)

7. Development of Transparent Adhesive for Nano Composites, DMSRD Kanpur, 2005 – 2007, 10 lakhs (with Prof. Anil Kumar)

8. Development of bi-functional solid catalyst for trans-esterification of Jatropha oil, SHELL Energy Banglore, 2007-2011, 40 lakhs (It is one of my PhD work) `

9. Recovery of wax from slack wax and improvement of pour point of oil, Agarwal Oil Mills, Kanpur, 2007-2009, 7 lakhs (with Prof. Anil Kumar)

10. Technology development for end use of glycerol from biodiesel production, DST, 2008-2011, 46 lakhs (It is one of my PhD work)

11. Development of Heterogeneous Catalyst for Oxidative Desulfurization of oil, TEQIP-II MANIT Bhopal 10Laks

12. Consultancy project is running with YOHANA Paint Bhopal (through MOU between MANIT and Yohana Paints), "Developing Anit IR Paint for Defence Purpose"

Ph.D Thesis: Total 05 (ongoing)

1. **Deeptiraj Pant** Development of Heterogeneous Catalyst for Various Industrial Reactions **(at Final stage and is submitting in July 2016)**

2. Ramswaroop Singh Thakur, Catalytic hydrodeoxydation of Oils

3. Ashwani Rathore, Reactive separation of Organic Acids (ongoing)

4. Subha J, Development of Nano composites from Polymeric Waste

5. Shourbh Singh Raghuwansi,

M.Tech Theses:Total 07(2 completed and 5 ongoing)

1. Ms. Monmee Phukan, 2014

2. Richa Tomer, Development of Solid catalyst for Biodiesel Production. 2015

Books and Book Chapter:

[1]. S. Lal, K.S. Anisia and A. Kumar, Heterogeneous complex catalysts having ionically bonded macro-cyclic complexes bonded to montmorrilonite clay for industrial reactions in Pillared clays and related catalysts, Elsevier, Amsterdam, 2010

[2]. Sunder Lal, and Anil Kumar#, Computer Control of Chemical Equipment and Plants, under review)

[3]. Sunder Lal, and Anil Kumar#, Chemical Process Synthesis and Design (in Preparation)

#Dr. Anil Kumar, Professor Department of Chemical Engineering, IIT Kanpur

PUBLICATIONS:

[4] Savita Dixit, Sandhya Pal and Sunder Lal, Synthesis and Characterization of Cation Exchange PVA-g-PAA/PBI sulfone Membrane for the Electrolysis of Sodium Chloride, Journal of membrane Science and Research, 2016 **(SCI accepted)**

[5] Sunder Lal and Deeptiraj Pant, "*Development of heterogeneous Ni-Ni complex/HPA-RNi catalyst for the hydrogenation of Benzene"* Asian Journal of Chemistry, 2016**. (SCI Accepted)**

[6] Sunder Lal, Gulam Gaush Zeelani[1], Afzal Ashrafi[2], Ashok Dhakad[3], and Gourav Gupta[4], Catalytic Oxidative desulfurization of liquid fuels: A review, International Research Journal of Engineering and Technology, Vol.03 Issue 02, February, 2016 (Accepted)

[7] Sunder Lal and Ramswaroopp Singh Thakur, "Hydrogenolysis of Glycerol using complex Catalyst Fe-Fe/Al_2O_3" Asian Journal of Chemistry May, 2016. **(SCI)**

[8] Sunder Lal and Deeptiraj Pant, "*Catalytic Oxidative Desulfurization (ODS) by Using HPA supported Alumina Catalyst"* International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 08, pp. 1396-1400 Nov-2015.

[9] Sunder Lal, Richa Tomer. Deeptiraj Pant and Ramswaroop Singh Thakur,"*Development of Mg-SO42-/ZrO2 Heterogeneous Catalyst forming Biodiesel from Karanja Oil"* International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 03 pp.1818-1824 June- 2015.

[10] Sunder Lal, Richa Tomer. Deeptiraj Pant and Ramswaroop Singh Thakur, "*Development of Mg-SO42-/ZrO2 Heterogeneous Catalyst- forming Biodiesel from Rice Bran Oil"* International Journal of Innovation Sciences and Research, Volume: 04 Issue: 06 pp.-262-268, June- 2015.

[11] S. Lal, K.S. Anisia and A. Kumar, Depolymerization of HDPE to wax in presence of catalyst formed by homo-nuclear macrocyclic zirconium complex, Applied Catalysis A: General, 303, 9 – 17, 2006. (**SCI**)

[12] S. Lal, K.S. Anisia, M.J.L. Kishore and Anil Kumar, Development of Heterogeneous Catalyst by Ionically bonding Macrocyclic Zr-Zr Complex to Montmorillonite Clay for Depolymerization of Polypropylene, Journal of Molecular Catalysis A: Chemical, 265, 15-24, 2007**(SCI)**

[13]. Sunder Lal et al., An efficient intensity based generalized signcryption scheme, Theoretical Computer Science, vol.412, issue 45 pages 6382-6389, 2011**((SCI)**

[14]. Sunder Lal et al., The improved biogas systems project: Result and future energy for Sustainable development, Vol. 3, Pages 28-42, 1996 **((SCI)**

International Conference:

[15] Sunder Lal, Subha Jayaraman and Deeptiraj Pant ,Development of Polyaniline based copolymeric Nanocomposites for Electronic Applications, Sixth International Conference on Advancement on Polymeric Materials, Held at Indian Institute of Science Banglore during Febraury 20-22, 2015

[16] Sunder Lal, Deeptiraj Pant and Richa Tomer, "*HPA Loaded Modified Alumina Catalyst for transesterifiation of Jetropha Oil forming Bio-diesel"* 14 AIChe, Annual Meeting Atlanta, USA, during Nov. 16- 21, 2014.

[17] Sunder Lal and A.K. Mishra, "**Depolymerization of HDPE waste to Wax"** Seventh International Conference on Solid waste Management during August 2-6, 2009 at Phidalphia USA.

National Conference:

[18] Sunder Lal, " Heterogeneous Catalyst for the Transesterification Reactions, Third national Conference on Bioenergy and BioTechnology and Diversified during 5-6 December at Government Science College, Reeva.

[19] Sunder Lal and Sunita Kumari, "Development of Solid catalyst for Transesterification of Soyabean Oil" National Conference on Green Energy and Environment conducted Department of Chemical Engineering at NIT Raourkela during 21-22 December 2011

[20] Sunder Lal, Ramswaroop Singh Thakur, Deeptiraj Pant and Richa Tomer, "*Hydrogenolysi of Glycerol using macrocyclic complex catalyst [Ni-Ni]-L/Raney"* CHEMCON-2015 at IIT Guwahati- 68th Annual Session of IIChe during December 27-30, 2015

[21] S. Lal, K.S. Anisia and A. Kumar, Catalytic Depolymerization of HDPE in presence of homonuclear macrocyclic Zirconium Complex chemically bonded to Alumina support, CHEMCON – 2005, IIChE Annual Meeting, Delhi

Research Contribution to Industries:

We are working on developing the Anti IR paint with collaboration Yohana Paint Mandideep Bhopal for Defence application as well as Bullet proof material.

Design of Heterogeneous Complex Nano Catalysts

From the study of literature, it began to appear to me that as a chemical engineer, I could effectively conduct research if it is focused on surface chemistry. In view of this, I have started working on catalysis and membranes where the nature of surface plays a major role in determining the final property and activity of the material.

Work reported in the literature in chemical engineering on catalysis was limited to catalysis by single metal and in an effort to create cluster of metals (having at least two metals) which are separated from each other by molecular distances, we decided to synthesize complexes. The study of complexes is a major research area in chemistry because it is believed that molecules placed at these distances behave synergistically to give unique reactivity. These have been utilized to catalyze biological reactions near room temperature and have never been used for reaction temperatures beyond 100^0C. However chemical engineers deal with reaction which require high temperatures and pressures which is region of operation when these complexes breakdown.

In our work, we argued that complexes near surfaces of the support are expected to be more stable. This is based on observation that water adsorbed on the surface has higher boiling points. In view of this, in all our works, we modified the surface of the support by function number of metals and the nature and number of ligands in the clusters of catalyzing metals. When the elements are placed at molecular dimensions, their synergistic effect was indeed lead to a superior activity, this way carrying out any given reaction more efficiently. We have this way utilized the heterogeneous complex catalysts for following different reactions:

(a) oxidation of alkanes,
(b) depolymerization of polymer waste materials
(c) hydrogenolysis of glycerol,
(d) biodeseal from oils
(e) deoxygenation of oils and fats without hydrogen,
(f) desulfurization of thionyl products without hydrogen

(g) denitrification of alkyl amines without hydrogen.

With our catalysts, we observed lower temperatures, pressures, better yields etc.

(1) Development of Charged Membranes:

Chemical Engineers are greatly interested in separation processes and in this regard, separation by use of membranes is the most important. The membranes are classified by their pore sizes and most of the applications of separation is based on the rejection by physical size of molecules of solute and this way limiting application. In our work we have mostly focused on polymer membranes which are traditionally dense membrane. In order to overcome this problem we devised a composite initiating system which would form polymer syrup from which membranes could be easily cast and subsequently cross linked in the second stage. The charges are introduced into these membranes by chemical modification of these polymers and the resulting membranes begin to give nano separation due to the charges distributed on the walls of pores.

Next important step is to estimate the charge density on the walls of the pores of the membranes. This is done by carrying out separation of ionic solutions (such as separations of chromic acid from its solution in water) and the curve fitting the experimental data by space charge model which would yield the desired information where the wall charge density is an explicit variable. The curve fitting requires the repeated numerical solution of the space charge model of set of two dimensional transport equations in presence of charge on pore walls which are highly computationally intensive. To overcome this problem, a semi analytical solution was developed which can easily be used to estimate the overall charge.

Contribution to Process and Device Development Activities

1. Development Of Process for Depolymerization Of HDPE:

In view of the fact that polymer wastes (particularly polyethylene) are non biodegradable, an intense research is being carried out internationally to develop a process for its utilization. In the year 2000, I accidently discovered a catalyst to convert HDFC to wax with complete conversion. A local industry became interested in this work and presented IITK forty two liter reactor to carry this reaction. With the experience so gained, we assembled a prototype of the full process on 6.5 liter reactor. We have now assembled the process which has been working for last two years.

In view of recent crunch on petroleum crude availability and the availability of gases from offshore drilling (consisting of mainly methane), considerable amount of research has been in progress on gas to liquid technology (GTL technology) consisting of following two stages. In the first stage through reforming reaction, methane is converted to synthesis gas (a mixture of CO and H_2) which is converted in the second stage to liquid fuels and waxes using Fischer-Tropsche catalysts. Our process developed treats the PE as a source of hydrocarbon and utilizes the polyethylene waste to be converted into waxes, which is exactly the reverse of the GTL process.

After the formation of the product we characterized the wax to be microcrystalline with cuboids of $90A^0$ whose melting point could be controlled to any value by varying the reactor residence time. We subsequently studied the wax market and found that the waxes could be derived from mineral resources (such as coal, mica deposits etc), from trees (such as carnouba) or paraffin wax from petroleum crude. Depending upon the oil content, the price could be as high as Rs 2500/kg and our wax belonged to this category. On examination of downstream technologies involving wax, it was found that it is used as candles (about 5% market), polishing industries (about 50% market) and adhesives (about 45% market). We found that all waxes available in the market had different surface properties therefore all applications of waxes depended heavily upon the type of wax used. This was particularly important for all those applications involving wax emulsions in water were needed. When we started looking into the technologies involving wax, we found that our wax had a natural tackiness and would adhere to all surfaces. This simplified our task and we could easily prepare all variety of adhesives (adhesives for wigs, for metal to glass or wood, for tapes, bottle sealing, glass to metal, heat or pressure sensitive etc.), laundry calendaring wax, all kind of greases, leather polishes, car polishes, floor polishes etc.

(2) A novel membrane for Chlor alkali process:

The chlor alkali process converts sodium chloride into sodium hydroxide by electrolysis and is a common method for producing the latter. Industrially this is the most energy intensive process since the NaOH is a bulk chemical and the total energy required is immense. Even for the most industrialized country like USA, it consumes as much as 5% of the entire electricity produced. Industrially, a Nafion membrane (produced by Dupont, USA) is used in an electrolysis chamber which operates at 3-3.5 volts with power consumptions of 0.1 kWatt/k-mol of NaOH produced. The NaOH is a bulk chemical and the total energy required is immense.

Our research has lead to a development of polyvinyl alcohol-grafted -poly acrylic acid which was chemically modified to have benzi imidazols functional groups. In order to introduce these groups, we synthesized aromatic compounds having bis conjugate amine groups through solid phase reaction. It was found that within the dectrolysis cells, for the same current, the voltage kept falling even below the thermodynamic voltage of 2.2V. The power required also went down to 0.02 kW/kmole of NaOH produced which is one fifth of the value required commercially now-a-days.

(3) Development of Proton exchange membrane for methanol fuel cells

Fuel cells have two electro catalysts and a membrane and traditionally, the former are noble metal catalysts and the latter has been Nafion-117. Our research aimed at replacing the latter with a cheaper indigenous membrane and the noble metal catalysts by cheaper metals. The literature revealed that people are looking into the PBI membranes as replacement of Nagion-117. However, the monomer used for this is extremely expensive, this way the rest of fuel cell becoming prohibitively expensive. We decided to synthesize these monomers also from commercially available materials and found an alternative and considerably cheaper route to synthesize these.

Once the selection of membrane was done, the next important step was to prepare an ink adhesive to be used for preparation of the membrane electrode assembly (MEA). In order to keep the interface resistance negligible, we utilized the same grafted polymer which we had used for synthesizing the membrane along with a cross linking agent having sulfonate functional groups. In addition, graphene was synthesized and added to the adhesive ink solution. The complete MEA had very low resistance, five times better power generation compared to an MEA prepared from Nafion membrane. In addition, the V-I characteristics gave a horizontal line over a very wide variation of current I suggesting a negligible internal resistance. This result is of considerable importance for fuel cell stack design where the internal resistance of the stack plays an extremely important role.

(2) Development of Batteries:

Batteries are also electrochemical devices and consist of a membrane, two electrodes, an electrolyte serving as the medium and a fuel utilized for electrochemical conversion. In this case the membrane serves as a barrier against mixing of catholyte and anolyte fluids and are dense (i.e. having no pores). The electrolyte and fuels are lithium salts (which are extremely expensive) and the modern membranes are prepared with ionic liquids mixed with polymer materials which serve as carriers for moving lithium ions from one chamber to another.

In our work, we used membrane electrode assembly (MEA) prepared earlier and treated batteries as fuel cells with no flow conditions. The membranes used by us in the MEA were charged having pores of 9 nm and had ionic liquid bounded to the polymer of the membrane. With wall charges due to an ionic liquid of the membranes, there are additional fluxes and hence, the batteries exhibit higher efficiencies.

Innovation in teaching, Development of Course Materials:

I have been teaching since 2010, most of the courses at UG level. Out of all the courses that I am teaching I would be resulted into text books, I describe in the following:**Chemical Process Engineering Design and Costing**:

During last six year of my carrier, when I started teaching Design course, the standard text book is being used that is Peter and Timmerhouse, Plant Design and Economics for Chemical Engineers. The design of plant included Principals of management of money, scheduling etc. and at that time, the literature on process Engineering began to propose the design problem as an exercise of optimization of the structure of chemical plants. Along with this optimal structure, it is also desired that there should also be a flexibility of operations during its life time as well as adhere to safety limits.

I have began to change the design courses, in which I would like to introduce

(1) safety norms
(2) techniques of computer monitoring of chemical plants
(3) concepts of reliability
(4) operability analysis
(5) networking, etc. in a Chemical Industry

I will also introduce two advanced level courses in the department where the emphasis was optimization and involved extensive computer applications. These concepts of process Engineering would be unified in a text book, Chemical Process synthesis and Engineering Design which I have started writing.

Chemical Engineering Controls:

After several years in Research and Development, I am interested in Controls. In earlier years, literature on Controls is full of linear control theories and practices. However Chemical Engineering systems are highly nonlinear, these results are not directly relevant and at times, they lead to wrong conclusions. In view of this, we defined nonlinear controls and showed how these equations could be arranged for chemical plants as a whole (With Professor Anil Kumar). At this time, the literature began to report several package programs such as Hysis and Aspen as well as Fluent which was mainly used for computational fluid dynamics. These were used for design of chemical plants as a whole as well as plant wide controls.