Professor M. Santappa Award Lectures - 2022

AWARD LECTURE 1

An overview of High-performance Polymers for Membrane-Based Applications

by

Prof. Susanta Banerjee

IIT, Kharagpur

Date: December 10, 2023 | Time: 11.45 am

Venue : MACRO-2023 at Bhupen Hazarika Auditorium IIT, Guwahati

AWARD LECTURE 2

Molecular Recognition Driven Controlled Supramolecular Polymerization

by

Prof. Suhrit Ghosh

IACS Kolkata

Date: December 10, 2023 | Time: 12.15 pm

Venue: MACRO-2023 at Bhupen Hazarika Auditorium IIT Guwahati

Organized by:

The Society for Polymer Science, India

AWARD LECTURE 1

Abstract

Polymers occupy a central role in the development of modern society. High-performance polymers are classes of polymer materials that are known to retain adequate mechanical, thermal, and chemical properties when subjected to harsh environments such as high temperature, high pressure, and corrosive chemicals. The development of these classes of polymers are crucial for many advanced applications, including their membrane-based applications. Polymeric membranes are selective materials and a rapidly growing field for several industrial applications, such as membranes for low-k applications, membrane separation of gas and liquid mixtures, water purification, and solid polyelectrolyte membranes in fuel cell applications. All these applications requires design and preparation of functional high-performance polymers that are processable and survive severe test conditions during their use in the form of thin films. Several aromatic polymers, e.g., poly (arylene ether)s, polyimides, polyaramids, polytriazoles, etc., has shown great promise in these direction due to their excellent mechanical and thermal stabilities. However, the major drawback of these classes of polymers is their processing difficulty due to their infusible nature and insolubility in common organic solvents that restricts their processability by melt and solution processing techniques.

The incorporation of fluorine polymers in the form of 3F (-CF_3) and 6F [-$C(CF_3)_2$-] groups resulted in organo-soluble polymers. There has been a remarkable growth of research in semi-fluorinated polymers. It has been observed that incorporation of different fluorinated groups into the macromolecular chain not only increases the solubility but also improves many other polymer properties, e.g., reducing dielectric constant, increasing gas permeability, and also helping in the formation of phase segregated morphology that help in enhanching proton conductivity. The talk will cover different design approaches used to prepare different classes of fluorinated polymers in our group. The synthetic strategies, characterization, and detailed properties of the developed polymers with special emphasis on their membrane-based applications e.g., low-dielectric constant materials in microelectronics, membranes for gas separation, and proton exchange membrane properties will covered in this talk. This talk will address many of the practical problems that address the inherent trade-off between gas permeability and selectivity and likewise the membrane stability and proton conductivity through manipulation of the fractional free volumes (FFV) and incorporating different structural elements in the membrane-forming polymers by macromolecular engineering.

References:

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2. Banerjee, S. (**2015**) Handbook of Specialty Fluorinated Polymers: Preparation, Properties, and Applications; Elsevier: Amsterdam, 329 pages.
3. Banerjee, S.; Bera, D. (**2017**) Polycondensation Materials Containing Bulky Side Groups: Synthesis and Transport Properties, In: Membrane Materials for Gas and Vapor Separation: Synthesis and Application of Silicon Containing Polymers, First Edition. Ed. Y. Yampolskii and E. Finkelshtein (John Wiley & Sons, Ltd.), Chapter 7, pp. 223-269.
4. Banerjee, S.; Ghosh, A. (**2017**) Semifluorinated Aromatic Polymers and Their Properties, In: Fluorinated Polymers: Volume 1: Synthesis, Properties, and Simulation, Ameduri, B.; Sawada, H., Ed.; Royal Society of Chemistry: Cambridge, Chapter 5; pp 103-189.
5. Banerjee, S.; Ghorai, A.; Roy, S.; Voit, B. (**2020**) Preparation of high-performance polymers by click chemistry and their membrane-based application; In: Advances in Chemistry Research, Nova Science Publishers, Ed. James C. Taylor,Volume 64, Chapter 2.
6. Ghorai, A.; Banerjee, S. Phosphorus-Containing Aromatic Polymers: Synthesis, Structure, Properties and Membrane-Based Applications, *Progress in Polymer Science 138 (2023) 101646.*

About the speaker

Susanta Banerjee received his M.Sc., M.Tech. and Ph.D. degrees from the Indian Institute of Technology Kharagpur, India, in 1988, 1989, and 1993. He started his research career with the Defence Research & Development Organization (DRDO), Govt. of India, and worked there as a Scientist from 1992 to 2004. Dr. Banerjee was an Alexander von Humboldt Research Fellow at the Technical University Munich from 1997 to 1999. In 2004, he joined as Lead Scientist at GE India Technology Centre (JFWTC), Bangalore and worked there till the end of 2005. He moved to IIT Kharagpur in 2006 and become full professor in 2011 in the Materials Science Centre. His research interests include designing and polymers and membranes thereof for low-k applications, gas and liquid separation, all-solid polyelectrolytes for fuel cells, and polymers and carbon-dot-based nanomaterials for electroluminescent applications. His research has successfully demonstrated new polymers that showed high permeability and selectivity and has given a direction in developing new proton conductive membranes for fuel cell applications. He has published 240 original research papers those have received more than 7000 citations with h-index of 46. He has made more than 153 presentations at scientific conferences in India and abroad. He has several (08) granted patents (as an inventor) in his credit. He is author of nine chapters and one book, "Handbook of Specialty Fluorinated Polymers: Preparation, Properties, and Applications," published by Elsevier. He is the recipient of several awards and medals. A few of them are the Defence Technology Spin-off Award, GE Management Award, Materials Research Society of India (MRSI) Medal, and Fellow of West Bengal Academy of Science and Technology and awarded Institute Chair Professor by the IIT Kharagpur in the year 2020. **For the fourth consecutive year** (2020, 2021, 2022, 2023), *his name appeared* in the list of the top 2 percent most-cited polymer scientists released by Stanford University. He is well known for mentoring postgraduate students and has supervised 26 Ph.D. and 40 master students. He handles several extramural-funded research and consultancy projects and collaborates with several research groups in Germany, USA and Russia.

AWARD LECTURE 2

Abstract

Co-existence of multiple pathways in supramolecular polymerization of a single building block has been recognized in many examples in the recent past. Despite significant recent development on this topic, it still remains a challenging task to identify generally applicable strategies to synthesize a supramolecular polymer with predictable internal order and mesoscopic structure. In this work, we have revealed pathway control in supramolecular polymerization of a carboxylic acid functionalized naphthalene-diimide-carboxylic-acid (NDI-1) monomer by a small amount of an organic base such as 4-dimethylaminopyridine (DMAP).[1] NDI-1 spontaneously self-assembles in decane to produce a mixture of aggregates (J- and H- aggregates) leading to the formation of mixture of short fibres and ill-defined particles (**Agg-1**, Scheme 1). With 100 % of DMAP, irrespective of cooling rate, only J-aggregate was noticed with entangled fibrillar morphology and gelation (**Agg-2**). Even with 10 mole % of DMAP, upon rapid cooling of a NDI-1 solution in decane, similar J-aggregation, morphology and gelation was evident (Agg-2a). When this same solution was slowly cooled, it produced predominant H-aggregate with 2D disc type morphology (**Agg-3**). Such 2D morphology and H-aggregate (**Agg-3**) was the only product when solutions were slowly cooled in presence of relatively less amount of DMAP (2.5 %). Such pathway control is attributed to H-bonding between DMAP and carboxylic acid group,[2] which eliminates the possibility of closed chain dimer formation but still may allow nucleation for open chain H-bonded pathway by H-bonding between the carbonyl oxygen of the complex and hydroxyl group of a free acid either in parallel or antiparallel fashion depending on the cooling rate and amount of DMAP (Scheme 1).[2] This presentation will describe such molecular recognition driven pathway control in supramolecular polymerization and copolymerization.[3]

References

[1] Chakraborty, A.; Ghosh, G; Ghosh, S. *Chem. Sci.* **2019**, *10*, 7345–7351.
[2] Chakraborty, A.; Manna, R. N.; Paul, A.; Ghosh, S. *Chem. Eur. J.* **2021**, *27*, 11458– 11467. Chakraborty, A.; Das, P. K.; Jana, B.; Ghosh, S.*Chem. Sci.* **2023**, *14*, 10875-10883.

About the speaker

Suhrit Ghosh was born in 1976 in India. After completion of the undergraduate education (Chemistry major) in the Presidency College (now University), Kolkata, he was admitted in the integrated PhD program(Chemical Science) at IISc, Bangalore in 1997. He received the MS degree (Chemistry) in 2000 and continued for PhD till 2005 under the supervision of Professor S. Ramakrishnan. Then he moved to the group of Professor S. Thayumanavan at the University of Massachusetts, Amherst, USA, for postdoctoral studies (2005-2007). Subsequently he worked as a Humboldt postdoctoral fellow (2007-2008) with Professor Frank Würthner at the University of Würzburg, Germany. In 2008 he joined IACS, Kolkata, India,as an Assistant Professor where he currently holds the position of a Senior Professor in the School of Applied and Interdisciplinary Sciences. He was selected as an Associate of the Indian Academy of Sciences(2009-2012). He is the recipients of the B. M. Birla Science Prize (2014), SwarnaJayanti Fellowship (2015), K. Kishore Memorial Award (2016) from the SPSI, Bronze medal (2017) and CNR Rao National Prize for Chemical Sciences (2023) from the CRSI.He is an elected Fellow of the Indian Academy of Sciences (admitted in 2022). He is a member of the Editorial Advisory Board of *Macromolecules* since January 2021. Research interest of his group includes supramolecular polymerization of donor-acceptor π-systems, H-bonding driven assembly of amphiphilic π-systems/ macromolecules and biologically relevant stimuli responsive aggregation of amphiphilic polymers (polydisulfides, polyurethanes). He has co-authored in 132 papers in international journals and contributed to 4 book-chapters. Thirteen students have completed PhD under his supervision.

About Professor M.Santappa

Mushi Santappa born on October 2, 1923, obtained his BA (Chemistry) in 1943 from the University of Madras. He did his MSc (Chemistry) in 1946 from Banaras Hindu University. He obtained PhD (Organic Chemistry) in 1949 from University of London under the guidance of R.W. West followed by a second PhD (1951) in 'physical chemistry of high polymers' from Manchester University. Upon his return to India he joined the University of Madras (1952) as a Reader in Physical Chemistry and became a Professor in 1958. He served as Director, Central Leather Research Institute (CSIR-CLRI) from 1972-78. Subsequently he served as Vice-Chancellor of SV University, Tirupathi (1979-81) as well as the University of Madras (1981-84). He was conferred honorary DSc from Andhra, Madras, Sri Krishna Devaraya and Madurai Kamaraj Universities and honorary DLitt from Gulbarga University.

Professor Santappa published over 350 papers in peer-reviewed journals and guided 59 PhD students. He was awarded the S.S. Bhatnagar Prize for Chemical Sciences (1967), the Sir JC Ghosh Memorial Medal of Indian Chemical Society (1982), and the FICCI Award for Science and Technology (1985). He was elected Fellow of the Indian Academy of Sciences, Bangalore, National Academy of Sciences (India), Allahabad and the Indian National Science Academy, New Delhi.

Professor Santappa was initiated into the study of kinetics of vinyl polymerization as a PhD student working with Professor Meredith G. Evans, FRS (1904-1952) at the University of Manchester in the years between 1948 and 1951. Professor Evans, an early pioneer in the study of chemical kinetics, turned to the study of electron transfer reactions involving ferrous ions and hydrogen peroxide (Fenton reagent) and their ability to polymerize methyl methacrylate in aqueous emulsions Professor Evans elucidated the kinetics and mechanism of this reaction and further proposed that UV and visible light can promote internal electron transfer and, thus, vinyl monomers can be polymerized under the influence of light (photo polymerization). Professor Santappa's PhD work concerned photo-initiated free radical polymerization of vinyl monomers. Upon his return to India Professor Santappa built an active school of research on the study of kinetics of vinyl polymerization. Beginning in 1955 he published a series of over 150 papers on kinetics and mechanism of vinyl polymerization and determination of initiation rates and chain transfer constants for a host of initiators and vinyl monomers. Along with Professor Santi R. Palit at the Indian Association for the Cultivation of Science, Professor Santappa, established the first rigorous school for polymer science research in India and trained a whole generation of polymer chemists who went on to practice the discipline with great distinction. Professor Santappa brought great visibility to Indian polymer research for about three decades. In 1983, he organized India's first ever IUPAC sponsored International Symposium on Polymers at Madras (Chennai). In 1996 he authored a book which comprehensively reviewed the status of polymer science in India

About Professor M. Santappa Award

The Award was instituted by the Society for Polymer Science, India, in 1988 to honour Professor Mushi Santappa, a distinguished physical chemist and a pioneer in polymer science research in India. Professor Santappa was the founder of the Department of Physical Chemistry, University of Madras. Under his dynamic leadership and erudite scholarship, the Department became of hub of polymer science research in the period 1952-1970.

The award is given biennially by the Society to distinguished scientists for outstanding research contributions made in India during the ten years preceding the year of the award in the field of Polymer Science.

Prof. Santappa Award Winners of The Society for Polymer Science, India

1988 Dr. V. M. Nadkarni, National Chemical Laboratory, Pune
1988 Dr. S. Sivaram, National Chemical Laboratory, Pune
1991 Prof. Ashok Misra, Indian Institute of Technology, New Delhi
1998 Prof. B. M. Mandal, Indian Association for Cultivation of Science, Kolkata
2004 Prof. A.K.Nandi, Indian Association for Cultivation of Science, Kolkata
2006 Dr. C. P. Raghunadan Nair, Vikram Sarabhai Space Centre, Thiruvananthapuram
2006 Dr. P. P. Wadgaonkar, National Chemical Laboratory, Pune
2010 Dr. Pralay Maiti, Banaras Hindu University, Varanasi
2014 Dr Nikhil K. Singha, Indian Institute of Technology, Kharagpur
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