

First I. K. Varma Endowment Lecture 2025

Polymer Design Encoded for Microelectronics and Recyclability

by

Professor Padma Gopalan

University of Wisconsin-Madison,
Madison, USA

Date: December 15, 2025
Time: 11:20 am to 11:50 am

Venue: MACRO-2025 at Staudinger Hall
IIT Kharagpur Research Park, Newtown, Kolkata

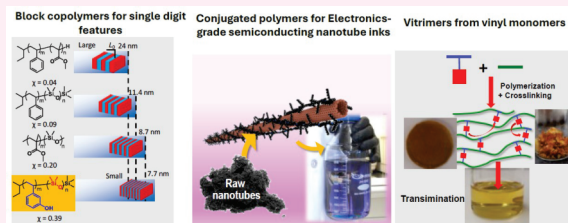
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Abstract

Over the last two decades my group has focused on polymers for microelectronics and optoelectronic applications. These include block copolymers that are synthesized with encoded information to define the size and shape of the resulting nanostructures which can then be used to pattern dense periodic lines and dots to access single digit features in a scalable, cost-effective manner for device fabrication^{1,2}. Concurrently we have pursued the design of conjugated polymers to enable high speed electronics beyond silicon, by assembling a monolayer array of single walled carbon nanotubes(SWCNTs) with 5- 10 nm pitch for field effect transistors and RF amplifiers. These conjugated polymers have many functions embedded in the structure such as ability to selectively sort semiconducting CNTs from a heterogenous mixture, degradability for easy removal after device fabrication, and self-assembling characteristics to define the pitch between the tubes. I will highlight the latest advances made by our team in this area³⁻⁵.

The second part of my talk will focus on a new type of vitrimer that we have developed recently that can be made from any commercial vinyl monomer using a free radical mechanism. Vitrimers bridge the gap between thermoplastics and thermosets to address the trade-off between recyclability and thermomechanical properties by incorporation of dynamic covalent bonds in the network structure. The polyimine vitrimers that we have developed show superior creep resistance, improved Young's modulus, and hardness. Our approach bypasses amine-aldehyde condensation, hence expanding the monomer scope. I will present detailed stress relaxation experiments and oscillatory shear experiments to fully characterize the viscoelastic properties of the vitrimers. We further show that transimination reaction can effectively reprocess the vitrimers, while offering the advantage of increased resistance to hydrolytic degradation. Our methodology decouples polyimine vitrimers design from monomer limitations, providing a scalable route to tailoring high-performance vitrimers.



References:

1. Azuma, K. et al. *Macromolecules* 51, 6460–6467 (2018).
2. Sun, J. et al. *Macromolecules* 54, 9542–9550 (2021).
3. Kanimozhi, C. et al. *Macromolecules* 52, 4278–4286 (2019).
4. Oliveras-Santos, S. et al. *Macromolecules* 57, 3588–3594 (2024).
5. Dwyer, J. H. et al. *Nanoscale Adv.* 3, 1767–1775 (2021).

About the speaker

Prof. Gopalan received her Ph.D. from Cornell University in Chemistry and postdoctoral work at Lucent Technologies and Bell Laboratories. She worked as a Research associate at the National Aerospace Laboratory in India and as a R and D scientist at Grinwell Norton. She joined the University of Wisconsin-Madison in 2003 and is currently a Professor in the Department of Materials Science and Engineering. Her research is funded by NSF, DOE, ACS, DARPA, Army, and Wisconsin Alumni Research Foundation (WARF). She has received several awards, including the NSF-CAREER award in 2005 and the Kellet Mid-Career award in 2022. She has also been a Co-leader in the NSF-MRSEC center on campus and was appointed as a visiting Professor through the World Research Hub at Tokyo Institute of Technology from 2018 to 2020.



About Dr. I. K. Varma

Prof. Indra Kumari Varma was born on 15th January 1939. Her contribution to the growth of polymer science in India and the training of a large set of human resources is beyond imagination. In fact, she has trained the largest number of women polymer chemists in our country. Apart from creating good quality students, she excelled in scientific research and championed the creation of the Center for Polymer Science and Technology at IIT Delhi.



Prof. I. K. Varma has been a real trailblazer. She received a gold medal in BSc in 1956 from Allahabad University. She did her MSc and DPhil from Allahabad University and PhD from Glasgow University in 1965. Later, she received a DSc degree from Glasgow University in 1986. She started her academic career at IIT Delhi in 1966 as a Lecturer in the Chemistry Department. In 1977, she became the first female professor in all the five IITs of that time.

Prof. Varma spent most of her independent teaching and research career at IIT Delhi. She excelled in various domains of polymer science and technology. Apart from numerous awards, she also held the Modi Chair Professorship, the Reliance Chair, and served as an Emeritus Professor at IIT Delhi. She has been President of The Society of Polymer Science India (SPSI) (1994-2001), President of the Indian Thermal Analysis Society (1986-1991), and Regional Editor of the *Journal of Thermal Analysis and Calorimetry* (1986-2002).

Prof. I. K. Varma worked on leading-edge technology throughout her professional life. Her first external project at IIT Delhi was from ISRO in the 1970s. In the 1980s, she worked at NASA-Ames Research Centre at Moffett Field, California, USA for over two years on flame retardant polyimide resins and was awarded five US patents for this work. She visited the Space Shuttle Launch Pad at the Kennedy Space Center in Florida, USA to explore polymer utility in high-end applications. She realized there is an immense need of the hour to replace the existing persistent commodity polymers. Therefore, later she worked on biodegradable polymers with Prof. Ann-Christine Albertsson, Royal Institute of Technology (KTH), Stockholm, Sweden. This contribution of hers was acknowledged, and she became a recipient of the Honorary Doctorate degree from KTH in 2009. As a working woman, Prof. Varma managed her professional and personal life with ease. Here is a quote from Prof. Varma, "Life without determination has no meaning whether it's the domestic front or office." Prof. I. K. Varma was well supported by her husband Prof. Dharmendra Singh Varma (1934-2021), a daughter and a son. Prof. Varma has been a role model and inspiration to generations of students and will continue to be so.

About I. K. Varma Endowment Lecture

An endowment lecture to honor Prof (Mrs.) I. K. Varma, and it will be called the Prof. Indra Kumari Varma Endowment Lecture. This lecture will be a regular feature of our biannual meetings and will kick off from MACRO 2025. The Endowment Lecturer will be an eminent and well-recognized polymer/material scientist of international standing. Special efforts will be made to identify women scientists of outstanding merit.