



# DEPARTMENT OF MATERIALS SCIENCE & ENGINEERING, IIT KANPUR

## PROF. E C SUBBARAO DISTINGUISHED LECTURE SERIES

### Utilizing Cold Sintering in the Design and Integration of New Functional Composite Materials

**Dr. Clive A Randall**

Director, Materials Research Institute  
Distinguished Professor of Materials Science and Engineering  
The Pennsylvania State University, University Park, PA 16802 USA

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#### About the Speaker



Clive A. Randall is a Distinguished Professor of Materials Science and Engineering and Director of Materials Research Institute at The Pennsylvania State University. He was Director for the Center for Dielectric Studies between 1997 and 2013, and in 2013 formed a new Center as Co-Director, the Center for Dielectrics and Piezoelectrics, for which he still serves as Technical Advisor since 2016. Prof. Randall received a B.Sc. (Honors) in Physics from University of East Anglia, UK (1983), and a Ph.D. in Experimental Physics from University of Essex, UK (1987). He has authored/co-authored over 500 technical papers. He also holds 15 patents in the field of electroceramics. His research interests are in the area of discovery and compositional design of functional materials for electrical energy transduction and storage, defect chemistry and crystal chemistry and their impact on phase transition behavior, electromechanical devices based upon electrostriction and piezoelectrics, supercapacitors, thermoelectrics, and microwave materials. Professor Randall has been honored with Academician of World Academy of Ceramics, IEEE Distinguished Lecturer, Fellow of the European Ceramic Society, Fellow of the American Ceramic Society, Fellow of IEEE, and a member of the National Academy of Inventors.

#### Abstract: Utilizing Cold Sintering in the Design and Integration of New Functional Composite Materials

Typical ceramic sintering temperatures occurs at 0.5 to 0.95 of the melting temperatures ( $T_m$ ), in oxides; we conventionally sinter around 800 to 1800 °C. This lecture reviews various chemical pathways, and variables such as pressure, temperature, and time that enable the cold sintering processes to occur at low temperatures. Using model systems, it is possible to contrast the energetics and mechanisms with conventional sintering processes regarding densification and grain growth kinetics. With the introduction of a cold sintering strategy, a common processing platform ~ 200 °C enables the integration of multiple materials that permits new types of composites and devices to be designed. The power of such design versatility will be demonstrated with number of functional ceramics and multilayer devices impacting a broad number of applications. Beyond the successful examples, the many challenges and opportunities of cold sintering will also be discussed, including the vision of a sustainable cyclic economy.

#### About E C Subbarao Lecture Series



**Dr. Eleswarapu Chinna Subbarao** received BSc (Glass Technology) (1949) from Banaras Hindu University (BHU), BS (1952) and MS (1954) degrees in Ceramic Engineering from the University of Washington, Seattle; and PhD (Ceramic Technology) (1957) from the Pennsylvania State University. His doctoral thesis pioneered work on domain effects in ferroelectric ceramic barium titanate. He worked at Westinghouse Research Laboratories, Pittsburgh, PA (1956-63). In 1963, he joined IIT Kanpur, worked there as first Head of Metallurgical Engineering Department.; then as Founder-Director, Tata Research Development and Design Centre, Tata Consultancy Services, Pune.

Dr. Subbarao organized the first conference on Materials Science Education in India (1966) and established an interdisciplinary postgraduate programme in materials science at IIT Kanpur, also an Advanced Center of Materials Science, thus ushering in material science education and research in India. He was the first Dean of Faculty at IIT Kanpur and played a pivotal role in assembling world-class faculty at the IIT. He served on the Editorial boards of many national and international journals. He also served as Member, INSA Council (1982-84). Professor Subbarao received the INSA Prize for Materials Science (1995), National Metallurgists' Award (1970), Homi Bhabha Award in Applied Science (1978), ID Varshnei Memorial Lecture Award (1987), Distinguished Materials Scientist of the Year by MRSI (1991), NP Gandhi Memorial Lecture Award (1995), Distinguished Alumnus of the Institute of Technology, Banaras Hindu University (1998), and Honorary Fellow of IIT Kanpur (2006). He was elected Fellow of the Indian Academy of Sciences, Bangalore, Indian National Academy of Engineering and the International Academy of Ceramics. Dr. Subbarao currently staying with his son, who's an alumnus of IITK in M.E. in 1979, in Los Angeles.

#### About the Donor



**Mr. Ramamritham Ramkumar** born in 1951 did his B.Tech in Metallurgical Engineering from IIT Kanpur in 1972. Then he moved to Canada to pursue MBA from the university of Toronto.

Mr. Ramkumar is a businessperson who has been at the head of 6 different companies.

Presently, he occupies the position of Chairman at ASL Print FX Ltd., Independent Chairman of Meta Materials, Inc., and Chairman of Process Research ORTECH, Inc. Mr. Ramkumar is also on the board of Metamaterial Technologies, Inc.

In the past he held the position of Director at Snipp Interactive, Inc., Chief Executive Officer of INSCAPE Corp., Chief Financial Officer, VP-Operations & GM at Reff, Inc. and Charter Member at The Indus Entrepreneurs. Mr. Ramkumar has also served on the boards of numerous other public companies listed on the TSX and NASDAQ. Over the last 10 years Mr. Ramkumar has been an investor in a number of business ventures ranging from flexographic printing to technology development in the area of extracting metals from minerals.