J Mater Sci (2009) 44:2177–2180
DOI 10.1007/s10853-009-3363-5



# Preface and foreword special issue: Prof T R Anantharaman

Received: 21 December 2008 / Accepted: 19 February 2009 / Published online: 31 March 2009



## A tribute to Professor Tanjore Ramachandra Anantharaman

Tanjore Ramachandra Anantharaman had a brilliant academic career. He topped Madras University at every stage of his educational career and obtained his BE degree in Metallurgy in 1950 from the very first batch of the Indian Institute of Science, Bangalore. This stellar performance won for him the Rhodes scholarship and admission into Oxford University. His D.Phil. (1951–54) research was related to a study of stacking faults and the hcp–fcc phase transformation in cobalt. This research was carried out under the supervision of J.W. Christian in the department headed by W. Hume-Rothery during a historic period when older metallurgy was giving way to new metallurgical science (borrowing from the riveting dialogue between the older metallurgist and the young scientist in Hume-Rothery's celebrated book, electrons, atoms, metals and alloys, 1948). After 2 years of postdoctoral research on the determination of phase diagrams in association with Konrad Schubert, as also on precipitation reactions in aluminium alloys in association with Volkmar Gerold, at the Max Planck Institut fuer Metallforschung, Stuttgart, which then was led by venerable Werner Koester, Anantharaman returned to India in 1957 to take up a faculty position at the Indian Institute of Science, Bangalore. He moved to Banaras Hindu University (BHU) in 1962 to head India's first ever (established in 1923) metallurgy department. It is here that he found his métier.

With trivial sums of money for research, nothing at all by present day standards, Anantharaman launched his legendary efforts to build one of the finest research schools in metallurgical science, a discipline that was witnessing yet another change, a metamorphosis into materials science. With his magnetic personal charisma, he attracted young talented students, over whom he held a magical sway that inspired them to bring out their best. Thus, began researches in the analysis of X-ray diffuse scattering from structural imperfections, liquid metal calorimetry, field ion microscopy, precipitation hardening and spinodal decomposition in aluminium alloys, to name a few topics in which publications appeared in prestigious journals. Given his contacts overseas in the field of metallurgy and materials science, Anantharaman pioneered international collaboration by establishing exchanges between his department and renowned centres in the UK (Sheffield, Cambridge and Oxford Universities) and Germany (Stuttgart, Erlangen and Duesseldorf). His extraordinary academic leadership of his young team (Anantharaman at 35 years in 1962 was the oldest of the fledgling team) had the infectious effect of spreading research culture beyond BHU and across far-flung metallurgy and materials science schools in the country.

During his early years at BHU, Anantharaman grasped an opportunity to work at Caltech, Pasadena, with Pol Duwez, who had just then invented a technique for splat quenching, a process that brought about dramatic non-equilibrium phase changes in metallic alloys. On his return, Anantharaman added to the impressive basket of research

topics in his department the frontier field of rapid solidification with bountiful output of results.

The era of funded research had dawned in India and Anantharaman's heroic struggle was duly recognized by declaring his department as the first ever Centre of Advanced Study in an engineering field in the country. Anantharaman came to wield unmatched influence over the new science funding agencies in the country. Thus, a national electron microscopy facility was set-up and a national project on metallic glasses was undertaken in the department with substantial funds. The School of Materials Science and Technology was established in 1978, which offered the first M.Tech. programme in Materials Science and Technology in India.

The discovery of quasicrystals was announced in 1984. A paper published by the BHU group in 1978 was later recognized as one that had actually dealt with a decagonal quasicrystalline phase. Anantharaman got engaged in this area, given his record of work on non-equilibrium structures, once he was free from administrative responsibilities. He also got involved in archaeometallurgy. His penchant for detail is reflected in his prolific publications and in his books (*Metallic Glasses: Production, Properties and Applications*, 1984, *Rapidly Solidified Metals: A Technological Overview*, 1987 and *The Rustless Wonder: A Study of the Iron Pillar at Delhi*, 1996).

A Fellow of all the three Science Academies of India and a Fellow of the Indian National Academy of Engineering, numerous national honours came the way of Anantharaman. Among those from abroad, mention may be made of the Sorby Award of the International Metallographic Society, the Honorary Memberships of the Deutsche Gesselschaft fuer Materialkunde, the Corresponding Membership of the Royal Belgian Academy of Overseas Sciences and D.Sc from Oxford University.

Well-versed in Sanskrit and German besides Tamil, Hindi and English, he is deeply interested in spirituality, religion and philosophy. He has authored two books in German, one on the *Bhagavad-Gita*, 1961 and the other on *Erkenntnis durch Meditation*, 1977. He naturally tends to interpret spiritual matters in scientific terms. The result is his book entitled *Ancient Yoga and Modern Science* published in 1997.

This tribute by one who was fortunate to have been Anantharaman's first PhD student is best summed up by saying that he transcends the conventional notion of a professor. Admittedly, his impact on his students is perennial. His erudition, his gifted speech, his intensity for physical metallurgy and his lucid discourses on arcane philosophical subjects have indented on the minds of his students an indelible imprint. Students came to him as raw individuals and went out to become acclaimed professionals. Having spotted and nurtured talent with resolute determination, Anantharaman justifiably lays claim to the success of his students: around thirty-five of them became professors in the Universities in India and abroad, and a few occupied high offices like Directors of National Laboratories, heads of Science Agencies and distinguished professional bodies. Anantharaman has thus demonstrated that a sustainable way to materialize one's vision is by creating new leaders, who in their own way build new institutions.

A testimony to Anantharaman's stature is contained in the galaxy of luminaries, who visited his department in a not-so-easily accessed city of India. Among these were Cyril Stanley Smith, Pol Duwez, André Guinier, Werner Koester, Bruce Chalmers, Erwin Muëller, Morris Cohen, Robert Cahn, Bernard Ilschner, Robert Maddin, Severin Amelinckx and Sumio Iijima. Rightly, the citation on the occasion of his 80th birthday referred to Anantharaman as a *man for all seasons.*

P. Rama Rao, The International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad, India.

## Foreword

This Special Issue of *Journal of Materials Science* contains a number of the invited articles presented at the *International Conference on Metals and Alloys: Past, Present and Future (METALLO 2007)* held at the Indian Institute of Technology (IIT) Kanpur, India during 7–10 December 2007. The conference was organized to honour the outstanding contributions of Professor Tanjore Ramachandra Anantharaman (TRA), doyen of the present day Metallurgical Education and Research in India, to the various subfields of metallurgy and materials science and also to celebrate his 80th birthday.

The first article of this special issue is written by TRA's first doctoral student and a distinguished metallurgist in his own right, P. Rama Rao. In this article, he discusses the unique contributions of TRA to Metallurgical Engineering Education and Research. This is followed by selected articles that have been rigorously reviewed and found suitable for publication and illustrate how this particular discipline of Metallurgy has evolved over the years from more conventional to the modern era of Materials Science. As a demonstration of the research on ancient materials, the two articles by Craddock [1] and Barnett et al. [2] report on the aspects of archaeometallurgy. In the article by Barnett et al. [2], the detailed analysis of wootz steel using a modern characterization tool (Electron Back Scattered Diffraction) provides insight into the possible manufacturing routes of such ancient steel. Another article by Kirchheim and co-workers [3] deals with the physical

metallurgy aspect of oxygen diffusion in solid palladium. From the classical 'Physical Metallurgy' aspect, some articles report newer understanding on the process of grain growth (Voorhees and co-workers [4]). The advent of new characterization tools enables us to investigate the microstructure of materials at a finer scale down to atomistic level. The use of three-dimensional atom probe to investigate the cast microstructure of a Ni-based superalloy for turbine engine is explained in the article by Muraleedharan et al. [5]. In the 'Mechanical Metallurgy' area, the characteristics of superplasticity in nanostructured materials (K. A. Padmanabhan [6]) as well as the creep behaviour of an alloy used for nuclear reactors (Rama Rao and co-workers [7]) are covered. Some critical issues related to the embrittlement problem in ferritic steels are addressed in the article written by Baldev Raj et al. [8]. Reddy et al. [9] deal with the classical issue of melting in a model eutectic alloy system. Biomaterials are gaining importance in the twenty-first century and an article by Bera and Ramachandra Rao [10] presents a novel biomimetic approach to produce hydroxyapatite (HAp) and Ag nanoparticles. It needs to be pointed out here that HAp has received wider attention in the biomaterials community because its composition is similar to the inorganic composition of natural cortical bone. Another area, which also drew significant attention in the last two decades, is the area of Nanotechnology. In an article by Ajayan and co-workers [11] the novel synthesis route to obtain Co–Ni nanowires is described. In the last few decades, surface coatings have been widely investigated for various engineering applications. In one of the articles by Sampath and co-workers [12], the critical analysis of the process parameters is presented to illustrate how to design coating deposition variables to obtain desired coating properties. Moreover, the evaluation of mechanical and wear resistance properties of spray-formed and cold-sprayed coating are covered by Srivastava et al. [13] and Sundararajan et al. [14]. Material degradation processes, e.g. wear and corrosion, being system-dependent properties, are influenced by both material parameters (grain size, hardness, etc.) as well as operating parameters (environment, load, etc.). The evaluation of wear resistance of some bulk materials, like intermetallic-reinforced stainless steel, is described in an article by Balaji and Upadhyaya [15]. In some related articles, it is demonstrated how the cryogenic environment can influence the sliding wear properties of a ductile metal, like Cu (Basu et al. [16]), or how the acid medium influences the passive film chemistry on stainless steel surface (Rao and Singhal [17]). Finally, computational approaches are adopted in Metallurgy and Materials Science. It has been illustrated by Lele and Sarma [18] how the cluster variation method can be used in combination with fundamental thermodynamic principles to predict phase diagrams. Overall, this Special Issue truly illustrates the significant progress being made in understanding structure–property–performance relationship of several bulk materials and coatings, while simultaneously covering the recent advances in physical and mechanical metallurgy aspects.

We thank the participants who have taken time to prepare their presentations, present them at the Conference, and write them up for publication in this special issue. We sincerely appreciate all the referees of the manuscripts, who by tradition will remain anonymous, for sparing their valuable time for critically reviewing the manuscripts to ensure high standards of archival publications. We are thankful to the members of the National and International Advisory Committees of the conference, and to the President and office bearers of the Indian Institute of Metals as well as the administration of IIT Kanpur for hosting this event. The conference was supported by various Governmental funding agencies, including INDO-US Science and Technology forum, Department of Science and Technology, Department of Atomic Energy, Council for Scientific and Industrial Research, Defence Research and Development Organization, US Asian Office of Aerospace Research and Development, US Air Force Office of Scientific Research and US Office of Naval Research Global. In addition, some private agencies also extended their financial support, which include Larsen & Toubro Ltd., Icon Analytical Equipment Pvt. Ltd., General Motors Corporation, USA, Carl Zeiss SMT AG, Germany and Oxford Instruments, England.

Our final words of special thanks are due to Professor Barry Carter, Editor-in-Chief, *Journal of Materials Science*, who kindly agreed to publish this Special Issue as a tribute to the distinguished contributions of Professor Anantharaman. We also acknowledge the co-operation received from Professor Mark Aindow, Deputy Editor-in-Chief, *Journal of Materials Science,* who interacted closely with us in seeing this Special Issue through. The editorial assistance received from Ms. Betty Pinney, Springer, is appreciated.

R. Balasubramaniam, Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur 208016, India.

Bikramjit Basu, Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur 208016, India.

S. Ranganathan, Department of Materials Engineering, Indian Institute of Science, Bangalore 560 080, India.

C. Suryanarayana, Department of Mechanical, Materials and Aerospace Engineering, University of Central Florida, Orlando, FL 32816-2450, USA.

Anish Upadhyaya, Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur 208016, India.

## References


1. Craddock PT (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-2942-1
2. Barnett MR, Balasubramaniam R, Kumar V, MacRae C (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3007-1
3. Gegner J, Hörz G, Kirchheim R (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-2923-4
4. McKenna IM, Gururajan MP, Voorhees PW (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3196-7
5. Muraleedharan K, Balamuralikrishnan R, Das N (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3025-z
6. Padmanabhan KA (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3076-1
7. Kishore R, Banerjee S, Rama Rao P (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-2962-x
8. Raj B, Saroja S, Laha K, Karthikeyan T, Vijayalakshmi M, Bhanu Sankara Rao K (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3199-4
9. Reddy B, Bhattacharya P, Singh B, Chattopadhyay K (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3146-4
10. Bera T, Ramachandrarao P (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-2861-1
11. Talapatra S, Tang X, Padi M, Kim T, Vajtai R, Sastry GVS, Shima M, Deevi SC, Ajayan PM (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3015-1
12. Colmenares-Angulo JR, Cannillo V, Lusvarghi L, Sola A, Sampath S (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3044-9
13. Srivastava VC, Rudrakshi GB, Uhlenwinkel V, Ojha SN (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-2924-3
14. Sundararajan G, Sudharshan Phani P, Jyothirmayi A, Gundakaram RC (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3200-2
15. Balaji S, Upadhyaya A (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3020-4
16. Basu B, Manoj Kumar BV, Gilman PS (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3043-x
17. Shankar Rao V, Singhal LK (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-2976-4
18. Lele S, Nageswara Sarma B (2009) J Mater Sci 44 (in press). doi:10.1007/s10853-008-3197-6