Advances in Materials and their Applications. P. Rama Rao. Wiley Eastern Limited, India. 1993. Price Rs 400. 376 + 8 pp.

During November 1990 the Indian Institute of Metals had organized an International Symposium on the broad theme of 'Materials for Advanced Technology Systems', to coincide with the Annual Technical Meeting of the Institute held at Tiruchirapalli, South India. P. Rama Rao who was the President of the Institute for the year had composed this Symposium, sending out invitations to selected specialists over-seas and heads of major technology missions in the country to representatively cover the various leading fronts of materials development and to focus on some of the new and novel trends in the current scenario. The present volume is a compilation of the 22 papers presented at this Symposium.

Materials have been defined as 'the working substances of our civilization—substances having properties which make them useful in structures, devices, machines and products'. The subject of materials science and engineering is concerned with 'the generation and application of knowledge, relating the composition, structure and processing of materials to their properties and uses'.

In the earliest stages of man's life on earth the materials that were available to him were mainly stone, wood, bone and skin which he learnt to fashion for his use. (It is interesting that these materials evolved and devised by Nature have provided the insights and models for the design of modern materials.) Human skills in the extraction and application of some of the common metals and the baking of bricks and pottery date back only a few thousand years. Systematic development of metallurgy and materials science as a *multi-disciplinary engineering discipline* has however happened barely in the last 100 to 150 years. The pace has accelerated considerably in very recent times, and the indications are that the possibilities of developing new materials and new ways of processing them, to achieve improved properties and develop entirely new properties, will never be exhausted. Against this back drop, the papers in the present volume portray the specialized understanding and experiences of the individual authors and in sum total they offer a very impressive picture of our current understanding of the materials structure and behaviour, the specific requirements and demands of materials performance in advanced technology systems, and the many-pronged approaches of the materials engineer in responding to these demands.

In the opening paper, based on his presidential address at the symposium, Rama Rao has emphasized and illustrated how the process and strategy of materials development can best be evolved only when applications are targeted for the materials in question. It is the need for a specific material in component form for a desired function—in a competitive environment of alternative choices—that provides the drive and the discipline, for designing processes and flow sheets leading to the emergence of a commercial product. He has illustrated this philosophy as derived from his own experiences, at the Defence Metallurgical Research Laboratory, for example in the development of tungsten alloy powder metallurgy product as projectile in defence ammunition, and the setting up of a pilot plant facility for the production of oxygen-free electronic grade copper for a variety of applications—starting with basic research and laboratory scale work, establishing appropriate linkages with the industry, and providing a proper organizational framework for project implementation.

In the paper outlining the fundamental materials science approach, B. H. Kolster (Foundation for Advanced Metals Science, The Netherlands) has observed that one-third of the scientific and technological effort of high-tech programmes in Aerospace, Nuclear technology, Electronics and Computer technology relates to the materials field, and this is true even in conventional areas like surface transport, building, sports and recreation. The investments on high-tech materials form a significant proportion of the total industrial turnover in the developed countries. Kolster has attributed the substantial advances and the major breakthroughs achieved in recent decades to the developments in microscopy and advanced analytical tools, inventions in materials processing, progress in the theoretical models, and importantly, availability of versatile computers.

If it is recognized that the property of any material is defined by its constitution—and the constitution itself has components of composition, structure and residual stress—the modern materials engineer has a wide range of strategies for modifying the constitution and so the properties, to achieve desired results. When we recognize that we also have a choice of different types of materials like metals, polymers, ceramics and composites, the potential possibilities are both bewildering and fascinating. Kolster has illustrated this, drawing examples from heat treatment of steels and nickel-based alloys, surface treatment by laser hardening and electro-deposition, and advances in joining technology including laser welding and diffusion bonding in metal matrix composites.

In making a projection for the next two decades, G. K. Bhat (Pennsylvania, USA) has anticipated far-reaching developments as applicable to metallic materials, new polymer materials, and advanced ceramic materials, progressing in mutual competition. The emphasis will be on defect-free materials, improved materials design and processing for better efficiency and to minimize costs, waste re-cycle, and environment-friendly technologies. He has given the examples of improvements in alloy steels and aluminium alloys, the likely demand for hydrogen storage alloys and shape memory alloys, and progress in production of fibres, semi-conductor chips and diamond films and coatings.

Nano-phase materials, which belong to the new frontier, are materials with ultra-fine grain sizes in the range of 5 to 50 nanometers, with a very large portion of the atoms in grain boundaries and interfaces. By virtue of their unusual structure, they are also vested with unusual properties superior to those encountered with normal materials. For example, it has been suggested that adequate ductility can be achieved in ceramics by following the nano-synthesis route. R. W. Siegel's paper (Argonne National Laboratory, USA) briefly describes the current status on synthesizing nano-phase materials, and the study of their structure and properties.

The paper by B. B. Rath and co-workers (Naval Research Laboratory, Washington, DC) comprehensively surveys the most modern techniques in the characterization of materials on the nanometer scale. In addition to scanning tunnelling microscopy (STM), the techniques of scanning tunnelling spectroscopy, photon STM, and atomic force microscopy, are described, and also techniques such as nanolithography, and nano-crystal formation by sputtering, for fabricating nanometer scale structures, that have potential importance in electronics and optics. This important survey includes as many as 183 references from the most recent literature.

Subhash Mahajan's paper (Carnegie Mellon University, USA) discusses the mechanism of atomic ordering and phase separation in ternary and quarternary III and V semiconductors. K. N. Tu's paper (IBM Research Division, New York) discusses the mechanisms of the formation of metastable phases in reactions in thin films.

In a variety of engineering application situations there are requirements of achieving gradients in chemical composition, phase distribution and morphology in materials. Processes such as surface carburizing or nitriding of steels, internal oxidation of alloys, ion implantation, and laser surface modification are already in industrial practice. B. Ilschner's paper (Swiss Federal Institute of Technology, Lausanne) on composition gradient materials describes possible new approaches to producing composition gradients, such as centrifugal powder metallurgy and galvano-forming, and also types of material systems where gradient development will offer definite advantages.

Structural impact is a subject of interest to a wide variety of engineering problems—as for example, the structural crash worthiness of vehicles, impact of meteoroids on spacecraft, integrity of nuclear power components under accident conditions, etc. The paper by Norman Jones (Impact Research Centre, University of Liverpool, UK) discusses the subject in relation to the material properties, and points out the need for generating much more experimental data. On the other hand, S. R. Reid's paper (UMIST, Manchester, UK) discusses material deformation mechanisms in situations involving large plastic strains and/or fracture in metal components, fracture and delamination in fibre reinforced composites, and intense crushing in cellular materials like wood.

R. W. Armstrong and co-workers (University of Maryland, USA) have analysed dynamic plasticity and fracture, in bcc and fcc metals, on the basis of dislocation mechanics taking into account strain rate, temperature, grain size and strain hardening The deformation and damage behaviour of nickel-based super alloys has been investigated by R. P. Wahi and co-workers (Hahn–Meitner Institute, Berlin) to identify the mechanisms by microscopic techniques. The role of grain boundaries in high temperature deformation (diffusion creep, creep fracture and superplasticity) is surveyed by R. C. Gifkens (Victoria, Australia).

Both low cost steels and cast irons and high value alloy steels are amenable to surface modification processes, for improvement of surface properties. The available treatments can be broadly classified as plating/coating, ion implantation, thermo-chemical and thermal treatments, where modifications are achieved over depths ranging from 0.1 micron to 10,000 microns. George Krauss (Colorado School of Mines, USA) has considered the criteria of choice of technique in relation to the performance requirements, and in particular described recent advances in plasma nitriding/carburizing, ion implantation, chemical vapour-deposition (of titanium carbide and nitride), physical vapour deposition and laser and electron-beam surface modification. It is a field that is continuously expanding, and the concepts are applicable to many types of materials beyond steels.

The paper by Daming Wang and R. L. Apps (Brunel University, UK) specifically discusses hydrogen-induced cracking, in multi-pass steel welds. Welded steel structures are extensively used in the industry and the problem of hydrogen-induced cracking is a matter of continuing concern.

Ever since its discovery 200 years back, nickel has played a major role as an engineering material, both in the form of nickel-based alloys and as alloying addition in ferrous and non-ferrous systems. While the development of nickel-based super alloys has been crucial for the aircraft jet engine industry, the availability of high-strength, heat-resistant nickel-based alloys and a whole range of stainless steels has been invaluable for the chemical process industry. The paper by Walter Betteridge (UK) has illustrated the high performance applications of nickel alloys and has also projected areas such as maraging and cryogenic steels, shape memory alloys, hydrogen storage systems and new galvanizing compositions, as areas for future growth.

Through extensive basic research in the laboratory and pilot plant development, substantial achievements have been registered in the development of advanced materials in the major technology mission programmes in the country, namely aerospace, nuclear engineering and defence technology. The progress has been competently surveyed by R. Krishnan (Gas Turbine Research Establishment), R. Chidambaram (Atomic Energy Commission) and Abdul Kalam (Defence Research & Development Organization). The materials discussed comprise nickel-based super alloys and advanced titanium alloys (for aero-engines), zirconium alloys for water cooled nuclear reactors and plutonium fuel materials and advanced stainless steels for fast reactors, and carbon fibre composites, maraging steels, titanium alloys, and electronic materials for a wide range of missile systems. Similarly another paper (P. C. Deb, Naval Chemical and Metallurgical Laboratory) has assessed the materials requirements in naval systems, including hull material, super structure, propulsion system, and instrumentation for protection, detection and camouflage.

Since the early eighties there has been a sharp increase in the growth of the Indian automobile industry, with large spurts in the production of cars, two wheelers and commercial vehicles. Materials contribute 70% to the costs of the automobile, and their quality decides the performance of the vehicle. C. V. Tikekar (Tata Engineering and Locomotive Company) has emphasized the importance of materials strategy, in lowering the costs of production and improving the efficiency of vehicle performance. He has specifically pointed to the continuing dependence on import of automobile quality steel sheets and plates. He has also indicated possibilities for the increased use of aluminium, and fibre reinforced composites, in light commercial vehicles and passenger cars.

The last paper, contributed by W. Johnson (University of Cambridge, UK), is by way of a memorial tribute to Benjamin Robins, mid-18th century military engineer scientist, for his pioneering contributions in gunnery, and experimental aero-dynamics—describing in particular his development of the ballistic pendulum (for measuring cannon ball speed), and design of a whirling machine for studying projectile shapes, and their resistance in flight.

It will be realized that all the papers are in the nature of specialist contributions, varying in individual content and style. All the same they fall into a few groups, with some inevitable overlap with regard to the materials and processes surveyed. Taken together, they represent a very impressive, panoramic portrayal of the advanced materials scene, both in India and in the western world. In terms of scientific content, quantitative engineering data, and analysis of materials strategy, the volume has a great value both for the research scientist and the design engineer. For the detailed thought given to structuring the symposium, for identifying so many eminent contributors from across the globe, and eliciting such excellent responses from all of them, Rama Rao deserves every appreciation and praise.

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The C-DOT Story. G. B. Meemamsi. Kedar Publications, Amritam A3, Sector 15, Noida 201 301. India. 1993. 150 pp.

The book has a rather meaningful cover epitomizing the C-DOT story. A plant about to flower, labelled "quest", the same plant trampled and mistreated, labelled "inquest" and presumably the same plant recovered with many flowers and buds, labelled "conquest". Only a gardener knows what it is to plant a seed and nurse the sapling against odds. Padma Shri Meemamsi can very well fit the role of a gardener trying out a new kind of plant in an alien environment and be somewhat lucky to see the plant bear fruits after a near miss.

The story of the digital electronic telephone exchange in India did not start with C-DOT (1981). In fact C-DOT was a culmination of the efforts of a group under the direction of Meemamsi way back in 1965 when the rest of the world was also trying to field test their first attempts. The only guide then was a two-volume Bell System on ESS. Technology in terms of processor, memory and peripherals was primitive from todays standard. The world should be grateful to ESS for the birth of a transistor which eventually transformed the field of electronics. We read that the demonstration of the Indian ESS in 1973 was quite a bit of touch and go and the author recalls a remark of a colleague 'Sir, we did not perform puja and break the coconut to invoke the blessings of the switch. That's why this happened'. Perhaps, Meemamsi a technologist did not take this remark seriously, for that can be the only explanation for the unwarranted interference by politicians and their henchmen at a later date. Coconuts should have been broken not at the altar but on the head of...

C-DOT tried to break many new grounds. India took courage to give a chance to Indian technological competence, thanks to the high profile marketing of the idea at the highest level in the government by Sam Pitroda who set up an organization with a totally new work style which was conducive to obtain commitment from employees and a purchase strategy to cut down procurement delays to a minimum. Perhaps, the only thing they borrowed from almost all Indian projects was to promise too much, in a very short time and at a ridiculous R&D budget. C-DOT's R&D budget was 0.04 billion dollar as against in excess of 2.5 billion dollar spent by any multinational company (MNC).

C-DOT is an existence theorem in that it proved that one can set up a world class technology development team on the Indian soil, which demonstrated that the brain drain can be stopped or even reversed if one wanted to. People's sensitivity was the essence of C-DOT management with work environment egalitarian, not hierarchical. Such ideas in managing Hi-tech groups in India have become common these days but one can still pick up new ideas by reading the quest portion of the book.

Whereas C-DOT was chugging along fine, the problem was that 'C-DOT was born in a hostile environment, without the blessing of the top policy-makers of the department of telecommunication (DOT), the sole user of the technology to be developed by it'. DOT seem to have been driven by 'service before self-reliance' in an environment where MNCs backed by soft loans offered quick solutions to the problem of communication bottleneck.

One cannot find out from the book what exactly C-DOT really promised for Rs 36 crores in 36 months. Presumably they promised a field-tested 10,000 to 40,000 line exchange with an astronomical 800,000 BHCA (busy hour call attempts). When progress was slow C-DOT tried to establish credibility by producing in a hurry PABX (128 line) and RAX (256 line). The sideline of RAX and PABX became so popular that the entry of MNCs in that area failed even after some local companies had licensed foreign technology. No wonder the public relation cells of the humiliated MNCs were working overtime.

The fall of the Congress Government in December 1989 and takeover by the National Front Government provided an opportune movement for settling scores. Meemamsi explains the origin of the logo of C-DOT which when looked carefully is C and i. Does one need a flag more red than that, for the new government to want to put C-DOT in its place? India should be ashamed of what took place in terms of the witch-hunt of C-DOT in 1990. One can pick up almost any reason if one was determined to find fault with. What started as a serious technical review of C-DOT ended in a drama worthy of Bollywood (the popular name given to describe the Bombay film industry) and Sri. K. P. P. Nambiar exhibited an ability to serve as 'cat's paw', which surprised many who had known him as a no-nonsense technocrat. Antics of the minister Sri Unnikrishnan were no less peculiar. Whereas the committed team of C-DOT made one feel proud that 'India can do it', the witch-hunting crossed decency, making India feel naked in front of MNCs. It is to the credit of Sri Sundaram and Dr Shenoy that some honest evaluation of C-DOT was attempted.

But it seems the verdict was decided well before the facts to be examined by the committee were collected. It is a pity that the committee did not have a mature attitude to slippage, which are normal in such path-breaking projects. It is not that similar projects anywhere in the world did not have such slippages and cost overruns, except that they did not worsen the problem by mindless witch-hunting.

One can only wake up with a nightmare wondering what would have happened if the National Front Government had not fallen. C-DOT recovered and is well on its way to instal the first 10,000 line exchange. In the meantime technological obsolescence is setting in. Will the country give itself an MNC in the form of modernized C-DOT