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Spin–statistics connection in two dimensions

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The spin-statistics connection—that species with integral angular momentum obey Bose statistics and those with half odd integral spin obey Fermi statistics—is an important ingredient of field theory in the familiar (3 + 1)-dimensional space–time. For a two-dimensional space, which admits fractional statistics, we establish such a connection and study the minimal set of constraints necessary to achieve this in various two-dimensional manifolds. The minimum assumption that we make is the existence of antiparticles and the possibility of pair creation and annihilation. With these we find that the dimensional representations correspond to familiar bosons and fermions and the fractional statistics is sustainable only for multicomponent representations.

Self-organized criticality in nature

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Many natural objects and phenomena, such as soot particles, mountain ranges, and $1/f$ noise in electrical networks, display power-law correlations in space or in time. In the conventional theory of many-body systems, one can get such long-range correlations only for very special values of system parameters when the system is at a phase-transition point. Recently, Bak *et al.* have introduced theoretical models in which an open dissipative system organizes itself into a steady state showing power-law correlations without need to fine-tune any parameters. These are said to show self-organized criticality. The idea has attracted much attention as one providing a framework for the description of the ubiquitous power laws in nature.

The simplest of these models is of a sand-pile. Sand is dropped on a flat table at a slow, steady rate. For long times, one gets a sand-pile whose mass has small fluctuations about an average constant value, excess added sand coming out from the edges. The quantities of interest are the relative frequencies of different-sized avalanches caused by adding a tiny amount of sand. This model has a very interesting mathematical structure, and we have obtained several exact results about its behaviour. Earthquakes can be described by a similar model. Stresses build up at a steady rate along fault lines owing to movement of continental plates. Relaxation of stress occurs in irregular bursts, with larger bursts less frequent. This gives a qualitative explanation of the well-known Gutenberg–Richter law in geophysics.

These models give power laws without fine-tuning any parameters. Though highly simplified, they capture some essential features of the phenomenon. Models taking account of other complicating factors, or describing other phenomena, are also being studied.

Pressure-induced amorphization

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Amorphous solids are traditionally prepared by quenching a melt sufficiently rapidly to prevent crystallization, the result being that they are a metastable, kinetically frozen state of the liquid. However, several new methods have been discovered that induce a direct solid-state transition from a crystalline to an amorphous state[1] (interdiffusion, radiation damage, mechanical alloying, cold rolling, etc.). During the last five years, the pressure variable has been added to this list. Mishima *et al.*[2] were the first to obtain a glass through compression of hexagonal ice. They noted that the melting temperature of ice Ih falls with increasing pressure and an extrapolation suggested that ice should melt at 77 K between 0.5 and 1 GPa. As this temperature is well below the glass-transition temperature, the melt would be an amorphous solid. Following this, Jeanloz[3] suggested that similar transformations might occur when solids with melting curves having positive slopes are decompressed at a suitable temperature. Since the publication of ideas, there has been a rapid increase in the number of materials that have been shown to undergo the crystalline–amorphous transition with pressure. We review the experimental

data and describe our experiments on $LiKSO_4$ and $AlPO_4$ (refs. 4, 5).

This loss of long-range order under pressure can generally be understood on the basis of a joint three-level free-energy diagram. In this, the initial crystalline state is driven to a high free-energy state with respect to a metastable amorphous state and a new equilibrium crystalline state. The metastable high-energy crystalline state is achieved in response to severe structural strains due to pressure increase/decrease, and tends to lower its energy by the formation of the more energetically favoured crystalline phase. However, it is prevented from doing so by the growth-controlled kinetics of the system. Since the metastability of the initial crystalline state cannot be maintained beyond mechanical stability limits the crystal undergoes mechanical 'melting'. Some molecular dynamics calculations on quartz[6] will be used to illustrate the phenomenon.

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2. Mishima, O., Calvert, L. D. and Whalley, E., *Nature*, 1984, **310**, 393.
3. Jeanloz, R., *Eos*, 1984, **65**, 1245.
4. Sankaran, H., Sikka, S. K., Sharma, S. M. and Chidambaram, R., *Phys. Rev.*, 1988, **B38**, 170.
5. Sankaran, H., Sharma, S. M., Sikka, S. K. and Chidambaram, R., *Pramana—J. Phys.*, 1990, **35**, 177.
6. Chaplot, S. L. and Sikka, S. K. unpublished.

Advantages and limitations of amorphous silicon alloy materials for large-area electronic devices

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Hydrogenated amorphous silicon is an exciting thin-film, electronic material with properties that have generated novel applications. Low preparation costs; capability for large-area uniformity; high photosensitivity; high resistivity of the intrinsic material and easy, efficient dopability; strong visible-light absorption and the possibility of variation of the band gap over a large range by suitable alloying are some of its major advantages. Its limitations lie in the low carrier mobilities caused by trapping in shallow, band-tail states that are a consequence of disorder. To overcome this, it is possible to make the material microcrystalline by using a simple variation of deposition conditions. This, however, did not work for the alloy materials, especially the wider band-gap ones, till we used a combination of fluorine-based gases to obtain astounding results. The other major problem in this material is its ability to undergo a modification in its electronic and photosensitivity properties under intense visible-light illumination. Such changes, which result in a degradation of device characteristics with time, can be thermally annealed out and, as we have recently found, annealed out at room temperature using ultraviolet illumination. We have also shown that the changes can be controlled by altering gas composition during the preparation process.

X-ray and optical studies of magnetized white-dwarf binaries

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White dwarf stars mark the end-point in the evolution of low-mass stars. With no nuclear reactions taking place in their interior to sustain their radiation losses, they just cool off gradually, becoming fainter and fainter till they become black dwarfs. As single stars, white dwarfs do not show any unusual phenomena. However, when a white dwarf possessing a strong magnetic field, about twenty to sixty million gauss, is found in a binary, it becomes a spectacular source of soft X-rays and exhibits several other unusual characteristics in the optical and X-ray bands. During the evolution of the binary, the white dwarf starts accreting matter at its magnetic poles from its late-type companion star overflowing its Roche lobe. Accretion columns formed above the magnetic poles of the white dwarf become sources of X-ray and optical photons. The in-falling gas gets shock-heated and emits thermal *bremsstrahlung* X-rays while the cyclotron emission from electrons gives rise to linearly and circularly polarized optical and UV radiation. The X-ray and optical-light curves of these binaries exhibit orbital modulation, quasiperiodic oscillations, flickering, etc. These binaries are synchronous systems known as Am Her binaries or Polars. A related class of binaries, known as DQ Her type or Intermediate Polars, have a white dwarf with a weaker magnetic field (10^6–10^7 gauss) and a spin period shorter than the orbital period. This class of binaries are sources of coherent optical and X-ray pulsations similar to those detected from the well-known X-ray pulsars. Temporal and spectral studies of these sources in the X-ray and optical bands provide insight into the radiation emission processes, the nature of the compact object, the geometry of the system and the question of the existence of accretion disc in them. The characteristics of these fascinating stars will be discussed based on the X-ray and optical studies of a few of them carried out by us.

stimulation of tubulin in the 30,000 *g* supernatants from N cells by [^{3}H] colchicine-binding assay could be at least partly due to rapid translocation of the dimeric soluble tubulin into insoluble membrane fractions or due to presence of higher, oligomeric forms of tubulin that are insensitive to the [^{3}H] colchicine-binding assay.

Potential use of monoclonal antibodies and tumour cell lines in management of cancer

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With advances in cancer research, assessment of the extent of residual disease with the help of tumour markers, and of cancer cell-directed cytotoxic potential of patients' lymphocytes are now considered a component of cancer management. Development of monoclonal antibodies (MAb) directed to tumour antigens and continuous growth of tumour cell lines in tissue culture have contributed much towards this achievement.

We describe development of MAb against squamous cell carcinoma (SCC) of the oral cavity—a common malignancy in India—and development of four SCC cell lines from oral cancer tissues. The MAb reacts exclusively with SCC cell lines and SCC tissues. It also stains metastatic nodes of SCC and dysplastic (precancerous) cells from oral and cervical mucosa. The cell lines retain their original epithelial malignant cell characteristics, evaluated on the basis of morphology, growth pattern, doubling time, DNA flow cytometry, keratin expression, expression of class I MHC antigens and untrastructural features.

The potential use of this and other such biological material in cancer management will be further illustrated by demonstrating (i) use of MAbs in assessment of tumour load, and in immune scintigraphy to diagnose metastasis, (ii) use of MAbs in complement-dependent and cell-mediated cytotoxicity, and (iii) use of tumour cell lines as targets to measure cytotoxic potential of lymphocytes from patients.

Intracellular replication of choleraphage ϕ149

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Choleraphage ϕ149 has much taxonomic importance as it serves to differentiate between the classical and *el tor* biotypes of *Vibrio cholerae*, the causative agent of cholera. This phage can infect and lyse all strains of classical vibrio but none of the *el tor* biotype. The DNA of ϕ149 is a linear, double-stranded molecule of molecular weight 69×10^6. The DNA molecules are a limited set of circular permutation of the bacteriophage genome. The intracellular replication of ϕ149 DNA involves a concatameric DNA structure which serves as the substrate for the synthesis of mature phage DNA. A model for the packaging of the concatameric DNA by a head-full mechanism starting from a unique 'pac' site on the concatameric DNA has been proposed. ϕ149 DNA makes an abortive attempt to replicate in *Vibrio eltor* cells but the concatameric DNA molecules produced are defective and unstable. From the gene bank of *V. eltor* DNA, a 1.2 kb fragment has been identified, the products of which cause destabilization of ϕ149 concatameric intermediates. This fragment codes for two proteins, of molecular mass 22,000 and 14,000 Da. Both these proteins are inner membrane proteins, and the 14,000-DA protein might have a role in preventing the binding of concatameric DNA to functional sites in the membrane essential for packaging. Sequences homologous to the 1.2 kb *V. eltor* DNA fragment are present even in the classical vibrios. However, in classical vibrios these genes are not transcribed. The restriction-fragment length polymorphism detected in the hypertoxinogenic strain of classical vibrio, using the 1.2 kb DNA fragment as a probe, can be utilized to develop a genetic probe for hypertoxinogenic strains of *V. cholerae*. The nucleotide sequence of the 1.2 kb fragment reveals a region of overlap between the coding regions of the 14,000- and 22,000-Da proteins.

Materials matter

Materials Science and Engineering. P. Rama Rao, Subrata Ray and S. Ranganathan, eds. Special issue of *Indian Journal of Technology*, Vol. 28, numbers 6, 7 and 8, June–August 1990.

With increase in complexity of the majority of modern systems, the integrity of system performance is largely determined by the availability of suitable materials. After all, a system is only an assemblage of materials, devices, controls and guidance, all of them playing equally critical roles. Bearing in mind India's endeavours, in recent times, to build sophisticated systems, it becomes strategically wise to address the developments relating to materials that have taken place both in India and abroad and to draw up a state-of-the-art working paper on the subject. This can provide a much-needed focus and a rallying ground for researchers working in various types of institutions in India and contribute directly to an increase in the efficiency of their efforts.

This reviewer is happy that such an exercise has been undertaken by such eminent metallurgists as P. Rama Rao, Subrata Ray and S. Ranganathan. The special issue of *Indian Journal of Technology*, on materials science and engineering (vol. 28, numbers 6, 7 and 8, June–August 1990), which reads more like a white paper on the subject, reflects the directions provided by the perspicacious editors. Every Indian institution that does advanced research relating to materials should possess copies of this issue. In spite of the fact that the topics discussed are highly advanced, the personal authority applied by the expressive authors has made their work a pleasure to read. Developments relating to conventional materials, like common structural and forming quality steels etc., have been kept out. Although there are two quality papers on process modelling by Y.V.R.K. Prasad and O. Prabhakar's group, work of other schools of thought on related topics is sadly missing. However, the theme of the treatise is sustained by the coverage extended to such vastly different materials requirements as those of aeronautics and other transportation, rockets and missiles and other defence, power generation, microelectronics and bio-engineering.

The lead article, 'Materials selection in engineering design', describes a typical approach that is lately being advanced by Mike Ashby. This technique will be useful to groups working on generation of data bases, be it for materials, processes or design. In spite of the abundant availability of desk-top computing power, I would still venture to term the strategy futuristic.

The article 'Aerospace mill product development at Alcoa' follows Ashby's advocation, and, superbly illustrates the significance of the various R&D efforts undertaken at Alcoa over the past few decades. This particular article, which dwells on fundamental concepts and describes how a standard procedure can be evolved for the development of new materials by following simple logic, should be read by all students aspiring to become metallurgical engineers. Staley emphasizes the fact that local volume fraction, rather than total volume fraction of constituent particles, is the major contributor to achievable material toughness and other important properties. As a consequence, modelling, involving the construction and analysis of Dirischlet tessellations, supplemented with suitable experiments, plays a significant role in the optimization of particle distribution for producing better materials. Understandably then, apart from some elastic-plastic and superplastic finite element metal-forming analysis codes, Alcoa have ported Dirischlet tessellation codes into their computer at Pittsburgh. A lucid article by Gokhale and Ramachandran continues where Staley has left off, and adds another dimension to the topic, development of aluminium–lithium alloys. The pragmatic authors acknowledge that low ductility and toughness of these alloys had been a major hindrance to their exploitation and describe efforts that are mainly designed to overcome these obstacles.

The authoritative vein continues in state-of-the-art accounts by Gupta and Krishnamurthy of rare-earth technology and by Banerjee and Sundararajan of intermetallic compounds *vis-a-vis* their ductility. The latter article provides an in-depth review of the literature pertaining to anomalous flow behaviour in ordered alloys. Rodriguez and Mannan review world trends in the development of special steels for fast breeder reactors, apart from highlighting Indian efforts. This, and the subsequent article on alloy and ceramic nuclear fuels development and fabrication at the Bhabha Atomic Research Centre by Ganguly, should further reinforce the fact that materials development holds the key to the building of a system, which in this case is the nuclear reactor. Ceramics and glasses are also dealt with by Umarji (La–Ba–Cu–O system), Mukhopadhyay (bubble-memory materials) and Chakravorty and Das (conducting glasses).

Kulkarni highlights the mechanistic aspects of transition phenomena in superabsorbent polymers and related applications. An extensive review by Mahajan *et al.*, of polymer, metal and ceramic matrix composites presents the composite concept, which permits the development of stiffer, stronger and tougher materials with improved high-temperature capability. Ray's overview of cast metal matrix composites deals mainly with the two different processes for making the composites, viz. the metal impregnation processes like squeeze casting, vacuum casting, etc. and the dispersion processes, in which the dispersoids, both particles and fibres, are mixed with molten alloys and cast by pressure or gravity die-casting. Ray lists various potential applications of the metal matrix composites, while asserting that these materials are poised to enter the shop floor now. Menezes, presenting mostly original work, prescribes experimental procedures for the electrosynthesis of (a) microlaminated composites by cathodic deposition of metals at inert electrodes and (b) semiconducting heterojunctions by anodic oxidation at reactive electrodes. The author asserts that electrodeposition can be readily scaled up for the fabrication of large, complex structures and that electrochemically grown semiconducting films have several photovoltaic and other electronic applications.

Incorporating some elegant transmission electron micrographs of the so-called tetrahedrally close-packed phases in superalloys, Kuo demonstrates the power of the technique to determine crystal structure at an atomic level. Chattopadhyay and Ranganathan provide an insider's view of the relatively new field of quasicrystals. This article also serves to introduce the subject from the basics and is an excellent starting

point for newcomers to the concept of quasiperiodicity.

Thermodynamics of metastable liquids has been an area of long-standing interest with respect to both nucleation of crystalline phases and formation of glass on rapid solidification. As experiments are difficult to conduct in the temperature and composition regimes wherein the liquid phase is inherently unstable, many theoretical models have been proposed for the estimation of thermodynamic properties. Ramachandrarao presents expressions, derived from hole theory, for free energy and entropy. This model is useful in the development of expressions for viscosity, critical cooling rate, etc., which are important parameters involved in glass formation. The article on solid-state electrochemical sensors in process control by Jacob and Mathews starts with a succinct review of present knowledge on oxygen probes, together with advances in the development of nonisothermal galvanic sensors, and proceeds to describe the design of temperature-compensated reference electrodes. Use of auxiliary electrodes in the detection of chemical species in the gas phase that are not mobile in the solid electrolyte, e.g. Si, is elucidated. Finally, the causes of common errors in galvanic measurements and tests for correct functioning of galvanic sensors are given. Sircar's article on the design of oxidation-resistant high-temperature alloys briefly outlines the thermodynamic and kinetic factors involved in the formation of protective reaction products on alloy surface.

The concept of processing maps advanced by Prasad and the finite-difference formulation devised to tackle solidification problems by Kannan *et al.* have been discussed in simple and direct terms, and researchers working in these fields should take a look at these articles. The difficult subject of relating textures with formability is dealt with by Mishra. An obvious interest a metallurgist has in the processing of materials in space is in the aspects relating to solidification. Dhindaw demonstrates, by a study on melt-processed Al–SiC composites, how the low-gravity environment facilitates obtaining a more uniform distribution of SiC particles in the Al matrix. Ogale provides an extensive review of the current status of ion implantation research, supplementing it fully with a description of activities in the University of Poona. An application of Auger electron spectroscopy in the assessment of engineering steels, dealing with the maximization of the fracture toughness of special steels, is described by Misra and Rama Rao.

Considering the fact that such a wide range of topics in materials science and engineering has been dealt with, I strongly recommend that researchers find time to go through this issue.

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International Conference on Aluminium

Place: Bangalore, India
Date: 6–8 February 1991
Contact: INCAL Secretariat
INCAL-91
C/o Aluminium Association of India
P.O. Box 1250
Bangalore 560 012

The theme of the conference is 'Aluminium—Strategies for the 90s and beyond'. The broad areas to be covered are: Recent developments in mining, refining and smelter techniques; Energy conservation in smelter and processing; Recent developments in metal processing technique and equipment; Alloy development and structure property correlations; Modern techniques of metal joining; Surface treatment and corrosion; Aluminium–matrix composites; New applications and technology forecasting.

Asia-Pacific Conference on CFC Issue and Greenhouse Effect

Place: Singapore, Republic of Singapore
Date: 15–17 May 1991
Contact: Conference Secretariat
Associated Conventions and Exhibitions Pvt. Ltd.
204, Bukit Timah Road
04-00 Boon Liew Building
Singapore 0922
Republic of Singapore

International Symposium on Recent Trends in Prevention and Management of Genetic Disorders

Place: Hyderabad, India
Date: 9–11 April 1991
Contact: Prof. P. P. Reddy
Director
Institute of Genetics
Hospital for Genetic Diseases
Begumpet, Hyderabad 500 016

International Symposium on Tropical Crop Research and Biotechnology

Place: Trivandrum, India
Date: September 1991
Contact: Dr N. Krishnan Nayar
Department of Agricultural Botany
College of Agriculture
Kerala Agricultural University
Trivandrum 695 522

Third International Zinc Coated Sheet Steel Conference

Place: Barcelona, Spain
Date: 6–7 June 1991
Contact: V. K. Sudhakaran
Secretary,
Indian Lead Zinc Information Centre
B6/7 Shopping Centre
Safdarjung Enclave
New Delhi 110 029