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Irreversible magnetization of superconductors

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SUPERCONDUCTORS *required for large-scale applications* must be able to carry current without dissipation in their mixed state. It was recognized three decades ago that this requires impurity sites, or dimensions comparable to the coherence length, which will act as pinning centres for flux vortices. Such samples must also show irreversibilities in their magnetic behaviour. The large (a few hundred angstrom) coherence lengths in conventional superconductors imply that pure samples would not show such irreversibilities. The discovery of high-temperature superconductors (HTSC), with coherence lengths of 10 Å and less, changed this scenario and magnetic irreversibilities are observed in the best of these single crystals.

This talk first briefly reviews the macroscopic model developed three decades ago to correlate magnetic irreversibilities with the critical current density d_c. We shall then discuss the various developments of this model during the last five years (P. Chaddah, *Pramana-J. Phys.*, 1991, **36**, 353), and the experimental observations in HTSC that spurred these developments. We shall discuss our experimental results on conventional superconductors that reproduced some features that were considered novel to the HTSC. We shall also discuss some limitations of this macroscopic model. We shall conclude with our recent experimental results depicting the two-component nature of sintered HTSC.

Phase transitions in cellular automata

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CELLULAR automata show an amazing variety of dynamical behaviours, ranging from simple-period to chaotic to 'complex'. The periodic and chaotic behaviours are commonly observed in nonlinear and dissipative systems. More intriguing, and not as well quantified, are behaviours which are neither chaotic nor periodic and typically show complicated propagating structures. Characterization of this so-called complex behaviour is a major unsolved problem, the interest in which lies in the fact that complex cellular automata rules show properties akin to those of many interesting systems in computer science, biology, chemistry and physics. We take a physicist's route to characterizing complex CA rules, following Langton, where we look at the space of CA rules and try to link emergence of complex behaviour with phase transitions. We study in detail the nearest-neighbour one-dimensional CAs and coupled map lattices based on the 'tent' map (proposed as models for turbulence). We find that qualitatively complex rules do occur at those parts of the CA space where correlations show large peaks.

Probing the universe with radio surveys

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THE vast majority of radio galaxies and quasars are at very great distances. Radio waves from these sources would have taken a significant fraction of Hubble time to reach us. By observing the statistical properties of radio sources at various distances, we can try to understand the cosmological evolution of the gross properties of the universe. The existing surveys have demonstrated successfully the existence of strong evolution of the statistical properties of radio sources on cosmological time scales. For instance, the spatial density of powerful radio galaxies appears to be about a thousand times more in the very distant universe compared to that in the nearby space. Similarly, the medium angular sizes of radio sources have been observed to change strongly with cosmological epoch.

A mathematical description of the cosmological evolution involves specification of the radio luminosity function — the epoch dependence of the number of a specific type of radio source of a given luminosity which lie in a given volume. Although radio surveys provide by far the most comprehensive observational material required for the determination of this function, a severe limitation arises from the absence of a satisfactory measure of distance from radio measurements alone. The common method available for determining the distance to a radio source is to measure the redshift of spectral lines emitted by its optical counterpart. This has been very difficult except for a negligible fraction of the known radio sources, since the majority of radio sources do not have optical counterparts visible in a typical optical telescope even when it is exposed to the object for tens of minutes. On the other hand, only a very small fraction of galaxies in optical catalogues

have strong nonthermal radio emissions, which are what make them visible to a radio telescope.

With the rapid technological developments seen in the fields of high speed electrons, CCDs, fibre-optic instrumentation, etc., the situation is now changing in modern radio and optical astronomy. With a large synthesis radio telescope, like the Giant Metre Wave Radio Telescope (GMRT) being built by Tata Institute of Fundamental Research near Pune, it should soon be possible to make very sensitive radio surveys over large areas of the sky. The spectral line capabilities of GMRT will enable us to use the redshifted HI line (hyperfine transition at 1420 MHz) as a tracer of distance. Similarly, on the optical front, fibre-optic technology will soon make it possible to measure the spectra of about 400 objects simultaneously. These developments in the instrumentation behind modern radio and optical telescopes, and the revolution in computing and archival capabilities being witnesses in recent times, are changing the whole nature of surveys leading to cosmological investigations.

One of the remarkable consequences of large radio-optical surveys in the nearby space is the revelation of inhomogeneities in the spatial distribution of galaxies. Since these galaxies trace the visible matter in the universe, large-scale voids seen in their spatial distribution would represent dark matter in a homogeneous and isotropic universe. With the surveys planned in the near future, one should be able to get a deep understanding of the large-scale structure of the universe.

Novel electronic structures in selected transition metal oxides

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ELECTRONIC structure of 3-D transition metal oxides is characterized by the simultaneous presence of comparable electron–electron interaction strength (U), oxygen–metal charge transfer energy (Δ) and oxygen–metal transfer integrals (t). This results in these oxides often being in a correlated mixed-valent state. The systematics in the electronic structure has been most conveniently described in terms of the so-called ZSA phase diagram. This diagram relates the metallic or insulating property with the strengths of U/t and Δ/t. Metal-insulator transition in presence of charge (electron or hole) doping is also readily understood in terms of the ZSA description. It has however been suggested that the ZSA diagram requires some modifications specifically for the description of the late transition metal compounds. Recently it has been realized that the electronic structure of several transition metal oxides cannot be very well described in terms of the ZSA diagram. A few examples of such oxides are $NaCuO_2$, $LnNiO_3$ (Ln = rare earth) and $LaNi_{1-x}M_xO_3$ (M = Mn, Fe or Co). The electronic structure as well as the metal-insulator transition in such oxides will be discussed with reference to the phase diagram.

Adsorption and transport in microporous solids

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THE analysis of transport processes in porous media is a complex problem that is of immediate concern in a variety of fields such as membrane science, heterogeneous catalysis, adsorption and non-catalytic gas–solid reactions. A correlated random walk theory (CRWT) of the transport is presented here, in which the pore structure is modelled as a network of randomly intersecting pores. For the case of gaseous diffusion, comparison with effective medium theory (EMT) and simulation results shows the new theory to be sufficiently accurate when percolation phenomena are not dominant. For nonlinear transport, as in adsorption, where the transport coefficient depends on the field variable, the CRWT is the only viable theoretical option, as the EMT is derived for the linear case. The CRWT is applied to adsorbate transport in micropores, in which the diffusivity is concentration-dependent, and the results are found to match experimental data for carbon dioxide in carbon black. Various isotherm model choices are considered, and based on the comparison with the transport data the classical Dubinin isotherm is modified to incorporate a Henry's law region. The modified isotherm is used to estimate pore size distributions from experimental adsorption data for carbon dioxide and nitrogen on carbon black.

Coupling of exothermic and endothermic reactions in methane/natural gas conversion

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BECAUSE of the energy crisis, there is a great need to develop catalytic processes which require much less external energy and also operate in an energy efficient manner. This could best be achieved if endothermic reaction(s) is coupled with exothermic reaction(s) by carrying them out simultaneously over the same catalyst or a mixture of catalysts in the same reactor. Further breakthroughs in the catalytic processes are therefore expected in the above.

Our recent highly promising results on the coupling of the following endothermic and exothermic reactions

in the conversion of methane and natural gas into ethylene/lower alkenes and syngas (i.e. H_2 and CO), respectively, will be discussed.

Coupling of endothermic cracking of ethane/lower alkanes (in natural gas) with their exothermic oxidative dehydrogenation to ethylene/lower alkenes over the same catalyst.

Coupling of endothermic steam and/or CO_2 reforming of methane with oxidative conversion of methane to syngas over the same catalyst.

The main advantages of the coupling of the exothermic and endothermic catalytic processes are expected to be as follows.

- Much less external energy requirement
- Very high energy efficiency
- Simpler reactor and reactor operation
- No existence of runaway condition
- Easier process control
- Less hazards
- Lower capital and process operation cost.

Role of Japanese encephalitis virus-induced chemotactic factor in the pathogenesis of disease

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THE present work shows that during JEV infection in mice the splenic macrophages secrete a neutrophil chemotactic factor named as macrophage-derived factor (MDF). This chemoattractant has been purified by chromatography and gave a single band of 10 kDa on SDS-PAGE. A variety of MDF-induced *in vivo* biological effects were studied. Injection of MDF in mice resulted in rapid increase in capillary permeability as assessed by leakage of radiolabelled albumin or Evans blue dye. This response can be suppressed by inhibiting histamine release. Intradermal injection of MDF results in neutrophil emigration and accumulation at the injected site. The increased capillary permeability can result in breakdown of the blood-brain barrier with leakage of plasma proteins and cellular infiltration in brain with consequent development of encephalitis.

The MDF-induced neutrophil activation studies show that JEV- or MDF-stimulated neutrophils released reactive oxygen metabolites and granule enzymes. The signal transduction and neutrophil activation are dependent on protein kinase C and preceded by a rise in free cytosolic Ca^{2+} concentration. Further observation shows that MDF downregulates serum iron levels with accumulation of iron in the spleen in reticuloendothelial cells. These observations suggest that MDF acts as an inflammatory mediator and may have a pathophysiological role during the course of the disease.

Portrait of a small spherical plant tymovirus

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THE life cycle of most viruses involves entry of the virus into a suitable host cell, disassembly of the protein coat resulting in the release of the nucleic acid, synthesis of viral-specific proteins using host cell machinery, replication of the viral genome, cell-to-cell movement and assembly of the progeny virions. Understanding these steps at molecular level is important not only for deciphering the mechanism of infection but also for evolving suitable strategies of the control of infection.

We have used Physalis mottle tymovirus (PhMV) as a model to study some of these steps in detail. PhMV is an icosahedral virus. Its genome is a single-stranded, positive-sense RNA molecule encapsidated in protein shell consisting of 180 protein subunits. Unlike in many other plant viruses, polyamines are essential for the integrity of PhMV structure. Replacement of polyamines with monovalent cations leads to release of viral RNA without appreciable disruption of the capsid structure. Determination of the primary structure of the coat protein and comparison with that of other viruses have provided insights into the nature of forces involved in capsid stabilization and design of experiments to locate regions of RNA–protein interactions. Experiments performed using monoclonal antibodies and UV cross-linking suggest that Lys-10 is at the site of the weak protein–RNA interactions. The epitopes within the region 22 to 36 and 75 to 110 are exposed in the intact virus. The architecture of PhMV that emerges from these studies is consistent with the canonical β-barrel structure observed in other icosahedral viruses.

The genome of the virus which is 6 kb in length codes for a 206 kDa protein (putative replicase) and a 70 kDa protein (involved in cell to cell spread of the virus) in addition to the 20 kDa capsid protein. We have initiated determination of the complete genomic sequence of the virus to understand its organization and expression. Determination of the 3′ terminal 2 kb sequence revealed that this region encompasses the coat protein gene and a 149-nucleotide non-coding region that appears to be important for replication. This sequence as well as the 5′ terminal 1.25 kb sequence have been used to construct a tymoviral phylogeny. Future work will involve identification of regions on the genome which could be used to inhibit viral replication.

Reactive oxygen metabolites in the generation of stress-induced gastric ulceration — Role of gastric peroxidase

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STRESS-INDUCED gastric ulcer is a global problem. Although the aetiology of stress ulcer has been studied earlier, the actual pathophysiology is still obscure. The objective of this study is to investigate the role of reactive oxygen metabolites in the pathogenesis of stress ulcer in experimental animals. Rats exposed to physical stress easily develop severe haemorrhagic gastric ulcer primarily due to increased parasympathetic activity in stomach as well as due to increased elaboration of glucocorticoids from adrenal cortex. These increased neuronal and humoral stimuli cause a series of physical and biochemical changes disturbing the fine balance between some aggressive and cytoprotective factors of gastric mucosa, leading to ulceration. Among various aggressive factors investigated, reactive oxygen metabolites such as O_2^-, H_2O_2 and $OH^\bullet$ have been found to play an important role in ulcer generation. Stress causes increased superoxide dismutase activity with concomitant decrease in peroxidase, causing a favourable condition for increased accumulation of endogenous H_2O_2 and $OH^\bullet$ as evidenced by increased lipid peroxidation of the membrane. These reactive metabolites also secondarily inactivate the peroxidase and help in further accumulation of H_2O_2 and $OH^\bullet$. The molecular mechanism of $OH^\bullet$ induced peroxidase damage has been studied in detail *in vitro* on purified gastric peroxidase. The results indicate that gastric peroxidase may contain Cu^{2+} loosely bound at a site very close to the haem. $OH^\bullet$ produced site specifically at the Cu^{2+} binding site immediately attacks the electron-rich site of the porphyrin to cause haem damage as evidenced by change in the haem spectra. Amino acid analysis of the enzyme indicates specific loss of lysine, which is expected to be involved in Cu^{2+} binding. Thus H_2O_2 which is normally scavenged by peroxidase, when increased due to stress and reaches a critical level, causes oxidative damage of this enzyme, finally causing mucosal damage, through lipid peroxidation. The damage is aggravated by acidity, increased pepsin activity and histamine release, with concurrent loss of prostaglandin synthetase activity which is required for cytoprotection by prostaglandin. Stress-induced gastric damage could be prevented by antioxidants, suggesting a role for reactive oxygen metabolites in stress ulceration.

Harvesting light energy in chemical synthesis

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ANCIENT civilization recognized the importance of light for the maintenance and sustenance of life on earth. Nature, through a sophisticated biochemical process called photosynthesis, has been harvesting solar light energy to make fuels. However, the orderly connection between the absorption of light by matter and its chemical and physical consequences has been developed only in the last three decades. This has revealed a rich range of transformations termed 'photochemical reactions'.

Our understanding of photochemical reactions has matured to a stage where synthetically useful reactions can be designed. However, selectivity in product formation has remained elusive due to the involvement of highly reactive and short-lived species. The discovery that the mechanism of photosynthesis is through electron transfer has opened up a new era in photochemistry during the last decade, where light energy is used only to trigger the photochemical event through photoinduced electron transfer (PET) processes and the rest follows by a well-established thermochemical 'dark-reaction' principle.

The contribution from our group is a comprehensive and fundamental research effort in elucidating the ramification of the PET reaction from synthetic and mechanistic points of view from polyfunctional organic molecules. A 'true photosensitized' photosystem has been developed to bring about one-electron oxidation of arenes, amines and organoselenium compounds. The resultant radical cations have been utilized in various transformations of synthetic importance.

One-electron oxidations from arenes have allowed for direct nucleophilic substitution reactions, while the same process from amines has provided reactive intermediates such as nitrones, iminium cations, azomethine yields and α-amino radicals. Applications of these intermediates has been shown in the synthesis of anticancer, anti-HIV and other biologically active compounds. PET from organoselenium compounds has led to the development of *in situ* generation of electrophilic selenium species and one-pot selenenylation and deselenenylation processes.

More recently, a novel photosystem has been developed using triphenyl phosphine as sacrificial electron donor to drive photoreductive processes.

Sequential development of our work in this area with historical background will be presented.

Regulation of expression of galactose-catabolizing enzymes in *M. smegmatis*

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MYCOBACTERIUM SMEGMATIS $mc^2\delta$ shows galactose-dependent growth in presence of glutamate. Galactose alone cannot induce *galK* while glutamate alone does so at low level, which is increased further when galactose is also present. The expression of *galK* in $mc^2\delta$ growing exponentially on glycerol with or without galactose is also glutamate dependent. Results also show that the uptake of galactose is not a controlling factor in this glutamate-mediated regulation. Exogenous cAMP stimulates the expression of galacto-kinase in $mc^2\delta$ only in presence of both galactose and glutamate. *Eingut* [*E* (glutamate) *in*dependent *ga*lactose *ut*ilizing] mutants of $mc^2\delta$ capable of growing on galactose without any amino acid have been isolated. In these mutants, (i) the expression of *galK* is partially constitutive yet not further enhancible by inducer and is inhibited by cAMP and (ii) the basal level of galactose uptake activity is low and is not significantly increased by growth on galactose and/or glutamate. We also show that the galactokinase is inducible while epimerase is constitutive in this mycobacterium. The results will be discussed.

Use of human placenta: A discarded tissue as a model to understand the process of differentiation

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THE placenta is an association of maternal and foetal tissues which develops during pregnancy in mammals. It serves a variety of functions such as transport of nutrients, as an immunological barrier, and as an endocrine gland by its ability to synthesize a variety of proteins, peptides and steroid hormones. Of the hormones the most important ones are chorionic gonadotropin, progesterone and estradiol-17β, all of which are indispensable for maintenance of pregnancy. In the present study, using steroid synthesis or receptor inhibitors such as 1,4,6-androstatriene-3,17-dione or Tamoxifen or RU 486, it has been observed that synthesis and secretion of alpha and beta subunits of CG is subject to negative control by estradiol-17β and positive control by progesterone. Using both *in vitro* and *in vivo* models, it has also been observed that CG secretion is also subject to positive control by gonadotropin releasing hormone. Studies have also revealed that one of the main functions of hCG is to regulate expression of LDL receptors which are involved in providing the important substrate, namely cholesterol, needed for synthesis of progesterone. Finally, an important role for estradiol-17β in the regulation of differentiation of protein synthesis in human placenta has been demonstrated.

New toughness parameters from tension tests based on micromechanism of ductile fracture

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THE first half of this lecture will attempt a historical perspective of the test methods for fracture toughness evaluation. Three major streams in the development of the philosophy of such tests are identified. Based on the phenomenon of ductile to brittle transition in metals and alloys (which include the ferritic structural steels), empirical but extremely useful temperature-based fracture testing approaches were evolved. The linear elastic fracture mechanics (LEFM) approach has the energetics of the fracture process as the cornerstone and its foundation had been laid by Griffith as far back as 1920. The general yielding fracture mechanics (GYFM) extends to conditions of more extensive crack tip plasticity than allowed in LEFM. In more recent years, studies on micromechanisms of ductile fracture and the allied philosophy of damage mechanics approach have come to the fore. In the fracture mechanics approach, structural integrity of component is considered to be limited by one or two dominant cracks. In contrast, in damage mechanics, attention is paid to the deterioration in the integrity due to evolution of damage. (Micro-voids for ductile fracture and creep cavities in creep fracture are two examples).

Through a new approach which belongs to the realm of damage mechanics, an empirical method of estimating ductile fracture toughness parameters from smooth, round specimen tensile data has been evolved in our laboratories, a method that can claim to meet the criterion of harmonious combination of *theoria* and *tekhne*, of contemplation and engineering skill. The simple energy-based approach is based on the stipulation that during tensile testing of specimens, though micro-voids may be nucleated as early as initial yielding, the gross micro-void growth takes place only beyond the necking point. With W_{pn} as the energy absorbed from necking to fracture, the parameter $\Gamma_f = W_{pn}/A_n$ estimates the average energy per unit area required to cause fracture; A_n is the cross sectional area of the specimen at the necking point. With A_f as the minimum cross section area at fracture $\ln A_n/A_f$ measures the average longitudinal plastic strain accumulated from the point of necking to fracture. A second parameter, $\eta_f = \Gamma_f/\ln (A_n/A_f)$, therefore estimates the average incremental plastic energy per unit volume of the specimen per unit longitudinal strain necking to final fracture.

The new parameters are very attractive for several engineering applications because approach exploits the widely used tension tests for the determination of fracture properties. The specific advantage of this method for evaluating fracture toughness of weld joints arises from the fact that for transverse weld tensile specimens, the minimum toughness of the joint is automatically evaluated as the specimen fails on its weakest section.

Role of differential uplift of mountains in the occurrence of earthquakes of the Himalaya

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GEOLOGISTS consider four longitudinal subdivisions of the Himalaya, namely the Outer, Lesser, Higher and Tethys Himalaya. Geological evidence for uplift of the Outer and Higher Himalaya relative to the Lesser Himalaya at the present time has been presented recently in the literature. In this talk, I argue that earthquake studies in the Garhwal Himalaya are in accord with the geological evidence. Firstly, ground elevations along the Saharanpur–Dehra Dun–Mussoorie highway were measured prior to the great Kangra earthquake of 1905. There was extensive damage in and around Dehra Dun. Observations after the earthquake revealed that elevations of benchmarks in the Outer Himalaya had increased by 10 to 14 cm as a result of the earthquake. The elevation increases diminished rapidly to the north in the Lesser Himalaya and to the south in the Indo-Gangetic plains. Secondly, small earthquakes have been observed in a 20–40 km wide belt along the boundary between the Lesser and Higher Himalaya. A composite fault plane solution for some of these earthquakes makes it plausible to assume that in the source region of each of these earthquakes rocks to the north moved up relative to those in the south along faults dipping at about 60° to the northeast. Thus it is possible to generalize and suggest that the Higher Himalaya are rising relative to the Lesser Himalaya along the earthquake zone in the Garhwal region. Within the plate tectonics paradigm of the earth sciences, these earthquakes and the differential uplifts are attributable to the underthrusting of Himalayan rocks by the Indian shield rocks in response to the convergence of the Indian and Eurasian lithospheric plates.