arbitrarily complicated interpolating topologies cannot be neglected (as is sometimes assumed). Once more it became clear that, despite all differences to (3 + 1)-dimensions, (2 + 1)-dimensional gravity is an important and useful test bed to study concepts and expectations in quantum gravity.

Carlo Rovelli gave a large scale survey on progress and problems in loop quantum gravity. Recent progress in physical predictions at the Planck scale mainly originate from calculations of spectra of operators (on the auxiliary Hilbert space of pure gravity) representing area and volume of two- and three-dimensional subsets. In absence of any matter degrees of freedom these subsets are mathematically specified in a non-diffeomorphism invariant fashion. Progress on the mathematical side was also reported. The long standing problems concerning the lack of a scalar product, overcompleteness of the loop basis and the implementation of the reality conditions seem to be settled now. Anomaly-free regularizations of the super-hamiltonian have been constructed, but there is still ongoing debate as to its physical correctness, since it does not define a deformation of the classical constraint algebra and hence seems to reproduce the wrong classical limit. Rovelli ended by emphasizing the complementary strengths and weaknesses of loop quantum gravity and string theory.

Renate Loll reported on the status of discrete approaches to 4-dimensional quantum gravity based on the Einstein action. She discussed results from Hamiltonian path-integral approaches with connection variables and dynamical triangulations. The common open problem is the absence of appropriate measures on the discretized configuration spaces. The choices explored so far seem too simple to lead to an interacting, diffeomorphism-invariant field theory.

There were two talks on topological issues in (3 + 1)-dimensional canonical gravity. Domenico Giulini started with discussing the role and significance of three-dimensional topology in the classical and quantum theories. One of the issues addressed was whether and how classical topology leaves its fingerprints in the quantum theory. In this context the mapping class groups of three-dimensional manifolds were argued to be the natural objects to look at, since they carry significant amounts of topological information and also enter the quantum theory through the reduction procedure. Giulini concluded by listing some general properties of 3D mapping class groups, like finite presentations, residual finiteness and semi-direct product structures. Sumati Surya reported on some work using Mackey theory to find interesting representations of 3D mapping class groups and discussed their physical implications. Thinking of the 3-manifold as configuration of elementary 'geons' (i.e. prime-manifolds), she showed and discussed the general absence of spin–statistics correlations at the kinematical level, and also the possibility of novel 'cyclic' statistics types which she encountered with three RP-3 geons.

Two talks and an additional discussion session – filling the gap that the cancellation of Ashoke Sen's talk left – were devoted to black hole entropy. V. Frolov's talk centered around the problem of universality of black hole entropy which, despite some impressive derivations, like e.g. by counting states of D-branes, is still an open one. He discussed the idea of entanglement entropy, some of its problems, and how they can be solved in some models of induced gravity. He reported on recent work on such models showing that universality exists within a special class. In Parthasarathi Majumdar's talk the different approaches to understand black hole entropy were compared. In particular, the string calculations and viewpoints now came to their right. A final discussion session, solely devoted to all kinds of questions relating to black hole entropy, marked the end of this most pleasant meeting.

Domenico Giulini, Institut für Theoretische Physik, Universitaet Zürich, Winterthurestrasse 190, CH-8057 Zürich, Switzerland.

RESEARCH NEWS

3-D circuit boards by a novel electrochemical process

V. Lakshminarayanan

Electrochemical methods such as electroplating and electroless plating have been an integral part of micro electronic revolution. Electrochemical methods are used in printed circuit board fabrications and in precious metal plating which provide the substrate with the necessary electrical conductivity besides corrosion protection. With the ever-increasing complexity and component density in the electronic circuit boards, there is a need for miniaturization which has led to a great deal of research in the area of nanolithography. In this context, Jean-Claude Bradly *et al.*[1] offer an interesting alternative to the conventional techniques that has the potential for being a technique of choice in future.

The principle of this technique is based on the fact that the potential applied to a particle induces electrochemical reaction due to electric field-induced polarization. This method has been used to provide electrical contacts between metal particles physically isolated from an external circuit. In the experiments, the authors have aligned two copper particles perpendicular to platinum electrodes in an aqueous medium. For instance, one can use a small sized printed circuit board that is covered with a grid of holes capped by a copper ring[2]. When an electric field is applied, electrochemical oxidation of copper to cupric ions occurs on one particle while reduction of water occurs on the other particle electrode. This leads to a formation of a fractal wire of copper that is formed due to diffusion-limited aggregation that begins to interconnect the two particles. In other words, the particles

distort the electric field in such a way that the growth of the wire can be controlled in a predetermined direction. The growth time and morphology of the wire is controlled by the field intensity which is typically 15– 45 V/cm – similar to current density controlling these factors in conventional electroplating. The process starts almost immediately and the wire contact is completed within 45 s. The wire branches thus formed are a few micrometers in diameter which is of the same order as in computer chips.

It is significant to note that the process involves no direct electrical contaets with the wire and the particle and is caused due to the phenomenon of field-induced polarization. Secondly, no metal ions are present initially in the medium unlike in electroplating.

The process works this way: the voltage applied to the platinum wires create an electric field that surrounds the particles. This field polarizes copper and forces positive charge to one side and negative on the other. This happens on both the particles which makes them face to face with opposite charges. When a strong field is applied, the copper atoms are forced out of the particle as ions and these ions migrate to the opposite electrode to get deposited and the wire grows from then on. Ultimately the first branch to reach each copper particle would close the circuit and all growth would cease immediately. If the wire integrity is broken at any point during its growth by tapping the microscope stage-plate on which the process is conducted, quick regrowth was observed showing that the process is self-healing.

This process is well-known in fluidized bed electrodes, electrosynthesis and ultramicroelectrodes. This phenomenon called – bipolar electrochemistry – has been demonstrated on particle array to form microcircuits. This process is expected to help in the formation and construction of three-dimensional circuits, which should permit far denser information processing than that available from conventional 2-D lithographic process.

1. Bradley, J. C., Chen, H., Crawford, J., Eckert, J., Ernazarova, K., Kurzeja, T., Lin, M., McGee, M., Nadler, W. and Stephens, S. G., *Nature*, 1997, **389**, 268.
2. Wayt Gibbs, W., *Sci. Am.*, Nov. 1997, p. 24.

V. Lakshminarayanan is in the Raman Research Institute, Bangalore 560 080, India.

Sequence-specific DNA-binding molecules: A futuristic approach in drug design

Anil Kumar Ojha

Regulation of gene expression is the hallmark of subtleties and complexities of the biological world. Switching the pattern of gene expression changes the fate of a cell from one developing stage to another or, from a normal to a diseased one. Hence, it is needless to mention that understanding the components of regulatory switches and their interactions with other naturally occurring and synthetic molecules would be of unparalleled significance in controlling the dreadful diseases which are the consequences of misregulation of gene expression. Of the various approaches in this investigation, an important one is designing tailor-made small molecules that can recognize the specific sequences of base pairs on DNA. Although this seems to be a far cry, one group of investigators at California Institute of Technology has achieved remarkable success in controlling the 5S RNA expression using a synthetic sequence-specific DNA-binding molecule not only in the test tube but also inside a living cell[1].

The basic steps involved in synthesizing these molecules are: (i) identification of naturally occurring DNA-binding drugs; (ii) structural elucidation of DNA–drug complex; (iii) chemical modification of the drug to achieve an increase in length of binding sequences (a natural drug like netropsin binds to 4–5 AT pairs but it can be modified to bind to 13 bp by linking two molecules with a spacer like β-alanine[2]), binding specificity and affinity; (iv) *in vitro* and *in vivo* experiments to observe the effect of the drug on gene expression as well as its permeability across the cell membrane and stabilities in the cellular environment.

There are various naturally occurring DNA-binding drugs like netropsin and distamycinA, which have been a subject of great interest among investigators. In 1985, Richard Dickerson and coworkers published the X-ray structure of netropsin–DNA complex[3] which led some investigators to initiate the process of modification of netropsin to achieve its sequence-specific recognition. Since then, Dervan's group has taken a great lead in this study.

Netropsin (a polyamide with *N*-methylpyrrole backbone and guanidium tail, Figure 1) is a crescent-shaped molecule which binds to the minor groove of 4–5 successive AT base pairs of double helix DNA. The X-ray structure indicates that amide group of netropsin participates in bifurcated H-bond with N3 of adenine and O2 of thymidine. The pyrrole rings fit parallel to the bases through van der Waal interactions between its CH group and C2 of the bases. Its binding to GC region is probably sterically hindered by amino group of guanine present in the minor groove. Hence, incorporating another heterocyclic ring which could interact with the amino group of guanine as hydrogen bond acceptor (e.g. pyrimidine, *N*-methylimidazole, etc.) would facilitate the molecule to bind to GC region of the DNA. The molecule can be further improved by putting a linker (like γ-amino butyric acid) between two molecules. Thus, a variety of dimeric molecules (hetero, homo, parallel or antiparallel) can be designed to bind to the desired target sequences. The linker in an anti-parallel dimeric molecule would form a hairpin structure on binding to DNA and would facilitate the molecule