In order to overcome these problems much interest is presently focused on bioactive coatings (hydroxyapatite [HA] ceramics, Ca-phosphate containing glasses or glass-ceramics). Nearly all experts in this field agreed at last years biomaterials meeting in Kyoto, Japan, that dissolution of at least the HA coatings occurs within about four to six years in the body environment, and that only their combination with undulating surfaces will provide the reliable mechanical interlocking with the surrounding bony tissue necessary to yield some improvements.

The multivariant statistical evaluations of the more recent follow-up studies gave further details on the influence of different implant shapes and sizes as well as operational procedures. There was even the recommendation to abandon the use of conically shaped acetabular components (*D. A. Fisher*, Indianapolis, IN, USA and *T. H. Mallory*, Columbus, OH, USA, paper no. 9 of the AAOS Meeting). A marked detrimental influence of medication by making interface remodeling necessary for osseo-integration was demonstrated for indomethacin and ibuprofen and, to a lesser degree, aspirin (*T. M. Trancik* and *M. Mills*, Trans. 35th Meeting ORS, Las Vegas, 1989, p. 338).

Besides the overview already given in Table 1, it appears that the now nearly 30 years (since *Charnley*'s introduction of the PMMA bone cement) of large scale clinical experience with implants in orthopedic surgery allow for a much more detailed understanding of implant related responses and many of the side effects. Their feedback in the application of implants, however, will become more and more difficult to judge because of the relatively high success rates already achieved.

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Conference Reports

Molecular Electronics—Science and Technology

By Ari Aviram*

The conference on molecular electronics took place during the week of February 19. to 24. 1989 on the island of Hawaii in Kona, under the sponsorship of the Engineering Foundation. Seventy scientists took part in the program that consisted of 34 invited talks, 16 contributed talks and 10 posters.

Molecular Electronics is the study of molecular properties that may lead to signal processing. Though the name of the field implies technological applications, the state of the art is at a stage that requires considerable basic science groundwork to foster a solid foundation for building future technology. In essence this is an exciting aspect of the field, since it provides an opportunity to break new ground in our understanding of the molecular universe and to develop new techniques for interaction with single molecules or small groups of molecules.

Recent advances in nanolithography and scanning tunneling microscopy have given a boost to the field of molecular electronics. As such, the conference program was organized around these developments as well as several other themes that represent the multidisciplinary facets of this young science. The organizers prepared the program to probe the following questions: What are the limits of current solid state technology? What is the status of nanolithography? What are the current approaches to molecular signal processing and the theoretical basis for those approaches? What are the current methods that will permit interaction between the macrocosm and the molecular world?

The trend for miniaturization and compaction in current solid state technology for microchip fabrication may stall

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when the dimensions of individual conventional devices reach a few hundred Angstroms. This was the assessment presented by Dr. *Robert Keyes* of IBM. These dimensions are still large when molecules are considered since molecules are on a scale of tens of Angstroms. Therefore, it is expected that molecular electronics will only become more desirable when lithography dimensions of about one hundred Angstroms are reached. Nanolithography, the art and technology responsible for fabrication of the fine patterns which are the essence of the microchip, has already reached dimensions in laboratory demonstrations that permit interaction with molecules. This was reported by four leading scientists in the field; Professor *Pease* of Stanford, Professor *Smith* of MIT, Professor *Wilkinson* of Glasgow University and Dr. *Chang* of IBM.

The advances reported, offer exciting possibilities for the fabrication of molecular electronic components. Fabrication of microstructures with linewidths in the 10 nm to 100 nm region is now well established. Not only simple structures for quantum transport studies have been fabricated, but complex circuits and chips for silicon field effect transistors (FET's) and GaAs high electron mobility transistors (HEMTs) with gate lengths down to 70 nm have also been successfully fabricated and perform well. While the electron beam method remains the key lithography approach, focused ion beam and X-ray proximity printing techniques are now available with resolution down to 30 nm. Very thin resist material based on Langmuir–Blodgett films suitable for nanolithography have been developed with defect density almost as low as conventional resists now used in the integrated circuit manufacturing. The use of the scanning tunneling microscope (STM) as a nanofarbrication tool with the capability of directly manipulating molecules and selectively pinning and unpinning molecules with feature sizes as small as 0.4 nm was also shown. These represent the smallest man-made structures ever reported, and the STM may well prove to be a key technique for the fabrication of the sub-10 nm structures needed for molecular electronics in the future. However, it was pointed out by Dr. *Chang* and by Professor *Smith* that although it is possible to produce today the patterns needed for molecular electronics, mass-producing them is something else altogether. The electron beam method currently employed is too slow for commercial applications at the one hundred Angstrom level and a significant amount of development work has to be invested in order to produce a satisfactory commercial nanolithography technology for molecular electronics.

Following these insights on nanolithography, the program focused on current techniques that enable interaction with molecules. Attention centered on applications of STM. Among the participants was Nobel Laureate Dr. *Heinrich Rohrer* of IBM, co-inventor of the STM. Dr. *Rohrer* discussed a new technique of molecular electrochemistry with the STM. This technique permits electrochemical alteration of single molecules or groups of molecules that are addressed with the STM tip. The whole spectrum of current achievements with the STM was presented in a lecture presented by Professor *Calvin Quate* of Stanford University. He showed the ability of this instrument to disclose detailed aspects of molecular activity, such as the sequence of molecular interactions that leads to blood clotting.

The core of the program consisted of presentations regarding various approaches to molecular electronics. Three basic approaches emerged as the dominant representatives of current thinking. One is molecular photonics, also termed "Optical Computing". This approach was outlined by a number of speakers who discussed theoretical aspects as well as the preparation and properties of new materials. Professor *Robert Munn* from UMIST, Manchester, described new computational techniques to calculate linear and nonlinear optical and dielectric properties of molecular crystals, and Professor *David Bloor* from Queen Mary College, described optical studies of the third-order optical non-linearities of polydiacetylenes, and progress towards nonlinear optical devices using these materials.

Another approach was that of Professor *John Barker* from Glasgow, who presented arguments that the best architecture of a molecular computer would require departure from current von Neumann architecture and development of cellular automata. He presented molecular structures that form the proper logic for this architecture.

The third approach outlined was the new theory for molecular electronics that describes molecular switches and a blueprint for future molecular electronic devices. This concept was presented by Dr. *Ari Aviram* of IBM. The theory describes cross-structured molecules that can be employed in a planar technology to fabricate memory cells, logic gates and other components that are needed to form complete molecular integrated circuits.

The conference devoted a large portion of the program to theoretical papers that give justification to the field. Theories were presented for intramolecular electron transfer and the formalism for computing such events. The two presentations by Professor *Mark Ratner* from Northwestern and Professor *Noel Hush* from University of Sydney were important in this respect. Also, the formalism of computing the efficiency of molecular switches was presented in a paper by Dr. *Christian Joachim* of CNRS, France.

Contributions of special interest included electrochemical enzyme control, by Professor *Masuo Aizawa* of Tokyo Institute of Technology, and a synthetic approach to molecular switches outlined by Professor *Jean-Pierre Launay* of Pierre et Marie Curie University in Paris. Also significant was the talk by Professor *Gareth Roberts* of Oxford University who described novel applications of organic thin films to a variety of devices including night vision telescopes.

The conference Molecular Electronics – Science and Technology was a very exciting and important meeting. It produced the recognition that molecular electronics is not just a gleam in the margins of theoretical papers but rather a new and important field of science that is nourished by many supporting sciences and technologies.