

“Nanoscience, Carbon and Quantum Computers”

Professor John Jefferson

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Professor Jefferson started by explaining that nanoscience aims to shape the world atom by atom creating new artificial structures that, because of their very small size, have very unusual properties. It involves the use of very small components only about $1/1000^{\text{th}}$ of the thickness of the human hair and has potentially wide application across almost all scientific disciplines.

Nanoscience was predicted by Richard Feynman in a lecture given in 1959 where he proposed that there was nothing in the laws of physics that prevented the manipulation of materials atom by atom. He issued two challenges, each with a \$1000 prize, for the first person to produce either a working electric motor less than 0.4mm in size, or to take the information on the page of a book and put it on an area $1/25,000$ smaller in linear scale in such manner that it can be read by an electron microscope. The first challenge was achieved within one year but the second took until 1985. Since then many of Feynman's original predictions have been realised.

The building blocks of interest to Professor Jefferson are forms of carbon. Diamond, the hardest natural substance is a 3-dimensional crystalline form whereas graphite has a planar structure and is relatively soft. It is now possible to isolate the individual layers of graphite, which are only one atom thick, which are very strong and hard and are known as graphenes. Amazingly the first demonstration of this involved separating layers with cello tape! Graphenes are the basic building bricks and can be assembled into nano-chips, transistors, fullerenes and tubes. They have a range of unique physical properties such as electrical conductivity 100 times greater than copper, a current capacity of 10^9 , a Young's modulus of about 1Tpa, tensile strength 100 times that of high tensile steel, thermal conductivity the same as diamond and very large surface areas. This makes them ideal for the future generation of high-density computer chips for which heat dissipation is critical. The current best processors carry about 1.78 billion transistors but it is estimated that numbers as high as 10^{15} should be achievable with nano techniques. He gave us examples of nano-tubes, bearings with virtually no friction, the “peapod” – a nano-tube filled with C_{60} fullerenes each of which had been impregnated with gold atoms, a 500nm electric motor and the world's smallest test tube! He also briefly explained the use of the Scanning Tunneling Microscope that is used to observe and manipulate nano-materials.

Professor Jefferson ended with a very brief introduction to the concept of quantum computers. The laws of quantum physics, which hold sway when dealing at the atomic level, in theory, offer the prospect of computers of greatly increased power and speed using qubits rather than binary code of conventional systems. Replacing silicon with carbon nano-tubes and superconductors may be the key to achieving this. Their use could be limited to certain types of mathematical problems such as the factorisation of very large prime numbers. One potential application of interest to both governments and the financial world is in the field of data security and encryption.

Given on Wednesday 9 April at the Ashcroft Centre