*Oxford Science Lecture Series:

Professor Sir Martin Wood

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Professor Sir Martin Wood, the speaker at the Oxford University Biochemical Society's seminar on 23 October 2006, recently explained his approach to science thus:

> *'I'm a hands-on engineer, better with my hands than my head and I get great tactile pleasure from the equipment we produce. I am rather good with machinery and enjoy making things (1).'*

This insight gives an understanding into how Prof. Sir Wood has forged such an incredibly successful career in the realm of superconductivity. Superconductivity is the phenomenon by which certain metals display exactly zero resistance to electrical current below a certain temperature threshold, and maintain this current for an indefinite period of time with no applied voltage. As a unifying theory describing the anomalous behavior of superconductors has yet to be articulated, the vast majority of our contemporary understanding of superconductivity is based on purely empirical research.

Prof. Sir Wood's own description of his participation in energizing the world's first superconducting magnet, while working as a senior research officer at Oxford's Clarendon Labs in 1962, perfectly illustrates the practical nature of superconductivity study. He and his colleagues set up a Niobium Zirconium coil of superconducting wire 1.9 cm in diameter, cooled it to the temperature of liquid helium (4 K) in a glass cryostat, and watched the coil's electrical resistance plummet as it reached its transition temperature. At that point they energized the coil from Wood's car battery, and upon detaching it from the battery leads, found that they had created the world's first superconducting magnet with an impressive field strength of 4.1 T.

Prof Sir Martin Wood in 2003 (1).

In 1959, while still tenured at Oxford, Prof. Sir Wood and his wife Audrey formed Oxford Instruments, a company intended to produce state-of-the-art equipment for university scientists. Initially, he was the only employee of this company that was located in its founders' garden shed. The Woods' decision to focus on the development of superconducting magnets in 1961 gave them their first major success, and has dictated the current trajectory of the company. By the late 1970s, bolstered by the increasing popularity of research techniques such as nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI), Oxford Instruments had established itself as a commercial enterprise unique in its dedication to the research and development of specialized technologies.

From his lecture entitled *The Horizons of Superconductivity*, it is clear that Prof. Sir Wood continues to be inspired by the sheer enjoyment he derives from the pursuit of science. He opened the lecture by pointing out that the phenomenon of superconductivity was discovered completely by accident in 1911, and that today, 95 years later, a unifying theory to explain the phenomenon still remains elusive. For Prof. Sir Wood, the element of mystery that permeates superconductivity research has translated into a consistent belief that his work could result in a completely unexpected discovery. The lecture was presented as a history of superconductors, starting with the liquefaction of hydrogen and helium, and continuing to the first observations of superconducting mercury and the search for other promising superconductors. He then described the current state of the scientific understanding of superconductors and their uses, and finished with his opinions regarding their likely applications in the future.

An important theme throughout Prof. Sir Wood's lecture was the requirement for state-of-the-art experimental equipment and sophisticated materials to aid the discovery and continued elucidation of superconductivity. The field's first major breakthrough came with the liquefaction of helium in Poland in 1908 by Kamerling Onnes. Onnes relied on incredibly complex distillation apparatus that enabled him to reach the temperature of 4 K necessary to condense helium gas; it was this apparatus, Prof. Sir Wood explained, that distinguished Onnes's work from Sir John Dewar's earlier achievement of liquefying hydrogen at the relatively attainable temperature of 14 K. Further low temperature experimentation led Onnes to the astonishing observation that mercury, when cooled to temperatures below 4.2 K, displayed an abrupt decrease in resistance to virtually zero. Other metals, such as lead, displayed the same resistive anomaly at extremely low temperatures. No available theory could predict or explain the phenomenon, and Onnes frantically consulted Albert Einstein for guidance as to what he had witnessed. Einstein could only advise his contemporary to continue with 'experimental characterization.' Such continued experimentation paid off and earned Onnes the Nobel Prize for Physics in 1913.

A magnet produced by Oxford Instruments for use by Oxford University.

More recent advances in superconductivity have been driven primarily by the empirical discovery of novel superconducting materials. Until 1986, the currently prevailing superconductor theory had convinced physicists that no superconductors could exist with transition temperatures greater than approximately 30 K. However, that same year, a lanthanum-based cuprate material with a threshold temperature of 35 K was discovered: a breakthrough that revealed the existence of so-called high temperature superconductors. Soon after, a similar material, in which lanthanum was replaced by yttrium, was revealed to have a transition temperature of 92 K. This marked a significant experimental leap, as this temperature is above the boiling point of nitrogen and therefore much more accessible for commercial applications. Many other cuprate superconductors have since been empirically explored, and expanding the prevailing theories of superconductivity to describe these materials is one of the major outstanding challenges of theoretical condensed matter physics.

Prof. Sir Wood's description of the current and future applications of superconducting materials revealed the pride and passion he continues to feel for his lifetime body of research. Advances in superconducting magnets continue to revolutionize non-invasive biological research and particle physics. NMR research facilities with field strengths up to 21 T, clinical MRI scanners of 3 T field strength and highly efficient cryogen recycling technology are now readily available for the non-invasive study of clinical and pre-clinical biological systems. Oxford Instruments has been a major leader in this field; the company is a pioneer of high field strength research magnets, and recently installed the world's first 21 T system. Beam-steering magnets used in particle physics also rely on extremely powerful superconducting electromagnets, and are ubiquitous in physics research centers such as CERN in Switzerland. Finally, one of the most exciting prospective applications of superconducting magnets is in transport. Magnetic levitation trains (maglevs) operate via suspension, guidance and propulsion from electromagnetic force. In theory, the negligible friction provides the maglev with the potential to reach top speeds comparable to those of aircraft. The world's first commercial application of a high-speed maglev is the demonstration line in Shanghai that transports people to the airport, a distance of 30 km, in just 7 minutes 20 seconds (top speed of 431 km/h, average speed 250 km/h). Other maglev projects worldwide are being studied for feasibility though, as Prof. Sir Wood pointed out, their exorbitant cost has limited plans to implement the maglev on a widespread scale in the near future.

Appropriately, Prof. Sir Wood underpinned both his own appreciation of empirical science and the empirical nature of the superconductivity phenomenon with a concluding presentation. He demonstrated the weak magnetic attraction between a powerful permanent magnet and yttrium barium cuprate oxide superconducting compound, at room temperature. Subsequently, he doused the superconductor in liquid nitrogen, until the nitrogen ceased to boil off, an indication that the metal had reached a temperature of 73 K. He then placed the permanent magnet back in the proximity of the superconductor, causing the magnet to levitate above the superconductor because of its extremely magnetic properties at this lower temperature. In watching the powerful repulsive force that had instantaneously developed between the two metals, one felt not far removed from Kamerling Onnes's bewilderment in 1908 at his accidental discovery of the principle of superconductivity in mercury.

References

1) *Sir Martin Wood and Oxford Instruments* http://www.science-enterprise.ox.ac.uk/html/OxSecNewsletter_003.asp. 3 November 2006.