ISIS

ISIS is a large experimental facility at RAL which is used by scientists from around the world to study materials in microscopic detail. The key to ISIS is the neutron – a fundamental particle that is used as a probe to study the properties of solids, liquids and gases at an atomic level.

ISIS is the most powerful source of pulsed neutrons in the world and the number of users is increasing each year. In 1992 more than 1500 scientists from 26 countries used the facility for their research.

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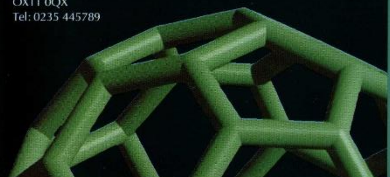


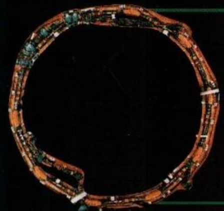
ATOMS

RAL
a mission to explore

WHAT IS ISIS & HOW DOES IT WORK?

The Machine

A large circular particle accelerator called a synchrotron accelerates protons to very high energies. Bunches of protons are released from the accelerator 50 times every second and this pulsing beam is directed onto a heavy metal target. The protons shatter the atomic nuclei in the target material into fragments which include copious numbers of neutrons. This process is known as spallation (from the geological term 'spall', meaning to chip or splinter) and thus ISIS is known as a **spallation neutron source.** The neutrons are directed down beam lines which radiate out from the target, feeding fifteen different instruments which scientists use to study the behaviour of atoms in a wide variety of materials, without causing any damage to the material in the process.



USING NEUTRONS

Neutron Scattering

Neutrons and protons are the minute building blocks for atomic nuclei. On their own, neutrons, being neutral, can penetrate deep into a sample through the electron cloud surrounding each atom and provide information about the nucleus at an atom's core.

At ISIS, beams of neutrons are used to bombard samples of different materials. The direction in which the beam emerges tells us the precise location of each atom within the sample, and hence the crystalline structure of the material. The neutron's change in speed (or energy) tells us how the atoms within the sample are moving. This leads to information on the forces which hold materials together and determine their properties.

In addition the neutron behaves like a tiny compass needle, interacting with the magnetic field in and around atoms, allowing the study of magnetic properties of materials on an atomic level.

WHAT DO WE DO?

Diffraction and Spectroscopy

Neutrons which rebound off atoms within a material without losing energy are said to have been elastically scattered. **Diffractometers** are the instruments used to detect these neutrons. They measure the numbers of neutrons emerging at different angles, leading to information on the crystal structure of materials.

Neutrons which emerge from the material having exchanged energy with atoms in the material are said to have been inelastically scattered. **Spectrometers** are the instruments used to detect these neutrons. They measure the change in neutron energy, providing information on atomic motions and inter-atomic forces.

The fifteen neutron beam instruments at ISIS are all special types of diffractometer or spectrometer. Each one is optimised to study a particular aspect of the interaction between the neutron beam and a sample of solid, liquid, or gas.

OTHER PARTICLES

Muons

The ISIS proton beam is also used to produce powerful beams of muons. These are used in a similar way to neutrons but provide unique chemical and magnetic insights into the structure and

properties of materials. The muon programme is now undergoing considerable expansion.

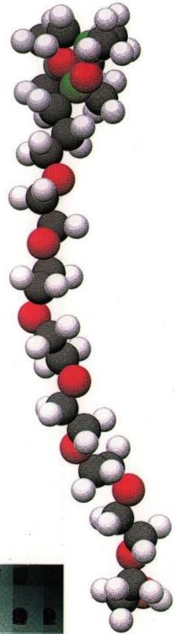
Neutrinos

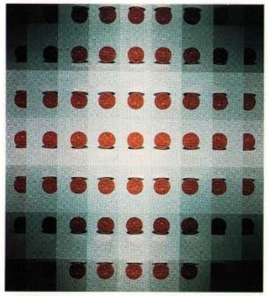
Current cosmological theories predict that there should be more matter in the universe than we have so far detected. Neutrinos, until recently thought to be weightless particles, may account for this missing mass. Scientists have built a large detector at ISIS to find out more about neutrinos, which are produced during the spallation process.

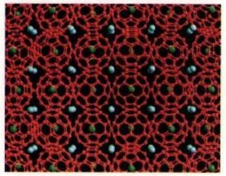
GETTING INTO *Materials*

Atoms, Molecules & Materials

Atoms are the fundamental building blocks of all materials. Atoms and their agglomerations such as molecules, crystals and glasses, are studied at ISIS. Much of today's understanding of materials has come from examining them in detail at the atomic level. Using ISIS we can discover exactly where the atoms are located, how they vibrate and what microscopic features cause a material to exhibit its particular physical properties.

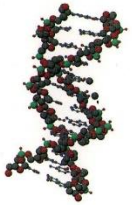






Atoms

Everything in the world is made up of atoms – minute spheres comprising a nucleus (made up of neutrons and protons) surrounded by a cloud of electrons. An atom is so small that even a speck of dust contains more atoms than there are stars in our galaxy.

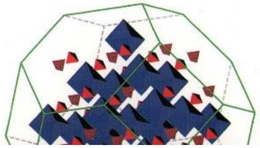


Using ISIS

The key to the properties of a material is the arrangement of its atoms. This atomic structure is examined using ISIS – a facility at RAL which uses the neutron to probe samples of materials using a technique known as neutron scattering. The way ISIS works is described overleaf and the illustrations on this page are just a few of the exciting topics that have been investigated using the facility.

New Materials

Using neutron scattering we can map out the precise atomic structures of materials which contain both light and heavy elements. This technique was used to great effect with the new superconductors discovered in 1987, which contained both oxygen and copper. Scientists at ISIS were able to map out the exact atomic structure of these materials and in doing so gained insights into why their electrical resistance disappeared below a certain temperature.

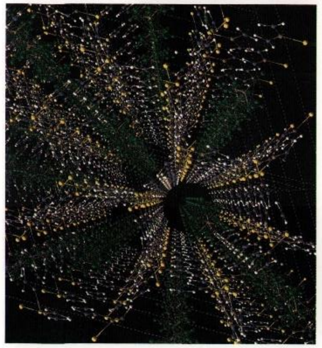


The recent discovery that carbon can adopt an atomic structure other than diamond or graphite caused a flurry of excitement in the scientific world, and instruments at ISIS have been used to study the new structures in detail. In the new compound, Buckminster-Fullerene, the carbon atoms arrange themselves into football shaped molecules which are packed together like marbles in a jar, each 'Bucky-ball' tumbling and spinning independently.

Biological Materials

Many biological materials such as membranes and enzymes perform complex functions in apparently simple ways. Exactly what they do and how they do it is under investigation at ISIS.

Water plays an important and varied role in biological functions. The molecular interaction between water and a helix, such as the DNA molecule, is one important area of interest. Agarose (a complex sugar which forms a gel with water) also consists of helical molecules. The interaction of water with the agarose helix has been studied at ISIS.



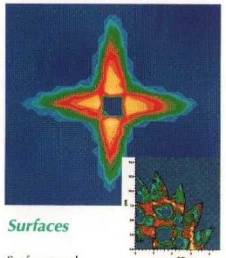
Technological Advances

The basic material used to manufacture batteries, manganese dioxide, has not changed for over a hundred years.

Modifications to this material have led to the production of batteries which now last six times as long. ISIS was used to study the atomic processes which occur as a battery runs down, to identify the reasons for the improved performance of the new design, and thus to contribute to future development.

Catalysts

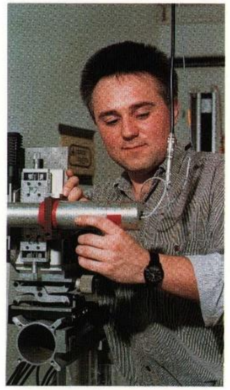
After petrol has been extracted from a barrel of crude oil, the remaining kerosene can be converted into petrol by passing it over a porous mineral called a zeolite. The zeolite not only speeds up the reaction but also remains unchanged and can be used over and over again. Zeolite is just one example of many hundreds of catalysts which are of vital importance to the chemical and pharmaceutical industries. The interaction of various catalysts and reactants has been studied at ISIS. The vital characteristics of the catalysts can be identified when they are studied at an atomic level.



Surfaces

Surfaces and interfaces play an important role in materials science and in a wide range of engineering applications. The CRISP reflectometer at ISIS is proving to be an important tool in the understanding of the structure of molecules adsorbed at surfaces and interfaces, and of the structure of thin films. CRISP has been used to study the organisation of detergent molecules at interfaces, providing details of processes in such varied applications as washing up, the way drugs are absorbed by the body and the dispersion of oil slicks.

The quality of a tape recording is determined by the magnetic structure of the thin magnetic film on which it is made. Magnetism in traditional iron films disappears in thin tape. At ISIS, analysis of the magnetic structure of the surface of recording tape has shown that films of cobalt remain magnetic even down to a single layer of atoms.



Inside Materials