Neutron scattering

Specialised neutron-scattering techniques offer unique insights into industrial materials, products, processes, equipment and infrastructure. This can lead to practical benefits such as improved materials, more efficient processes and longer operating lifetimes for plant and equipment.

Neutrons are particularly useful for studying atomic and molecular structures ranging in size from one nanometre (one millionth of a millimetre) to several hundred nanometres:

- They are a tool for determining the structure of molecules and materials; neutron scattering is complementary to x-rays. Hydrogen and deuterium can be distinguished using neutrons but not x-rays, because neutrons are sensitive to isotopes (atoms of the same element with different numbers of neutrons). Scientists can substitute deuterium for hydrogen in polymers and biologically important molecules to highlight particular features by neutron scattering.
- Neutrons are a ‘micromagnet’ and can therefore reveal magnetic properties of materials such as superconductors and computer memories.
- Their high penetration-depth enables the study of the inside of large pieces of equipment (such as aircraft engines), and inside vessels that have different conditions of pressure, temperature and environment.

ANSTO and OPAL

As the operator of Australia’s only nuclear facility for almost 50 years, ANSTO has acquired considerable expertise in using neutron scattering to solve problems and pursue opportunities in many areas of research and industry.

The OPAL neutron-beam facility is enhancing the power and versatility of ANSTO: combining a new reactor with a new suite of neutron-scattering instruments for scientific research and industrial applications. The organisation also maintains conventional analytical facilities relevant to a range of industries. ANSTO has particular expertise in X-ray techniques and will use the Australian Synchrotron in Melbourne when it comes online in 2007.

Biotechnology

Many biotechnological devices – including implants, biosensors and bioseparator films – depend on the properties and behaviour of proteins adsorbed onto the surfaces of materials such as polymers and silicon.

Techniques such as neutron reflectometry provide valuable information about the structure and orientation of surface-adsorbed protein layers under conditions approaching real life rather than in a frozen, crystalline or desiccated state.

For example, neutron reflectometry can shed light on how adsorbed proteins enable cells to adhere to implants, ultimately causing rejection by the body’s immune system. The technique can also improve our understanding of how proteins clog or foul artificial arteries, blood dialysis and filtration membranes, membrane biosensors, protein purifiers and heat exchangers in food processing. ANSTO can directly test the efficacy of remediation measures, helping to extend the efficiency and operating lifetime of these devices.

Manufacturing

ANSTO scientists exploit small-angle neutron-scattering (SANS) techniques to study polymers under conditions similar to those experienced during manufacture or under laboratory conditions that highlight molecular properties. SANS can be used to improve manufacturing processes for competitive advantage (for example, using recycled plastics) and overcome production problems such as shrinkage or warping of moulded components. SANS is also assisting the development of technologically advanced polymers for biomedical and optoelectronic components.
Neutron-scattering techniques provide useful information on the bulk structure of metals, metal surfaces and the small embedded particles (such as contaminants, alloying agents, inclusions and pores) that can affect the properties of an alloy. SANS can help businesses select the appropriate conditions for making alloys with specific properties or to explore new alloys and processing conditions.

Stresses caused by processes such as heat treatment, welding, casting and forging can reduce the operating life of structural and engineering components. Non-destructive neutron ‘strain scanning’ techniques can help identify and monitor problems and provide information on internal micro-mechanical properties. Strain scanning has been used to investigate the failure of materials in railway accidents, assist the development of welded structures for large aircraft, and verify a new in-situ repair process for power-station turbine blades.

**Food technology**

At ANSTO, SANS is also used to investigate food components such as proteins, polymers and emulsions, and to study manufacturing processes and rapidly-changing food structures in real time.

This versatile technique can lead to improvements in food safety, quality and nutrition, as well as reducing the time required to develop new products and bring them to the marketplace.

Current activities include determining how moisture content affects the physical properties of food proteins and examining the influence of processing on starch.

**Natural resources**

For the oil and gas industries, neutron scattering techniques are helping to improve the efficiency of oil recovery from porous reservoir rock, the transport of oil and gas reserves, the selection of drilling mud and the development of high-pressure inhibitors to guard against chemical deposits in pipelines.

Mineral mining and processing operations often involve complex, large-scale chemical interactions. Neutron scattering provides information on chemical structures and interactions in extreme environments that mimic industry conditions such as high temperature, high pressure and strongly acidic or basic solutions.

For example, ANSTO staff are using SANS to obtain molecular-scale information on the creation and growth of gibbsite crystals in the Bayer alumina process. ANSTO is also assisting the industry to design radically new processes, such as using ionic liquids (salt-like materials that melt at relatively low temperatures) as solvents.

**Advanced materials**

Neutron reflectometry can be employed to characterise the thin magnetic layers that form the basis of magneto-resistive random access memory (MRAM) technology and help manufacturers to design, build and optimise multi-layer storage devices. Superior to the current RAM technology used in USB drives, MRAM is widely considered the memory technology of the future.

Neutron scattering techniques can be used to study real batteries instead of model electrochemical systems. To help manufacturers improve the capacity and performance of lithium batteries, neutron diffraction can reveal what happens within a lithium battery during cycling.

To find out more about ANSTO’s neutron scattering capabilities and services, contact:

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