APPLICATION OF NEUTRON SPALLATION SOURCES

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Extended Abstract

Intense neutron beams provided by neutron spallation sources have a diverse potential for industrial applications and materials research. For this purpose a variety of thermal neutron techniques have been established. The materials under examination are often complex, such as oils, welds, engines, etc., and these often experience harsh chemical, mechanical, thermal, and processing environments. Under such conditions thermal neutrons are well suited to perform *in situ* measurements. Their high penetrating power makes neutrons also particularly well suited to non-destructive testing of real materials and components in their as-fabricated or in-service condition. Some of the major applications are discussed below.

A knowledge of the structure is an essential prerequisite to the full understanding of the properties of materials. Here neutron powder diffraction is the experimental tool of choice. A prominent example is the study of zeolites which have become key materials in the separation or cracking of petrochemical products. Para-xylene is the starting material for the synthesis of the essential polyester PET. Unfortunately para-xylene appears together with meta-xylene which cannot be used for the production of PET. A separation of the two modifications by standard techniques is not possible. However, meta-xylene fits well into the cages of the zeolite $Na_3Ba_{43}Si_{109}Al_{84}O_{384}$, where it is trapped and thereby isolated from para-xylene. The structural details of this important mechanism could only be revealed by neutron diffraction.

Neutron diffraction provides also a unique means of establishing applied and residual strains deep within complex materials. This technique is particularly welcomed by the engineers who must know – if they are to produce a safe and efficient design – the integrated stress that a component is expected to sustain, since the consequences of premature failure of a load bearing component can range from the inconvenient to the catastrophic. This is particularly true for industries such as aerospace and nuclear power where component failure is simply unacceptable. Neutron strain scanning is also central to optimising processing technologies (e.g., different welding techniques).

All kinds of imperfections in materials can be investigated and tested by neutrons. Small-angle and large-angle diffuse scattering sense defects, dislocations, small grains, precipitations, voids, and microcracks from single atom to 1000 Å scale. These imperfections are often not statistically distributed, but show preferred orientation or texture. Here neutron diffraction has major advantages, including the ability to follow the evolution of texture during recrystallisation at elevated temperature.

Neutron reflectometry is beginning to be exploited for the investigation of protective layers and coatings, and other surface related engineering applications. In such studies one can quantify distributions of impurity atoms in optical, polymer, metallic alloy and microelectronic materials in a controlled manner by depth profiling.

Neutron radiography covers a range of imaging and inspecting techniques. These methods are beginning to be used in real time application to follow changes as they develop, and finding application in diverse fields, including tribology and lubrication, studies of fast chemical processes (e.g. in pyrotechnics and aerospace), two-phase flow, transport of water and hydrogenous liquids in ceramics, concrete, soil and rocks, as well as solidification and segregation processes such as casting in materials science and metallurgy.

Neutron tomography extends neutron radiography to three-dimensional imaging. Industrial applications include examining objects with complicated internal structures, reciprocating engines and monitoring the performance of lubricants.

The development of batteries (superionic conductor), electrolytes (ionic conductor), hydrogen storage materials, and metal hydride battery components need the information about the mobility of the ions and transport properties. Here, only quasielastic neutron scattering can provide the information towards understanding the underlying diffusion mechanism.

Finally it should be mentioned that neutron scattering has made outstanding contributions to our detailed understanding at a microscopic level of technically important materials such as plastics, proteins, polymers, fibres, liquid crystals, ceramics, hard magnets and superconductors as well as to our understanding of fundamental phenomena such as phase transitions, quantum fluids, quantum spin systems, spontaneous ordering and photosynthesis. While such results usually have no direct impact on technological products, they are important ingredients which will come to fruition in industrial applications on a longer time perspective.

Engineering use of neutrons is currently restricted by the available beam intensities. Therefore the industrial user community looks forward to the next generation of neutron sources which will certainly be spallation sources driven by particle accelerators. At present such a source is being constucted in the USA (SNS project), and there are similar plans in Japan and Europe (ESS and AUSTRON projects).