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Adaptation of triple axis neutron spectrometer for SANS measurements using alumina samples at TRIGA reactor of Bangladesh

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Abstract

Double crystal method known as Bonse and Hart's technique has been employed to develop small angle neutron scattering (SANS) facility on a triple axis neutron spectrometer at TRIGA Mark II (3 MW) research reactor of Atomic Energy Research Establishment (AERE), Savar, Dhaka, Bangladesh. Two Si(1 1 1) crystals with very small mosaic spread ~1 min have been used for this purpose. At an incident neutron wavelength of 1.24 Å, this device is useful for SANS in the Q range between 1.6×10^{-3} and 10^{-1} Å^{-1}. This Q range allows investigating particle sizes and interparticle correlations on a length scale of ~200 Å. Results of SANS experiments on three alumina (Al_2O_3) samples as performed using above setup are presented. It is seen that Al_2O_3 particles, indeed, scatter neutrons in regions of small angles. It is also seen that scattering is different for different samples showing that it changes with a change in particle size.

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Keywords: Neutron spectrometer; SANS; Radius of gyration; Monochromator; Particle size

1. Introduction

The basic understanding of physical materials and biological matters requires a detailed knowledge of the arrangement and dynamics of their atoms or molecules. Small angle neutron scattering (SANS) is one of the powerful techniques that enable such information to be deduced at the

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nanostructural level. Using this technique, fluctuations of density, composition and magnetization, which are present in the sample, can be evaluated on a length scale ranging from 10 to 1000 Å [1–5]. In particular, it is used for studying the shapes and sizes of particles in a homogeneous medium. This technique has the applications in the study of a variety of physical problems. In a unique way, it opens the door to the 'nanocosmos' in almost all domains of science. They include classical metallurgy (precipitate hardening), materials research (nanocomposites), soft matter (gels colloid, polymers, micelle), chemistry (catalyst) and engineering (porous filters). SANS has a very strong potential utilization in applied industrial research for the following reasons. Contrary to the complementary microscopic methods such as transmission electron microscopy (TEM) and field ion microscopy (FIM), SANS is a nondestructive technique that allows large samples to be analyzed without any special preparation. Sizes, spatial correlations, distributions and shapes of particles, agglomerates, pores and fractal containing even light elements can be investigated not only in crystalline but also in amorphous states as well as in solution. It is the only method of monitoring magnetization fluctuations in materials in the mesoscopic scale.

SANS experiments consist of scattering of a beam of neutron from the sample and measuring the angular distribution of the scattered neutrons. That is, SANS experiment measures the differential scattering cross section, $d\Sigma/d\Omega$ of the material as a function of wave vector transfer, $Q(= 4\pi \sin\theta/\lambda$, where 2θ is the scattering angle and λ is the wavelength of incident neutrons)· The typical Q range in SANS experiments is 10^{-4}–$1\,\text{Å}^{-1}$. A large number of spectrometers, specially designed for low-Q experiments, are operating in many laboratories in the world. Most of these designs cannot be easily adopted for SANS experiments on a small reactor such as the one (TRIGA Mark II 3 MW) operating at Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh. There are hardware-related problems to establish sophisticated SANS facility at low-power reactor in developing countries. A solution to many of the hardware-related problems of SANS at lower-power reactors in developing countries is to use equipment which uses lower technology and which is locally maintainable. This paper examines the possibility of using the existing triple axis spectrometer (TAS) at AERE for the SANS experiments.

2. Triple axis spectrometer

A TAS is usually employed for inelastic neutron scattering experiments, such as measurement of phonon dispersion curves to study the dynamical properties of a sample. This category of experiment involves scattering of a monochromatic beam of neutrons from the sample and analyzing the energy of the scattered beam. It implies that TAS is used for measuring the energy transfer $h\omega(= E - E_0)$ and the wave vector transfer $Q(= k - k_0)$ during the scattering process.

A single-crystal monochromator is used in a TAS to monochromatize the white beam from the reactor by the process of Bragg reflection. The wavelength of the reflected beam is given by $\lambda = 2d \sin\theta_M$, where d is the interplanar spacing and θ_M is the angle between the incident beam and reflecting plane. The monochromatic beam is scattered by the sample and energy of the scattered beam is analyzed using another crystal called an analyzer. In the present context, we note that TAS consists of three tables—the first one for the monochromator, second one for the sample and third one for the analyzer. The three turn tables and the detector arm can be rotated independently in small angular steps (0.01°). This paper describes the use of above rotational facility of the three axes and Bragg reflecting geometry for carrying out SANS experiments.

3. Principle used in present SANS

SANS spectrometers are broadly divided into two categories. The most commonly used is the one at ILL Grenoble, France [4]. This uses the velocity selector as a monochromator and long flight paths before and after the sample to define the angular divergence of the beam. The other