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NUR reflectometer for neutron optics device investigations

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Abstract

A reflectometer with vertical sample position has been recently installed at the research reactor NUR. In this paper, a description of this instrument is presented. The test has been performed with a ten nickel–titanium bilayers monochromator with a total thickness of 300 nm. The nominal thicknesses of each bilayer are 15 nm Ti and 15 nm Ni.

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1. Introduction

Over the last 15 years, grazing angle neutron reflectometry technique has emerged [1–7] as a powerful technique for the investigation of surface and interface phenomena on nanometer scale [8–11].

A neutron reflectometry experiment consists in measuring the reflection of a neutron beam on a thin solid or liquid film at grazing incidence.

The modulus of the resultant between the incident, $\boldsymbol{K}_i$, and scattered, $\boldsymbol{K}_f$, wave vectors is given by

$$Q = |\boldsymbol{Q}| = |\boldsymbol{K}_f - \boldsymbol{K}_i| = \frac{4\pi}{\lambda} \sin\theta, \qquad (1)$$

where λ is the neutron wavelength and θ the incident angle.

The measured reflectivity as a function of the scattering vector $\boldsymbol{Q}$, gives information on the thickness of layers, roughness of multilayer system and on the variation of the refractive index perpendicular to the sample surface $n(z)$ [12–14]. For a nonabsorbing and nonmagnetic material, n

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is defined by [15]

$$n \approx 1 - \lambda^2 \frac{Nb}{2\pi}, \qquad (2)$$

where N is the number of scattering atoms per unit volume and b is the average coherent scattering length.

In particular, for a periodic multilayer, Bragg interference peaks occur for values of incident angle θ_B of the neutron beam given by

$$\sin\theta_B = \frac{m\lambda}{2d}, \qquad (3)$$

where d is the multilayer period and m is the order of the corresponding Bragg peak.

Substituting Eq. (3) into (1) yields

$$d = \frac{2\pi}{Q_B}, \qquad (4)$$

where Q_B is the Bragg peak position.

The neutron reflectivity technique has several advantages such as

(i) investigation of thin magnetic multilayers using polarized neutrons [16–18], and
(ii) varying the neutron scattering lengths between isotopes of the same element; isotopic substitution may be used to enhance the contrast of an interfacial structure without altering its chemical properties [19,20].

Recently, this technique was implemented at the research reactor NUR of CRND in Draria, Algeria, where a neutron reflectometer was installed [21].

In this work, we report the characteristics of the instrument and as examples of performance and potential application, the neutron reflectivity curve of a nickel–titanium monochromator was measured.

2. Instrument characteristics

The schematic representation of the NUR reflectometer is presented in Fig. 1. The instrument is composed of a pyrolitic graphite (0 0 2) monochromator, an in-pile collimator, and a reflectometer optical table in concordance with Fig. 1.

Monochromator: *A* pyrolytic graphite (0 0 2) crystal is used to give a neutron wavelength of 0.47 nm and a wavelength resolution ($\Delta\lambda/\lambda$) of about 5%. The crystal is placed in a shielded area. The monochromatic neutron beam is then coarsely collimated using a block of borate polyethylene

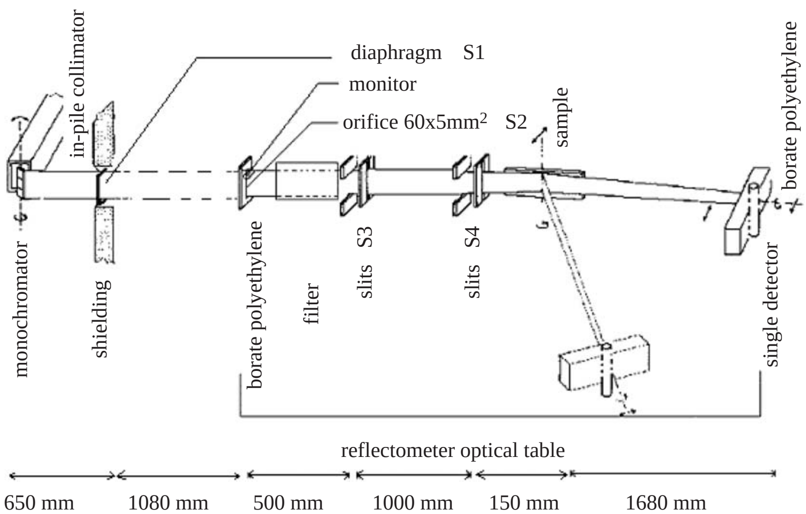

Fig. 1. Schematic of the neutron reflectometer installed at the research reactor NUR.