Appl Phys A (2010) 99: 255–263
DOI 10.1007/s00339-009-5515-5

Applied Physics A
Materials Science & Processing

Detection of nano scale thin films with polarized neutron reflectometry at the presence of smooth and rough interfaces

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Received: 18 August 2009 / Accepted: 30 November 2009 / Published online: 12 December 2009

Abstract By knowing the phase and modules of the reflection coefficient in neutron reflectometry problems, a unique result for the scattering length density (SLD) of a thin film can be determined which will lead to the exact determination of type and thickness of the film. In the past decade, several methods have been worked out to resolve the phase problem such as dwell time method, reference layer method and variation of surroundings, among which the reference method and variation of surroundings by using a magnetic substrate and polarized neutrons is of the most applicability. All of these methods are based on the solution of Schrödinger equation for a discontinuous and step-like potential at each interface. As in a real sample there is some smearing and roughness at the boundaries, and consideration of smoothness and roughness of interfaces would affect the final output result. In this paper, we have investigated the effects of the smoothness of interfaces on the determination of the phase of reflection as well as the retrieval process of the SLD, by using a smooth varying function (Eckart potential). The effects of the roughness of interfaces on the same parameters have also been investigated by random variation of the interface around its mean position.

1 Introduction

Spin-polarized neutron reflectometry is one of the most applicable probes to the study of thin films which have been developed theoretically and experimentally in the past decades. In this technology the reflectivity profile, $R(q)$, of a flat thin film in terms of the neutron wave number, $q = 2\pi \sin\theta/\lambda$, where λ is the neutron wavelength and θ is the reflection angle, is measured to obtain the scattering length density of the sample [1].

If only a single reflectivity curve of a thin film is measured, it would not result in a unique solution for the SLD of the sample as more than one SLD can be found which corresponds with the same reflectivity curve. In order to solve this problem, the knowledge of the phase angle φ of the complex reflection amplitude, $r(q)$, would also be decisive in determining the correct structure [2–5].

In order to retrieve the phase information in reflectometry problems, several methods have been developed such as reference layers [2] and variation of surroundings, which were first proposed and tested experimentally by Majkerzak et al. [6].

The reference method is based on three measurements of reflectivity from a composite sample which is consisting of a known and an unknown part. The method at first was presented by using three different known films as reference layers [2], however due to the difficulties of changing the reference layers for a distinct sample the method was later developed by using polarized neutrons and a magnetic film as reference layer [3].

The method of variation of the surroundings is based on two measurements of the reflectivity from a sample with variable surrounding medium. Such an approach is suited to a substantial number of systems in which the film is in contact with an aqueous reservoir serving as the transmitting medium whose SLD can be readily varied by exchanging heavy for light water. Although the method is practical, it brings about some limitation in variation of the surrounding medium by making us choose just aqueous or gaseous mate-

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