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Investigating the effects of smoothness of interfaces on stability of probing nano-scale thin films by neutron reflectometry

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Most of the reflectometry methods which are used for determining the phase of complex reflection coefficient such as reference method and Variation of Surroundings medium are based on solving the Schrödinger equation using a discontinuous and step-like scattering optical potential. However, during the deposition process for making a real sample the two adjacent layers are mixed together and the interface would not be discontinuous and sharp. The smearing of adjacent layers at the interface (smoothness of interface), would affect the reflectivity, phase of reflection coefficient and reconstruction of the scattering length density (SLD) of the sample. In this paper, we have investigated the stability of reference method in the presence of smooth interfaces. The smoothness of interfaces is considered by using a continuous function scattering potential. We have also proposed a method to achieve the most reliable output result while retrieving the SLD of the sample.

Key words: *neutron reflectometry, thin films, smooth potential, reference method*

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1. Introduction

In the past decades, neutron reflectometry has been developed as an atomic-scale probe with applications to the study of surface structure ranging from liquid surfaces to the solid thin films. The type and thickness of the nanostructure materials can be determined from measuring the number of neutrons, reflected elastically and specularly from the unknown sample [1–3].

Neutron reflectometry problems are generally divided into two groups; "Direct problems" and "Inverse problems". The goal of the direct problems is to solve the Schrödinger equation for a distinct sample so that the neutron wave function is determined; On the other hand, the application of inverse problems is to extract the information of the interacting potential by using the complex reflection coefficient [1].

Measuring the intensity of reflected neutrons in terms of the perpendicular component of neutron wave vector to the surface, q, provides us with useful information about the scattering length density of the sample along its depth. As with any scattering technique in which only the intensities are measured, the loss of the phase of reflection would result in unresolvable ambiguities on retrieving the SLD from measurement. Without the knowledge of the phase of reflection, more than one SLD can be found for the same reflectivity data. By knowing the phase of the reflection, a unique result would be obtained for the depth profile of the unknown sample [4, 5].

In the recent years, several methods have been worked out for determining the complex reflection coefficient such as: Dwell time method, variation of surroundings medium and the reference layer method which seems to be the most practical [1].

All of these methods are worked out for an ideal sample in which the interface of two adjacent layers is discontinuous and sharp. In this case, the reflection coefficient is determined by the solution of one dimensional Schrödinger equation for a step-like optical potential. However, as we know from a real

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