Effect of interfacial roughness correlation on diffuse intensity in a neutron supermirror

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Multilayer structures consisting of alternating Ni and Ti layers are widely used for neutron optical elements such as supermirrors [1]. Good interface quality in terms of sharpness and smoothness plays a critical role in determining the performance of those optical elements. We have developed a neutron supermirror using the ion-beam sputtering technique since it enables the production of layers with high density and small grain size. Reflected neutrons from a supermirror are divided into specular and off-specular (diffuse) components. Suppression of the diffuse component is important since it reduces the signal-to-noise ratio, a serious problem when a supermirror is used in a focusing system for such purposes as small angle scattering measurements. It has been shown that the diffuse intensity is decreased by more than one order of magnitude (down to 10^{-5} for the specular intensity) by adopting NiC/Ti multilayers instead of conventional Ni/Ti multilayers. In order to obtain insight into the mechanism that controls the diffuse intensity from a supermirror, the crystal structure of Ni and NiC monolayers and the interface structure of Ni/Ti and NiC/Ti multilayers were investigated [2]. The crystallite size in the NiC monolayer was found to be smaller than that in the Ni monolayer by a factor of 4.1 by x-ray diffraction measurement. The interface structure of the Ni/Ti and NiC/Ti multilayers was observed by neutron reflectivity and diffuse intensity measurements. For the NiC/Ti multilayer, the lateral correlation length was smaller by a factor of 3.6 than for the Ni/Ti multilayer, whereas the vertical correlation length was greater by a factor exceeding 25. Diffuse intensity calculations based on the distorted wave Born approximation revealed that these differences explain the difference between the diffuse intensity from the Ni/Ti and NiC/Ti supermirrors. The results of the measurements and calculations support our conclusion that a multilayer with a large vertical correlation length and a small lateral correlation length effectively suppresses the diffuse intensity from a supermirror.

References

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