Abstract

Supermirror is a layered structure in which the thickness of each layer evolves for depth to fit Bragg conditions at a wavelength band, which can reflect X-rays with a designate energy/angular response. The supermirror plays a crucial importance for hard X-ray telescope since it can enhance the throughput of a telescope as well as the abilities to determine its response profile. For the same reason, supermirror is also attractive for ground-based X-ray optical instrumentations. Design of the supermirror is important. However, most of the design methods are based on empirical rules. Moreover, due to the fabrication difficulties, numerical design and fabrication of a hard X-ray supermirror with flat top and smooth response, especially for telescope applications, has not been granted. In order to solve the designing and fabrication problem, my doctoral thesis is presented by two parts.

The first part of my thesis is a theoretical analysis of a block structure supermirror. A block structure supermirror is a layered structure which consists of several periodic blocks with different d-spacing, which can provide a broad bandwidth energy response. This kind of the structure is easy to fabricate. It is a great advantage from a practical point of view. However the design method for block mirror is based on several empirical rules. The essence of X-ray propagation has not been well understood. In order to understand the nature of X-ray propagation behavior in this structure, I granted my theoretical work. This work is based on Igor. V. Kozhenikov's theory which well explained X-ray propagation behavior in a depth-graded structure, but not applicable for block structures due to his
"stationary phase method". In my work, I developed Igor's theory and applied a simplification to analyze the X-ray propagation in a block structure. From my theoretical work, the oscillation of reflectivity profile can be well described. Moreover, a design rule can be concluded to provide a smooth reflectivity profile, which is a confirmation and development of empirical design rules. Based on my theory, I also invented a multilayer structure which can provide a better response profile (side lobe suppressed multilayer). It improves the response profile of a periodical multilayer, which is attractive and promising for ground-based X-ray optics.

The second part of my thesis is an experimental study of a supermirror structure with flat top and smooth response profile within a very wide energy/angular band. Such supermirror structure may provide great advantages in energy/angular response for telescopes due to less oscillation and extremely flatness. However, such structure is difficult to design and fabricate since its thickness distribution is a non-periodical style. In case that the fabrication ability is limited, no work reported so far can successfully obtain a real supermirror structures for hard X-ray telescope applications. In order to improve the response of our telescopes, I established a design and fabrication process to obtain a non-periodic structure with perfect angular/energy response. Firstly, I established a numerical optimization method to adjust the thickness of the structure layer by layer. Such method may effectively smooth out the ripples and obtain an extremely flat response profile. From a practical point of view, in order to check the fabrication difficulties and the robustness of reflectivity for different boundary conditions, evaluation process has been established to confirm feasibility of designed structure. Secondly, I granted a fabrication process to realize such structures. The testing results demonstrated that the fabrication process is a success. Thirdly, a fitting process has been introduced to explain the discrepancy of measured profile from designed profile. My design and fabrication process may successfully obtain a non-periodic supermirror with extremely flat top response, and may strongly improve the performance of telescopes as well as ground based X-ray optics in future.