Master Thesis

Development of conical thin foil hard x-ray telescope using epoxy replication method

Seiji Takahashi[1]

U laboratory, Department of Physics and Astrophysics, Graduate School of Science, Nagoya University

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Abstract

Hard X-ray imaging observations of astronomical objects using focusing optics have not been carried out yet. In the hard X-ray region above 10keV, the use of ordinary mirrors with single layer of metal as a reflecting surface is no longer realisitic. For such high energies, multilayers with depth-graded periodic length, so called "*supermirrors*", are known to be promising. Also, due to poor photon statistics in this energy region, photon collecting efficiency has to be maximized. From this reason, tightly nested thin foil optics is adequate.

The performance of a telescope is integrated into photon collecting power and image quality. The peak reflectivity of a multilayer, which has large impact on photon collecting power, strongly depends on the interfacial roughness which results from the surface roughness of substrates, material combinations, substrate temperature and deposition methods. The thin foil mirrors are impossible to fabricate via direct machining. Therefore, replication method is adopted. In this method, we deposit a multilayer onto a smooth glass master, and then transfer the multilayer onto a substrate via epoxy adhesive. We have to optimize processes not to cause deformation of foil mirrors, otherwise image quality, another key of telescope performance, is degraded.

We formed aluminum foils into conical shape and optimized parameters of epoxy adhesive(e.g. thickness, dilution rate, curing condition, etc.), and we established the epoxy replication method. Using the epoxy replication method, we made various mirrors; single layer of gold, single layer of platinum, platinum-carbon multilayer and platinum-carbon multilayer supermirror. Fabricated mirrors were then characterized by a uniform parallel beam of optical light, a laser scan profilometer and X-ray pencil beam facility. The angular resolution is obtained as ~ 2 arcmin, and the interfacial roughness is $3 \sim 4$[Å]. We showed, for the first time, that films other than gold can be replicated into large area foil mirrors with acceptable imaging quality. In addition, we showed that the interfacial roughness we obtained is significantly better than depositing multilayers onto pre-replicated foil mirrors. The reduction of interfacial roughness, thus improvement of reflectivity, will increase effective area of telescope by a factor of about 1.5.

The present research are developments of high throughput hard X-ray telescope onboard balloon experiment and ASTRO-G which is the future Japanese X-ray astoronomy satellite in the 21st century. This type of technology is also applicable to X-ray microscopes, X-ray optics for synchrotron radiation facilities.

[1] takahasi@u.phys.nagoya-u.ac.jp