Development of a light-weight X-ray imager for future explorer missions

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We would like to introduce a ultra light-weight X-ray optics and present recent results on X-ray performance test with these optics.
X-ray observatories are essential for X-ray astrophysics. Hence, revolution of observation technologies could lead to new discoveries. Detection of X-rays from the solar system objects including planets (Venus, Earth, Mars, Jupiter, Saturn), satellites (Moon, Galilean satellites), comets, and heliosphere is one of the discovery by recent X-ray observatories, i.g., Chandra, XMM-Newton and Suzaku. Representative mechanisms of their X-ray emission could be divided into three categories. First one is an elastic and a fluorescent scattering of solar X-rays by neutrals in the planetary atmosphere. Second one is a charge exchange with neutrals in the tenuous planetary exosphere and the cometary gas. Last one is collisions of energetic electrons in the planetary aurora with atmospheric neutrals producing bremsstrahlung emission and emission lines. Since these mechanisms are closely related to surrounding environments of the objects, we can obtain detailed information on planets such as density and spatial distribution of not-well known planetary tenuous atmosphere and magnetosphere. Overall pictures of them can be taken with remote sensing X-ray observatories. On the other hand, snapshots are obtained by the in-situ explorer missions. They are complementary to the in-situ explorer missions.
A key technique for the X-ray explorer or small satellite missions is a reduction in weight of optics. Conventional X-ray optics have a trend that optics with better angular resolution have larger ratio of the weight to effective area. Therefore, it is difficult to utilize them for the X-ray planetary missions which has a severe weight limit. Micro pore optics are being developed based on a concept of a miniature optics. To compensate decrease of reflection area, amount of mirrors are needed to increase. We have developed a novel type of micro pore optics with MEMS (MicroElectroMechanical System) technologies (Ezoe et al. 2006, 2010). We call them MEMS X-ray optics.
An instrument composing of the MEMS X-ray optics and a radio-hard semiconductor pixel detector is being developed. It aims at the first in-situ measurement of X-ray emission related to planetary atmosphere and magnetosphere. For example, JUXTA (Jupiter X-ray Telescope Array) is intended to observe Jovian X-rays (Ezoe et al., 2013). It covers 0.3-2 keV with the energy resolution of <100 eV at 0.6 keV. The major advantage of JUXTA compared to the Earth-orbiting X-ray observatories is proximity. Hence, if JUXTA has the effective area of 3 cm^2 at 0.6 keV and the angular resolution of 5 arcmin and orbits in ~30 Jovian radii at periapsis, these numbers scaled to the Earth orbit observation of Jupiter are 24 m^2 and 1 arcsec, respectively.
We fabricated the MEMS X-ray optics for JUXTA. The MEMS X-ray optics are made of 4-inch silicon wafer with 300 um thickness. A lot of micro-pores are formed in the thin silicon wafer by photolithography and deep reactive ion etching (DRIE). A typical pore width is 20 um and the sidewall of these pores play a role as X-ray reflective surfaces. After DRIE, sidewalls of the pore structures are smoothed by annealing in order to reflect X-rays with a micro roughness of less ~1 nm rms. Finally, the wafer is plastically deformed to a spherical shape. We constructed an approximately Wolter type-I telescope stacked two bending 4-inch optics with different curvature radii, and confirmed a clear X-ray focus for the first time (Ogawa et al., submitted in MST). We

also confirmed a need of improvement for a surface roughness and a vertical profile of sidewalls within pores.

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