The challenging development of lightweight glass mirrors for future X-ray telescopes

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Previously used mirror technologies are not able to fulfill the challenging requirements of future X-ray telescopes. A promising new technology under development is the hot slumping of thin glasses. Challenges, design trades and first results are presented, including the thermal shaping process, the development of low stress coatings and the mirror segments integration concept.

1 Introduction

Due to requests from the scientific community, future X-ray telescopes need large effective areas and good angular resolution. Thereby also the mass limit of the launcher has to be considered. Previously used mirror technologies are not able to fulfill the challenging requirements. Consequently new technical approaches for an X-ray mirror production are under development. A promising technology is the hot slumping of thin glasses. The Max-Planck-Institute for extraterrestrial Physics (MPE) and the Aschaffenburg University of Applied Sciences (HAB) started a cooperation to develop a suitable mass production process of thin X-ray mirrors. The proposed process steps are shown in figure 1, resulting in grazing incidence mirror segments for a Wolter-I type telescope with hierarchical integration of nested coaxial and confocal mirror shells [1].

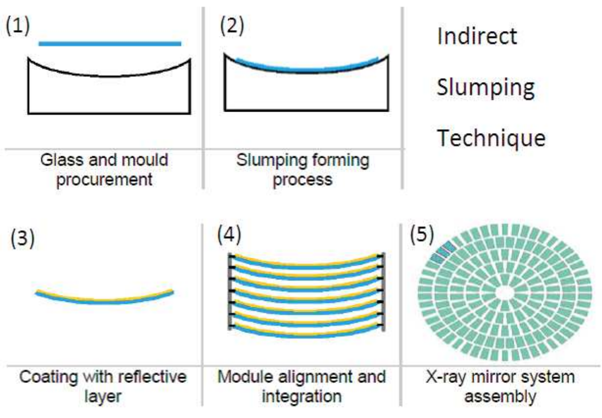

Fig. 1 *Process steps for an integrated X-ray telescope*

2 Glass mirror forming process

In figure 2 the proposed method of indirect slumping is shown, where a thin sheet of glass is positioned onto a concave slumping mold and heated up to the annealing point of the glass. This causes the thin glass sheet to deform under its own weight and to adapt the shape of the molds surface. Thereby the optical surface of the mirror is not in contact with the mold. So the micro-roughness of the mold is not affecting the mirror surface [2]. However, the indirect slumping has to deal with glass thickness variations, which need to be minimized in order to obtain a good quality mirror surface [3].

Fig. 2 *Mold for Wolter-I type telescopes with a thermally formed glass mirror inside the slumping furnace*

The choice of mold material is also very important for the quality of the replication. The thermal expansion of both materials should match well. A material well suited for the slumping process of thin glass sheets is a porous ceramics based on aluminum oxide with a very high thermal stability. The porosity enables vacuum supported slumping. This results in a better contact of glass and mold, avoiding air being entrapped between glass and mold. The chosen combined parabolic and hyperbolic mirror design gives a higher stability against vibration, less deformation at integration and avoids a complex adjustment procedure between both parts [2].

3 Mirror coating process

Another important task is the development of low-stress coatings for X-ray mirrors based on slumped thin glass substrates [4]. Requirements for the X-ray mirrors coating process are high X-ray reflectivity, low surface roughness, low-stress to avoid shape deformation of the substrate and a process suitable for serial production. Iridium coatings promise excellent X-ray reflectivity properties and the procured Iridium sputter target gives a unique possibility for the X-ray mirror coating development [5]. RF magnetron sputtering technology is applied for the Iridium coating process, using a sputtering equipment system supplied by Aurion Anlagen-technik GmbH, as shown in figure 3.

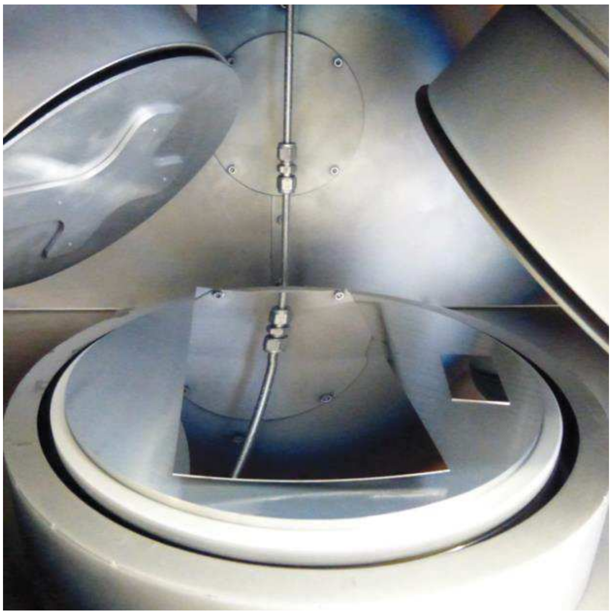

Fig. 3 *Sputtering chamber for X-ray mirror coating*

4 Coating stress evaluation

Coatings can apply stress to the glass substrate which may lead to unwanted surface shape deformations. In order to understand and reduce (at limit to avoid) this effect, a number of coating tests are carried out on flat D263 glass wafers, with Ø150 mm and thickness of 0.4 mm. The surface figure of these glass substrates is measured before and after the coating process by non-contacting optical topography and the comparison of metrologies allows for the application of the Stoney equation to derive the stress introduced in the substrate by the coating. Working of the deposition parameters, we can optimize the process for a zero stress coating. The metrology is done by a white light interferometer Top Map TMS 500 from Polytec with an LED light source of 525 nm and a vertical resolution below 2 nm [5].

5 Mirror integration process

Alignment and integration of slumped glass X-ray mirrors follows the paradigm of stress-free integration. An alignment and integration facility has been set up at MPE for the integration of prototype modules [6], like one shown in figure 4. Mirror alignment is obtained by optical metrology, deflectometry and a direct check by focusing a laser beam. The mirror integration into the structure is realized through gluing at some edge points, selected to minimize the effects of epoxy adhesive shrinkage.

6 Summary and Outlook

Next generation X-ray observatories require new mirror technologies. A segmented mirror approach by indirect thermal slumping of thin glass sheets can be an option and is under development at MPE. A coating process of low stress Iridium layers is being developed at HAB.

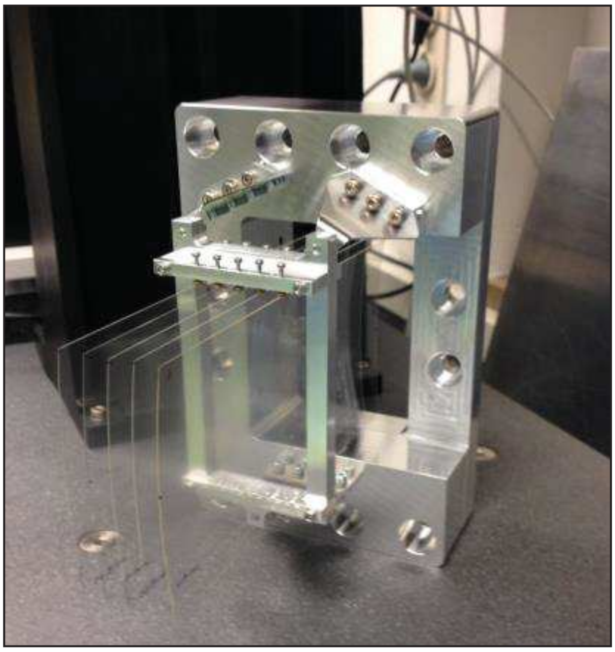

Fig. 4 *Mirror module demonstrator with five segments*

Acknowledgement

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