2° Forum della Ricerca Sperimentale e Tecnologica

Nested Optic With Chemical Bonding (NOW-CB)

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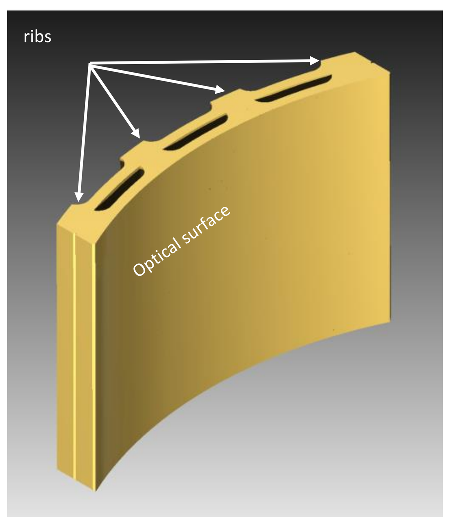
Main goal:

Demonstrate the feasibility of an X-ray optic for astronomy composed by a glass stack, jointed with the chemical bonding process.

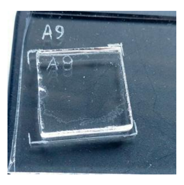


What is chemical bonding?

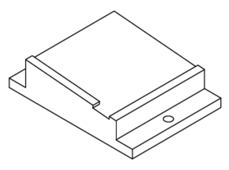
Silicate bonding involves the use of water based solutions of alkali silicates as a low viscosity additive for joining silicate glasses. This room-temperature bonding process is based on hydroxide catalysis. The mechanism consists of an initial etching reaction at the glass surfaces and subsequent re-solidification, with the generation of a complex connecting network of covalent Si-O-Si bonds between the bonded parts.

Flat sample

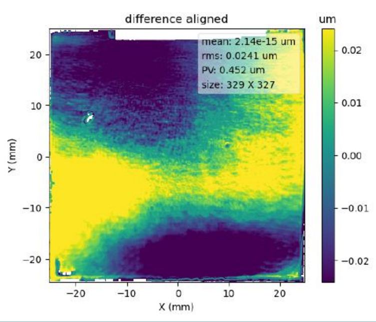
Some different tests on flat samples have been performed to characterize some important parameters:



- Effect of the gravity on liquid deposition
- Intrinsic stress of the chemical bonding layer
- Bonding strength with shear test
- Contact area and shape accuracy

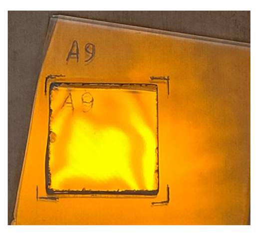


Chemical bonding successed also for a tilted sutup: 0-30°

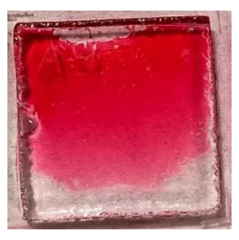


Interferometric metrology before and after bonding of a thin glass (0.2mm) on a thick (2mm) sample.

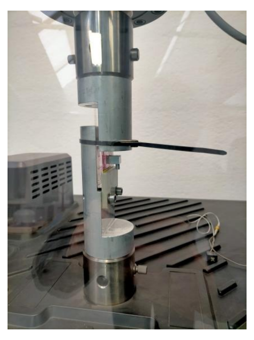
Results: 61-175 MPa

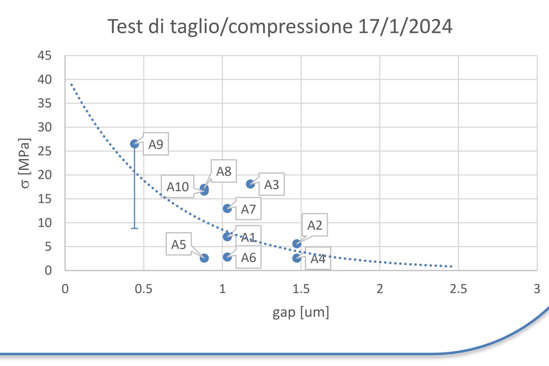


Fringes evaluation of the coupled surfaces



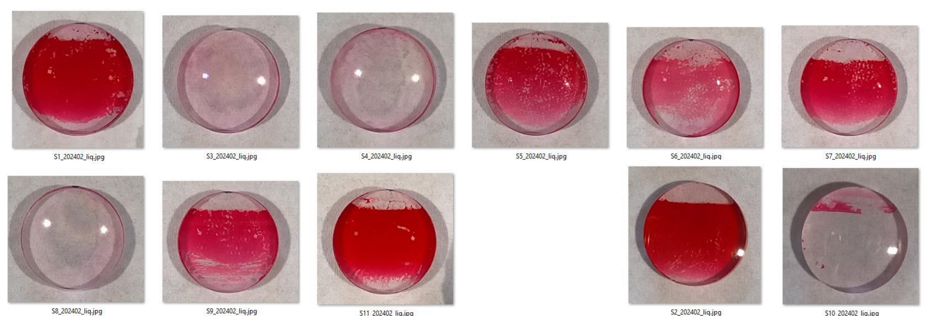
Coloured liquid evaluation for contact area

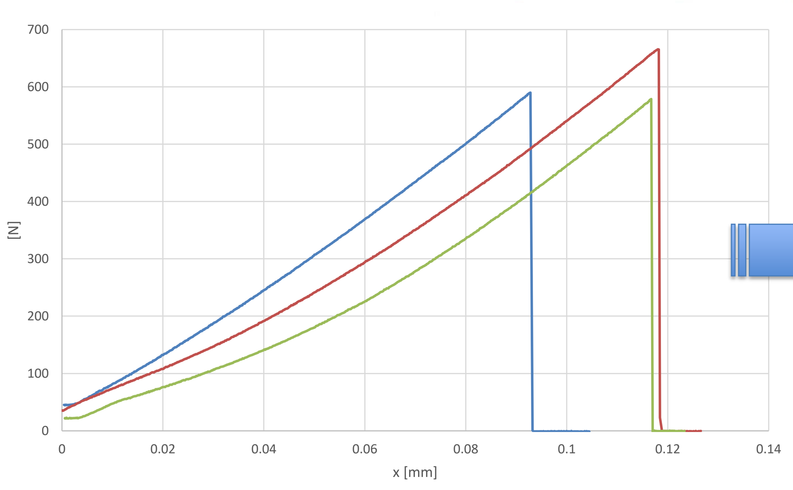




Curved samples

The chemical bonding succeeded on commercial spherical samples even if the adhesion appeared strong only on few samples in coherence with the contact area





Strength stress 1.17-1.35 MPa

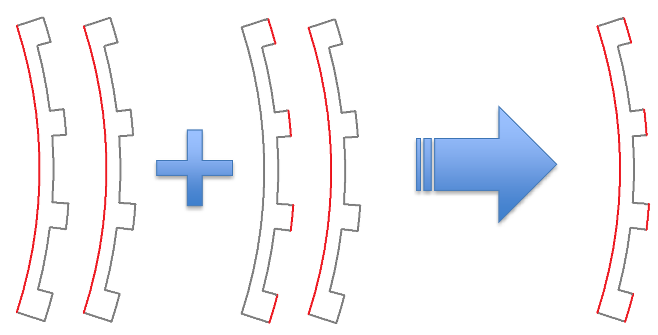
Challenges

chemical bonding on curved surfaces

The chemical bonding (CB) is a well known technique typically used to bond optics with flat surfaces.
It required a tight tolerance in the shape accuracy (~λ/10) and a good roughness (<10nm RMS). For this reason CB is applied generally for flat optics due to the ease to achieve such requirements for plane surfaces.
The X-ray optics are made by concentrical shell and for big optics is needed to build an assembly composed by smaller sectors. Each sector can be realized stacking different optics, joint by glue, usually an epoxy adhesive. The glue is subjected to some problems (i.e. shrinkage, humidity absorption, CTE mismatch with the optic), affecting the possibility to obtain optic with a very high angular resolution. The CB permit to avoid the glue and therefore open new possibilities in term of angular resolution.

shape precision between ribs and optical surface

The main technical issue to reach very precise surfaces compliant both to CB and to a very high quality X-ray optic is to realise a back surface ('ribs') with a very precise shape respect to the front optical surface.

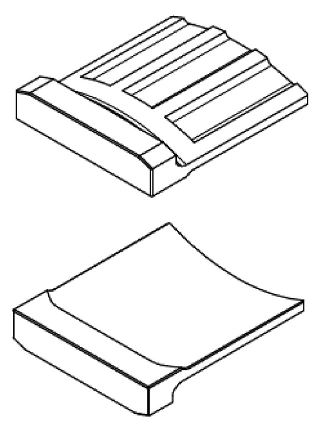


The high angular resolution is achieved with very high accuracy between the 2 optical surfaces (a); the CB requires a very high accuracy between ribs of the internal sector and optical surface of the external sector (b); the result is the achievement of a very high accuracy between ribs and optical surface of each sector.

Prototype

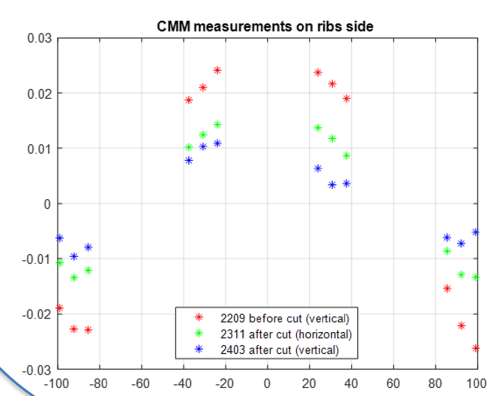
The supply of the two sectors is on-going and they will be ready for late 2024.
The optical configuration is parabolic with optical parameters chosen so that it is possible to measure the prototype with the BEATRIX facility available at INAF-OAB (Merate-LC).
The sectors are made in Clearceram and the phases of the manufacturing process are:

1. Rough machining
2. Polishing of optical and ribs surfaces
3. Water jet cutting
4. Figuring and polishing (Zeeko machine)

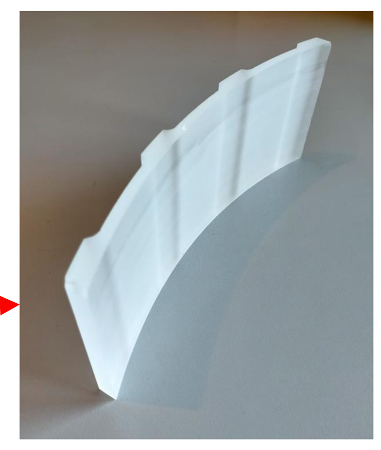


Sector #	R [mm]	Foc. [m]
1	162.0	12
2	170.0	12

Optical parameters



A sample cut with water jet has been measured to test the spring-back effect due to stress relief → PV=30 μm.



Sample cut with water jet

Conclusion

The NOW-CB project proceeds well, demonstrating the feasibility to chemically bond two curved surfaces (spherical). The feasibility on cylindrical surfaces must be yet demonstrated: it is the main goal on the coming months. The optimization of the procedure must be addressed in order to increase the bonded area: this can be achieved also with the acquisition of a robotic dispensing tool, able to adjust very precisely the amount of the liquid solution along a designed path.

One of the major criticalities is the supply chain for manufacturing the shell sectors for the final prototype. It takes more than expected, causing a delay of the program of 1 year. In the meantime the test on small commercial sample will continue and a cheap and simplified version of the final prototype is plan to be built to assess the aligning procedure of the two sector.

Robotic dispensing arm

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