On the modeling of two bonded silicon surfaces

N. Cocheteau[1*], A. Maurel-Pantel[1], F. Lebon [1], I. Rosu [1], S. AitZaid[2], I. SavinDeLarclause[2]

[1)] Laboratoire de Mécanique et d'Acoustique, Marseille, France.
[2)]Centre National des Etudes Spatiales, Toulouse, France.

[*]Corresponding author for tribo-lyon2013@sciencesconf.org

Direct bonding consists in joining two surfaces without the use of any adhesives or additional material. Usually, by bringing two flats, well-polished surfaces into contact at room temperature, they locally attracted to each other by Van der Walls or hydrogen bonds and adhere or bond.

Silicon direct bonding is used in the manufacturing of high performance optical system for terrestrial application such as Fabry-Perot interferometers, prism assemblies, etc. For example, this process has been used in the manufacture of the largest slicer ever used for the Multi Unit Spectroscopic Explorer.

Recently, this process is of particular interest to spatial instruments applications. Indeed, due to the fact that no mechanical part or glue are required, this is a high-precision production process and assemblies obtained present a dimensional stability. Even if a prototype has already passed with success the mechanical and thermal environment of space where the constraints involved (thermal fatigue, vibrations, etc.) are very different from those encountered on Earth, this is necessary to quantify the bonding strength to improve the mechanical performance of adhesive bonds without degrading optical performances of the material used and to find optimum parameters of the process.

Indeed, mechanical resistance of those bonded interfaces will depend on interface defects, and especially the nature of bonds involved. Indeed, room temperature bonding needs flatness and roughness perfectly controlled, and no particles contaminations on surfaces [1].

Mechanical tests such as double shear tests and wedge test were performed in order to characterize the influence of the different parameters of bonding process like annealing temperature and time or roughness.

Results show dependence between mechanical resistance and annealing time and temperature. When temperature increases, mechanical resistance increases non-linearly; and when time increases, mechanical resistance increases then stabilize. Moreover, we can observe a kind of equivalence between annealing time and temperature.

Then, a healing contact law, similar to [2], is developed in order to combine the mechanical properties of the bonded interface to the physical and chemical properties of bonded surfaces.

The aim of this study is to model this particular type of adhesive contact in the framework of continuum mechanics. A finite element model with cohesive element and this unilateral contact law will be used to simulate the wedge test [3].

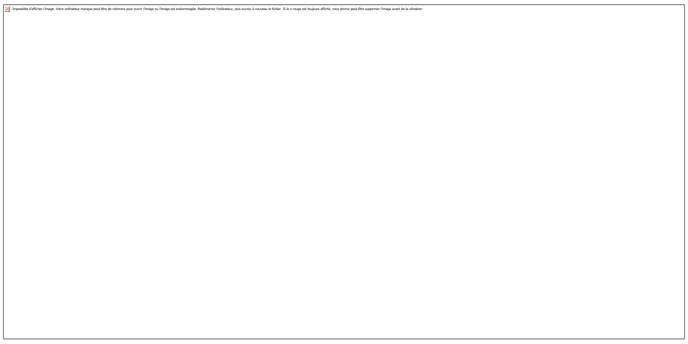

Fig.1: Results of double shear test: influence of annealing temperature

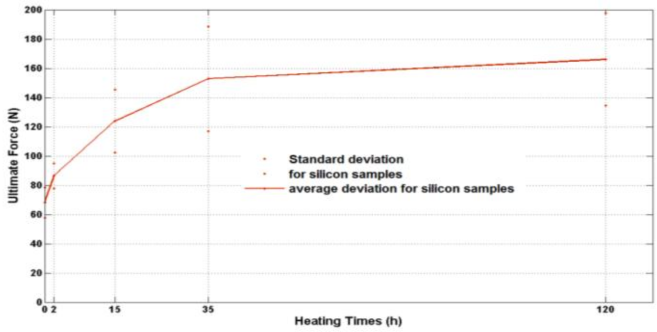

Fig. 2: Results of double shear test: influence of annealing time (T=200°C)

References

[1] A. Plobl, G. Krauter, Wafer direct bonding: tailoring adhesion between brittle materials, Material science and Engineering, R25, 1-88, 1999

[2] M.Raous et Al., A consistent model coupling adhesion, friction and unilateral contact, Comput. Methods Appl. Mech. Engrg., 177, 1999, 383-399

[3] N.Cocheteau,F. LebonI.Rosu, A.Maurel-Pantel, S.AitZaid, I.Savin De Larclause, On the modelling of the direct bonding of two silicon surfaces, Proceedings of the Eleventh International Conference on Computational Structures Technology, Civil-comp press, 2012