A NOVEL GLASSY CARBON WINDOW DESIGN FOR EXPERIMENTS USING SYNCHROTRON LIGHT

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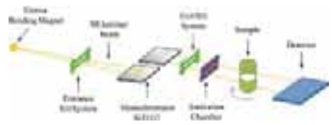
The SYRMEP (Synchrotron Radiation for Medical Physics) beamline at Elettra synchrotron is provided for a large number of experiments and researches in different fields including medical diagnostic radiology, life science and material science applications such as geology, volcanology, cultural heritage and agrifood technology. In this beamline there is a double-crystal Si (111) monochromator which selects energies in the range between 8 keV and 35 keV. At the end of its vacuum chamber there is a Kapton window through which the X-ray passes. Due to the energy of X-ray the Kapton window lasts for few weeks and it has to be replaced regularly which results in shutdowns and delays in important experiments and consequently extra costs. The idea of the present work is to design an alternative window of Glassy carbon which is supposed to increase the efficiency of the beamline. It is noteworthy that utilizing FEM software as a powerful tool considerably affects time and costs.

Introduction

The window that separates vacuum chamber from the air where the samples are located, is one of the most important parts in the optical hatch of the SYRMEP beamline. The area of the window which faces X-ray is a rectangle with height of 9.5 mm and width of 168mm. So the window is subjected to mechanical forces due to atmosphere pressure in one side and the vacuum on the other side as well as the heat flux which is absorbed from synchrotron light. To eliminate the problems of Kapton, a glassy carbon window is designed in rectangular shape to reach the following targets:

Schematic veiw of the beamlines of Elettra Synchrotron



Schematic view of the SYRMEP beamline

- Transparency against X-ray
- Much longer life time
- Low thermal resistance
- Acceptable stresses
- Low deformations

Experimental Hatch of the SYRMEP beamline

Exit slits (SYRMEP beamline)

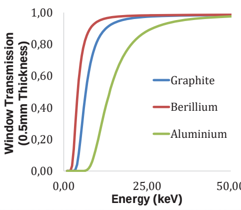
Available Kapton Window

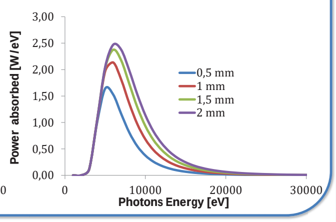
Safety shutter (SYRMEP beamline)

Heat Source and Transparency

The amount of energy which is absorbed by the window depends on several parameters including photon energy, thickness, and material of the window. The thickness can vary from 0.5 up to 2 mm to have desirable X-ray transparency needed for the experiments. Increasing the thickness reduces thermal resistance, but it increases the energy absorption as well.

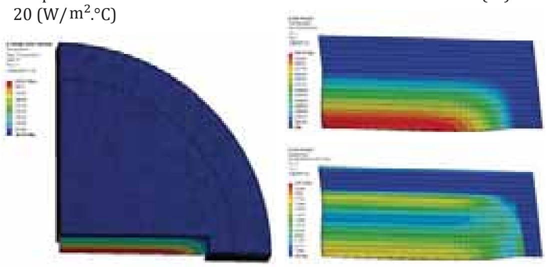
Thickness (mm)	Energy Absorbtion (W)
0.5	48.19
1	55.76
1.5	60.08
2	63.04





Primary FEM Analysis

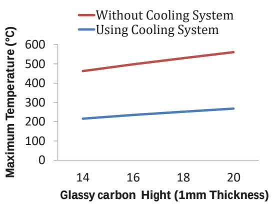
The first FEM Analysis was utilized to evaluate the final temperatures and stresses as well as deformations of the desired model which was requested by beamline scientists. A coupled thermal and mechanical analysis was used to obtain the results and check the preliminary design of this window. To have more accurate results, the thermal contact conductivity is considered between all faces. The ambient temperature and the coefficient of the convection are set to 20 (°C) and 20 (W/m^2.°C)

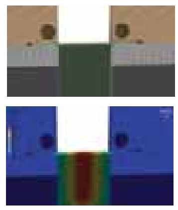


Based on the FEM calculation results which are shown on above pictures, in the worst scenario the maximum temperature is more than 430°C and the Von-Mises stress also exceeds 239 MPa. Therefore, the model needed to be modified and a water cooling system is also used to reduce the temperature as well as the thermal stresses.

Cooling System

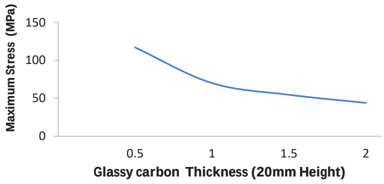
The heat flux is directly applied to the window which is a thin plate. So conduction between window and the other solid elements and the convection with air are not enough to cool down the window. Hence, an external water cooling system is added to decrease the temperature and consequently the thermal stresses. The cylindrical path has a diameter of 6mm and the velocity of the water is 1.5 (m/s) which has the inlet temperature of 20 (°C).

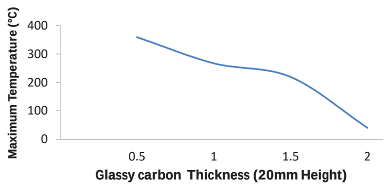




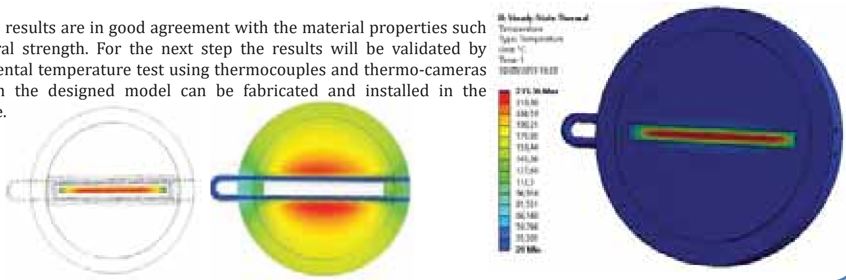
Coupled Thermo-Mechanical Analysis

A coupled study has been done utilizing Steady-State Thermal and Static Structural analysis systems as well as the fluid flow (Fluent) analysis system. Due to geometry design optimization the maximum stresses and temperature have been significantly decreased.





The final results are in good agreement with the material properties such as flexural strength. For the next step the results will be validated by experimental temperature test using thermocouples and thermo-cameras and then the designed model can be fabricated and installed in the beamline.



Conclusion

In this work all different important parameters of the window including material, geometry, and cooling system as well as their effects have been studied utilizing FEM simulation and an optimized prototype of the glassy carbon window has been designed. This design will lead to fabrication of the novel glassy carbon window which will be installed in SYRMEP beamline. After practical tests of this window. The idea can be used for replacing Beryllium windows which are toxic in SYRMEP beamline as well as some other windows of different beamlines.

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