§4. Thermal Stress Analyses of High Power Milimeter-Wave Windows by Finite Element Method

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It is important to analyze a maximum temperature and involved mechanical stress in the window materials under a transmission of high power millimeter-waves. Since the loss tangent of the window material usually has a increasing dependence with temperature, the abrupt locally increase of temperature leads to a so called thermal runaway and a destruction of the disk. We have been performing thermal stress analyses on the basis of three dimensional finite element method (FEM).

A flow of the transient thermal stress analyses taken into account the temperature dependence of the loss tangent is explained as follows. At first, the size of a window disk, an input RF power and its profile on the window and the value of initial temperature are given. Next using these values, a heat generation profile g(r) in the window material is calculated for the initial temperature, i.e. initial loss tangent value. This heat generation g(r) is considered in the transient thermal analysis computer code "ANSYS", which is basing on the finite element method in the three dimensional configuration, together with given boundary conditions and material properties. Then we can obtain a temperature profile. New temperature profile is used to calculate the loss tangent and new heat generation profile. Again ANSYS is run with new g(r). This procedure will be repeated until the RF injection pulse finishes. Thermal stress analyses are possible to be performed with above obtained temperature profile, given boundary conditions and mechanical characteristics of the material. Finally, if it is necessary, probability of destruction can be analyzed by the computer code "CARES" with the stress profile.

Figure 1 shows an calculated example of temporal variations of the peak temperature in the window disk during the RF power input. In this calculation we assumed a single-disk window of silicon nitride composite. The peak temperature increases monotonically during the RF pulse (84GHz, 500kW input power) because of inferiority of its heat conductivity. The increment of the peak temperature by unit time grows drastically with the peaking factors. For the case of the peaking factor of 4.5, however, the maximum temperature rise is limited to as low as 350°C at the end of the 10 seconds pulse.

Figure 2 shows thermal and mechanical stress analyses in the disk, using the temperature profile for the case of 4.5 peaking factor at 10 sec. Radial and azimuthal components of tensile and compressive stresses are plotted along the disk radius The maximum tensile stress reaches about 200MPa for the azimuthal direction on the vacuum side of the disk. These values of stresses are not so much big, compared with the material mechanical strength. In fact, the rupture probability of the disk under the tensile stress of 200MPa is analyzed to be 10^{-9} by CARES code.

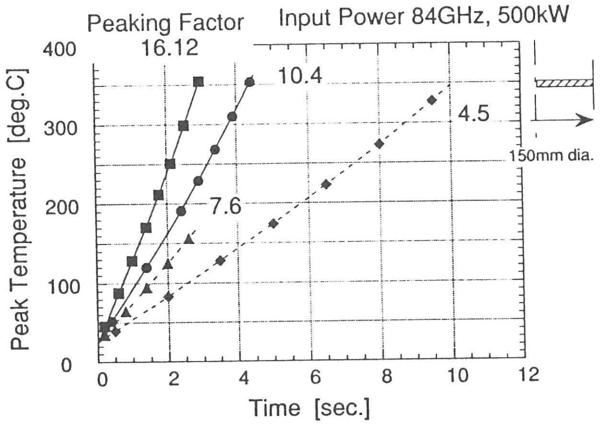

Fig.1 Temporal variations of the peakt emperature in the window disk during the RF power input.

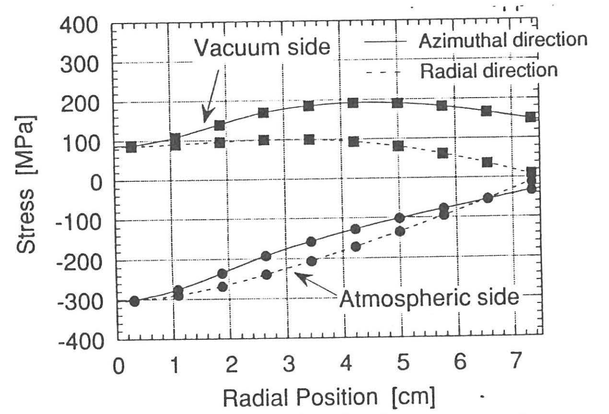

Fig. 2. Thermal and mechanical stress analyses in the disk