Surface and Bulk Internal Stresses in Li$_2$O-2SiO$_2$ Glass-Ceramics

H. Pinto$^{1,3}$, L. Ito$^{1,2}$, M. Crovace$^{1,2}$, E.B. Ferreira$^{1,2}$, F. Fauth$^4$, T. Wroblewski$^5$, E.D. Zanotto$^2$, A.R. Pyzalla$^{1,3}$

$^1$Institute of Material Science and Material Technology, TU Vienna, Karlsplatz 13, A-1040 Vienna, Austria
$^2$Vitreous Materials Laboratory (LaMaV), Department of Materials Engineering (DEMa), Federal University of Sao Carlos (UFSCar), CEP 13565-905, Sao Carlos, SP, Brazil
$^3$Max-Planck-Institute for Iron Research, Max-Planck-Straße 1, D-40237 Düsseldorf, Germany
$^4$European Synchrotron Radiation Facility (ESRF), BP 220, F-38043 Grenoble, France
$^5$HASYLAB at DESY, Notkestraße 85, D-22607, Hamburg, Germany

Glass-ceramics are polycrystalline solids fabricated by controlled crystallization of a parent glass. Their main advantages compared to other ceramic materials are the easily tunable thermal expansion coefficient, the lack of porosity, the easy microstructure control and the possibility to produce complex shapes. Their mechanical performance is not only determined by the microstructure, but, also by the residual stress state. The residual stress state is characterized by the superposition of macro and micro residual stresses. Macro residual stresses result from temperature gradients during fabrication. Micro residual stresses develop during cooling after the heat treatment due to differences in the thermal and elastic properties of the crystalline and amorphous phase. Both internal macro and micro stresses strongly influence crack nucleation and propagation processes and, thus, affect the functionality, reliability and lifetime of glass-ceramic components.

The aim of the present work was an analysis of the internal stresses generated in partially crystallized Li$_2$O-SiO$_2$ glass-ceramics produced by different heat-treatments. The Li$_2$O-SiO$_2$ system was chosen due to its great technological importance, e.g. in substrates of computer hard discs. In addition this system has been studied for several years, thus its microstructure can be well controlled. Internal stress analysis in the bulk of the samples was carried out using high energy synchrotron radiation. In the near surface zone the internal stresses were determined using medium energy synchrotron radiation. The experiments reveal the influence of different nucleation mechanisms at the surface and in the bulk of the specimens on the internal stress state.