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EXAFS and XANES Study of Annealed VAD Silica Glass

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Introduction

High pure silica glass (SiO_2) synthesized by flame aerosol method has been extensively used as optical material for microlithography due to its high transmissivity in the UV range and resistance against laser irradiation [1]. Moreover, high homogeneity in refractive index is of critical importance in synthetic silica for optical element in the UV range of very short wavelength, which can be obtained by controlling the material structure homogeneity [2]. In this way, silica glass synthesized by VAD (Vapor-phase Axial Deposition) method [3] was annealed in order to homogenize its structure, and consequently to improve its optical performance for use in the spectral range of extreme UV. In this study, the effect of annealing on short range structural homogeneity of silica glass was investigated using the X-ray absorption technique.

Experimental

Silica glass (SiO_2) boules were produced by nanoparticles synthesis method by flame aerosol method VAD [4]. The processing conditions used are listed in the Table 1. Afterwards, the silica was annealed with temperature higher than 1000°C.

Table 1: Processing conditions.

Parameters	Condition
$SiCl_4$ flux	150 sccm
H_2/O_2 ratio	1.5
Burner deposition angle	42°
Distance target-burner	57 mm
Preform rotating velocity	25 rpm
Consolidation time	2 hours

Si K-edge X-ray absorption spectra were recorded under vacuum at room temperature at BL-11B beamline of PF-KEK using InSb (1 1 1) double-crystal monochromator, and E/dE = 1200. The data were recorded in a total electron yield (TEY) mode.

Results and Discussion

Figure 1 shows Si K-edge XANES spectra of the quartz crystal used as a reference, the as-prepared and annealed silica samples. It was verified that a sharp and prominent peaks with almost the same high at around 1850 eV appeared for all samples. Therefore it can be inferred that the Si^{4+} valence state and SiO_4 symmetry were maintained after the annealing.

Further, by the comparison of the radial structure functions obtained by performing Fourier transform of EXAFS (Figure 2) of silica samples and quartz crystal, it was observed that the interatomic distance and coordination number (CN) for first neighboring oxygen atoms (Si–O) are lower than 1.61 Å and 4.0, respectively. Moreover, it can be observed that first neighboring oxygen atoms (Si–O) peak area difference between the center and outer diameter regions of as prepared silica was ΔA = 33%, while for the annealed silica was ΔA = 14%, indicating a more homogeneous radial structure in this last case. Therefore, the effect of homogenization of silica structure by decreasing the interatomic distance and CN for the Si–O took place by annealing process.

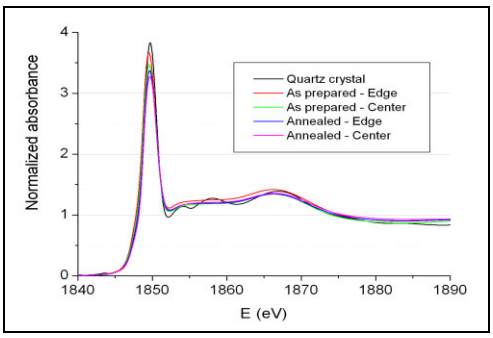

Figure 1. Si K-edge XANES spectra of reference (quartz crystal), as prepared and annealed silica samples.

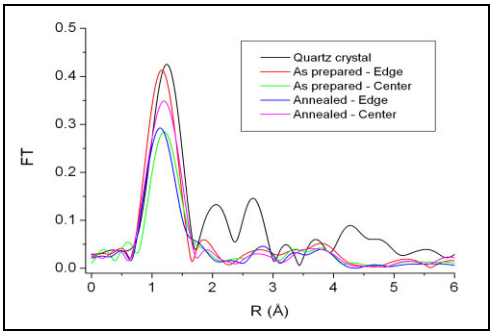

Figure 2. Radial structure function of quartz crystal, as prepared, and annealed silica samples.

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