Abstract – In this research, the effect of the processing parameters on the silica preforms produced by the VAD method was studied by Small-Angle X-ray Scattering technique aiming the development of homogeneous silica to act in the edge technologies of photonics and electronics devices.

RECENT research activities in the area of optical materials and nanofabrication have been developed to fulfill the fast advances in microchips fabrication by optical lithography. In fact, optical components in this case must present a very high homogeneity in refractive index and birefringence, besides a good transmissivity in the UV range. These properties can be obtained by controlling the structure homogeneity. Among various alternative materials used in the fabrication of these components, silica glass is the most useful due to its special optical and thermal properties. The VAD (“Vapor-phase Axial Deposition”) process, based on flame aerosol synthesis, is a cost-effective and versatile method for producing high purity silica glass. In this process, silica nanoparticles are synthesized by the hydrolysis and oxidation reaction of SiCl$_4$ in oxy-hydrogen flame and deposited axially on a rotating target that translates according to the deposition rate, forming a porous soot preform. Afterwards, the preform is sintered at a high temperature (~ 1400 °C) and transformed into a highly transparent preform. In this method, there is a number of processing parameters that can influence the quality of silica nanostructure.

In this work, it was studied the effect of H$_2$ and O$_2$ gas flux on the temperature distribution of the preform deposition surface in order to produce a homogeneous material, since the temperature is the most important parameter that influences the silica nanostructure. Preforms were produced by changing H$_2$ from 4500 to 6000 sccm and O$_2$ from 3000 to 4000 sccm, but maintaining the ratio H$_2$/O$_2$ = 1.5. The deposition angle, formed between burner axis and preform axis, was about 42°. Temperature profile measurements were obtained along flame direction by using an optical pyrometer, in steps on 1.0 mm during the preform deposition. As preform deposition surface is submitted to a gradual cyclic heating and cooling effect due to the preform rotation during the deposition stage, the average temperature profiles were calculated by mean values of equidistant temperatures related to the preform center (Fig. 1). Sintered preforms samples were characterized by small-angle X-ray scattering (SAXS) to obtain information about the silica nanostructure heterogeneities of the center and outer diameter regions. It was verified that silica preforms produced with H$_2$ = 6000 sccm and O$_2$ = 4000 sccm present higher flame temperature but smaller temperature variation (ΔT = 19 °C) along the deposition surface. Lower SAXS intensities, as well as a smaller intensity difference between the center and outer diameter regions (Fig. 2) were also observed, indicating a more homogeneous nanostructure. The maximum temperature variation (ΔT = 30 °C) for H$_2$ = 4500 sccm and O$_2$ = 3000 sccm also corresponded to the maximum SAXS intensity difference between the center and outer diameter regions (Fig. 2).

In conclusion, the temperature profile of the preform deposition surface effectively controls the silica nanostructure. The results show a good correlation with the homogeneity of post-consolidated silica glass.

References