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Fiber Optic Dielectric Nanoparticles Characterization by Atom Probe Microscopy

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The engineered processing of dielectric nanoparticles (DNPs) in optical fibers via luminescent ion-doping of silica-based glass aims at providing an enhanced spectroscopic behavior compared to pure silica. These DNPs should positively impact applications in high power fiber lasers, light sources with new wavelengths and telecommunications.

The prevalence of large phase immiscibility domains in silicate systems containing divalent metal oxides (Mg for instance) promotes the formation of DNPs through phase separation since heat treatments take place during the MCVD process.

Even after 60 years of glass-ceramics research, lack of experimental data concerning early nucleation stages imposes variations in composition and heat treatments as processing steps [1]. Although classical nucleation theory was the first model proposed to explain those phenomena, growth rate mismatches remain wide. According to this capillary assumption-based model, nuclei and bulk share similar structure-composition relationship. Recent articles disprove assumption of structure, pointing toward DNPs structural changes [2] and transition from amorphous nuclei to crystalline DNPs [3]. Compositional changes for small particle sizes (~1-10 nm) have been measured in alloys with Anomalous Small Angle X-Ray Scattering (ASAXS) [4] and in steels with Atom Probe Tomography (APT) [5]. Recent developments in APT has allowed the extension of such studies to glass-ceramics [6], and in the current work, we report experimental data disproving the second capillary assumption at the early stage of nucleation-growth process.

The atomic distribution map of Mg DNPs in silica-based glass doped with Mg, P, Ge and Er is reported in Figure 1 after APT analysis. In addition, quantitative assessment of Mg, P and Er content levels in DNPs smaller than 10nm in diameter (Figure 2) could refine the theories behind nucleation and growth mechanisms.

References

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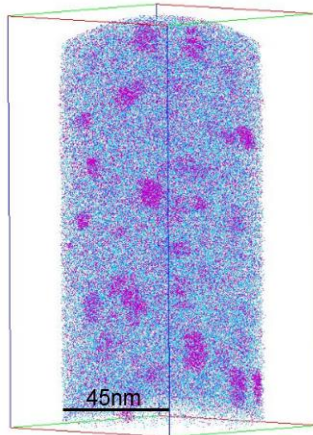


Figure 1. Mg-based dielectric nano-particles (pink) surrounded by silica matrix (blue).

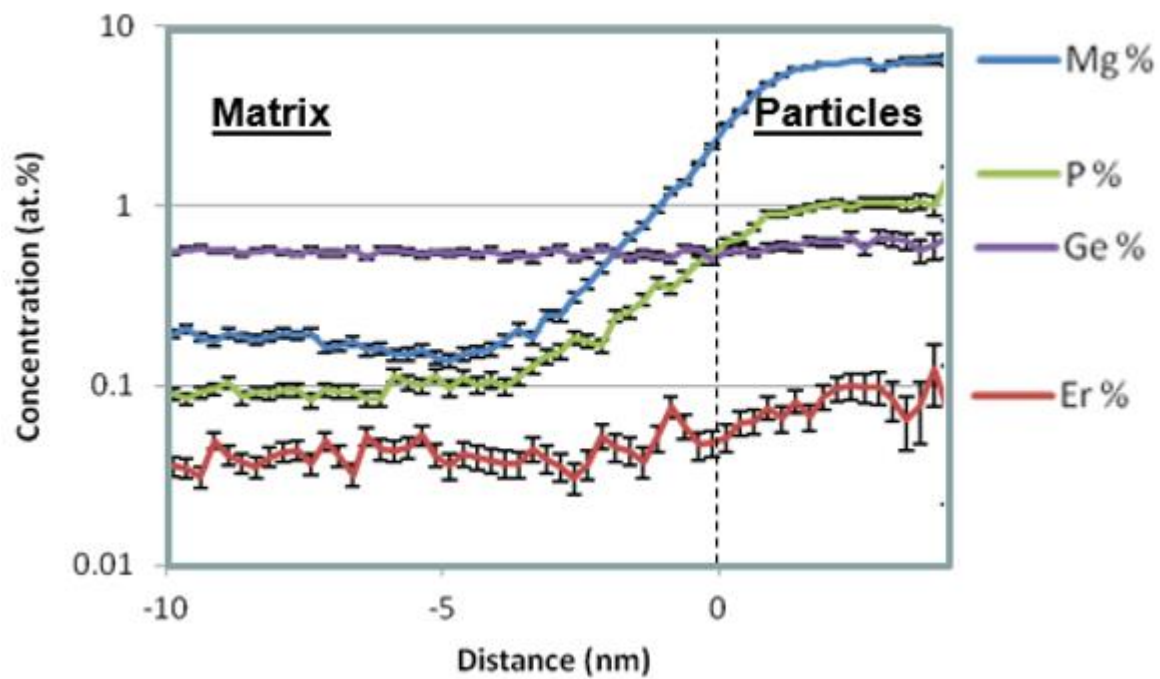


Figure 2. Proximity histogram displaying the evolution of Mg, Er, P, and Ge concentrations from the silica matrix toward the center of the Mg-based dielectric nanoparticles.