Atomic Scale Investigation of Heavy Elements in Glass

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Heavy elements doped glasses have been known to show various kinds of optical properties. For instance, lanthanides, such as Er and Tm, doped glasses are very useful as optical amplifiers. This is especially true for the Er-doped silicate glasses, which can simultaneously amplify the optical signals in the wavelength bands around 1.55 μm, have a sufficient gain flatness and have thus become indispensable in wavelength division multiple (WDM) transmission systems.

To achieve high performance optical properties, control of the dopant distribution in the glass is crucial. Some studies have been performed to capture evidence of the local structure around the heavy elements. However, spectroscopic methods, such as extended X-ray absorption fine structures (EXAFS), have yet to show us the atomic environment around single dopant atom because the information obtained through these methods is essentially averaged across multiple dopants. [1]

In this study, we utilize the atomic resolution high angular annular dark field scanning transmission electron microscopy (HAADF-STEM) technique to directly visualize the heavy elements in glass. For further quantitative interpretation of the information in the experimental images, the molecular dynamics (MD) and image simulations are also used.

Figure 1 shows simultaneously observed HAADF and bright field (BF)-STEM images of Er-doped silicate glass specimen. The BF image shows random phase contrasts and no lattice fringes were observed, indicating that the specimen is amorphous and does not have any long-range order. On the other hand, bright spots were apparently observed in the HAADF-STEM images. Finding the bright spot in HAADF image of amorphous glass indicates that some elements heavier than silicon and oxygen are present in the specimen. We have also performed EPMA analysis and confirmed that Er is the only heavy element in the specimen. Namely, the bright spots observed in the HAADF image can be ascribed to the Er atoms in the glass.

To make a quantitative interpretation, multislice STEM image simulation was performed. First, an atomic structure model of the glass specimen was constructed by the MD simulation. Then, the STEM image was simulated from the structure model. As a result, we found that the visibility of Er atoms in glass is strongly dependent on the defocus of the incident beam and the specimen thickness. Our analysis revealed that only Er atoms near the focus position in thin area can be visualized in the

HAADF-STEM image. Furthermore, we have found that the specimen thickness can be measured by combining both simulated and experimental HAADF-STEM images [2].

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References

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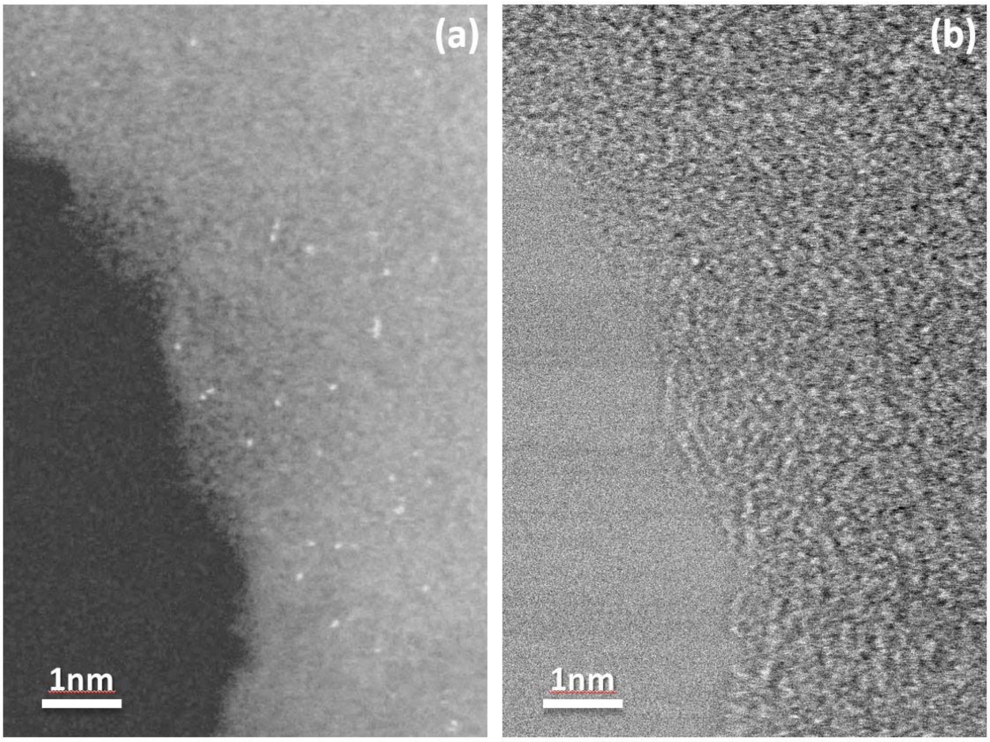

Figure 1 (a) HAADF and (b) BF image of Er doped glass fiber.