Characterization of Ag nanoparticles in heavy metal oxide glasses

Kristýna Jílková*†[1], Martin Havlík Míka[1], Petr Kostka[2,3], Marie Kudrnová[4], Marie Kudrnová[5], Ondrej Bošák[6], and Marián Kubliha[6]

[1]Department of Glass and Ceramics, University of Chemistry and Technology Prague, Technická 5, 166 28, Prague, Czech Republic – Czech Republic

[2]Laboratory of Inorganic Materials, Institute of Rock Structure and Mechanics of the Czech Academy of Sciences, V Holešovičkách 41, 182 09, Prague, Czech Republic – Czech Republic

[3]Laboratory of Inorganic Materials, University of Chemistry and Technology Prague, Technická 5, 166 28, Prague, Czech Republic – Czech Republic

[4]Department of Metals and Corrosion Engineering, University of Chemistry and Technology, Technická 5, 166 28, Prague, Czech Republic – Czech Republic

[5]Central Laboratories, University of Chemistry and Technology, Technická 5, 166 28, Prague, Czech Republic – Czech Republic

[6]Faculty of Materials Science and Technology, Slovak University of Technology, Bottova 25, 917 24, Trnava, Slovakia – Slovakia

Abstract

Metallic nanoparticles embedded in various glassy matrices are intensively studied due to their ability to modify the physical and chemical properties of the bulk glass phase. These nanomaterials dispersed in glasses find several applications, f. e. in ultra-fast non-linear photonics (e.g. optical and electro-optic modulators, switches, ultra-fast time response optical sensors), plasmonics and telecommunications. Silver nanoparticles attract a great attention due to their electrical, optical, catalytic and biochemical properties. Therefore, the researchers have focused on studying their physical, chemical, electrical, and optical properties (1, 2). Presence of metal silver nanoparticles in the glass matrix results also in unique linear and non-linear optical properties due to strong surface plasmon resonance. Non-linear properties of such nanocomposite materials depend mainly on the size, shape, distribution and concentration of metal nanoparticles (2).

The formation of silver nanoparticles has already been investigated in common glass systems based on silica, phosphate and borate oxides. However, these glasses exhibit much lower non-linear (Kerr) EO coefficient and also their transparency in infrared region is limited in comparison to the glasses based on heavy metal oxides. The heavy metal oxide glasses are further characterized by high refractive index, they show high stability against crystallization and are easy to prepare. They are characterized by high content of heavy metal oxides, usually PbO or Bi2O3, in combination with WO3, Ga2O3, GeO2 and/or other oxides. The PbO-Bi2O3-Ga2O3 system forms homogeneous thermally stable glasses with very good transmittance going from the visible up to mid-infrared region (up to 8μm). These glasses

*Speaker

†Corresponding author: Kristyna.jilkova@vscht.cz

exhibit also better physical and chemical properties (higher chemical resistance, lower thermal expansion coefficient) in comparison with halide and other non-oxide glasses that are transparent in similar spectral region (2).

In this work the silver nanoparticles were formed during thermal treatment in glasses modified by Ag2O and Sb2O3 addition. These glasses were prepared by conventional melt-quenching in PtRh crucible in an electric furnace. The presence, chemical composition and structure of the silver metal nanoparticles were confirmed with transmission electron microscopy (TEM) and x-ray photoelectron spectroscopy (XPS) analysis. TEM confirmed an increased number of spherical nanoparticles caused by additional heat treatment. The indexes of the selected area electron diffraction (SAED) pattern recorded on such particles matched the fcc-Ag crystalline phase, high resolution (HRTEM) mode identified the periodical arrangement in the particles corresponding to d-spacing of (111) planes in Ag and the elemental state of the present Ag in the heat-treated sample was confirmed also by XPS. Electrical measurements were chosen due to their sensitivity to any changes in the material structure. The electrical conductivity of glasses containing Ag/Sb changed during thermal treatment (the investigated temperature range of 240–290 ∘C), while the properties of the base glass without Ag/Sb addition remained practically unaffected (3).

References

(1) A. A. Menazea, et al., Precipitation of silver nanoparticles in silicate glasses via Nd:YAG nanosecond laser and its characterization. *Journal of Non-Crystalline Solids*, **513**, 49-54 (2019), DOI: 10.1016/j.jnoncrysol.2019.03.018.

(2) K. Jílková, et al., Electro-optic glass for light modulators. *Journal of Non-Crystalline Solids*, **518**, 51-56 (2019), DOI: 10.1016/j.jnoncrysol.2019.05.014.

(3) P. Kostka, et al. Electrical properties of PbO–Bi2O3–Ga2O3 glasses with addition of Ag2O and Sb2O3. *Ceramics international,* (2023), DOI: 10.1016/j.ceramint.2023.12.319.

Acknowledgements
K. Jílková acknowledges support from the grant of Specific university research (grant No. 107881905). O. Bosak and M. Kubliha thank the European Regional Development Fund, Research and Innovation Operational Program, contract No. ITMS2014+: 313011W085. We also thank Dr. František Lahodný for his help with preparation of the glass samples for measurements.

Keywords: Keywords: silver nanoparticles, heavy metal oxide glass, PbO–Bi2O3–Ga2O3 glass system