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Active Glassy Substrate Optimized for Fast Self-growth of Metallic Nanofilms by Bottom-up Process

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Abstract – Active glassy substrates have been developed to be used as active part of nanodevices. A limiting factor for some applications of one of these substrates was the slow kinetics for self-growth of silver nanostructured thin films. We present a $PbO-B_2O_3$ glass substrate doped with Ag_2O that allow us a very fast production of metallic nanostructured silver films by thermal reduction of Ag^+ ions around the glass transition temperature of the substrate, by nucleation and diffusion of Ag^0. In addition, the temperature to obtain this film in the lead borate glass is around 70ºC lower than the usual ones. AFM images allowed us to monitor the film growth as a function of time and temperature, and DSC analysis shows an increase in stability.

We have developed and analyzed the behavior of active glassy substrates to be used in hybrid nanodevices. Glasses based on $PbO-GeO_2$ family were used for thermal reduction of Ag^+ ions to produce nanostructured metallic thin films by nucleation and diffusion of nanoparticles inside the glass substrate. A nanostructured silver thin film self-assembled is formed on the surface of these glasses when the silver-doped glass is submitted to thermal treatment around the glass transition temperature (T_g), in a bottom-up process starting from the ion. Using this process, we have obtained nanofilms and studied this systems by molecular dynamics simulations analysis and experimental measurements to evaluate kinetic parameters related to the glassy systems, to improve technological applications [1,2].

Previously in our group, the silver films were obtained from oxyfluoride glasses composed by PbF_2–GeO_2–Al_2O_3 doped with AgF or Ag_2O [2], followed by oxide glass $PbO-GeO_2-Al_2O_3-Ag_2O$ as studied by Schneider [1]. Both vitreous matrices are able to form the nanostructured silver thin film by self growth, presenting, however, slow kinetics.

In order to optimize the thermally induced reduction and diffusion of silver nanoparticles to attain a faster production of the nanostructured film over the glass, a new vitreous substrate was developed. In this work, we have produced a lead borate glass composed by $PbO-B_2O_3$ doped with Ag_2O., the T_g of the new matrix decreased around 70ºC if compared the previous one, and the time to start the thermal diffusion was reduced in a half.

Figure 1 shows the silver nanofilm morphology observed by AFM and it is possible to identify the silver nanoparticles that constitutes the thin metallic film self formed on the surface of the lead borate glass after 30 minutes of thermal treatment at T_g.

The stability of vitreous materials depends on the kinetics and thermodynamics parameters [3]. These parameters were obtained from thermal analysis by differential scanning calorimetry (DSC) under different annealing rates. The calculated stability against crystallization of this new matrix will be presented, showing a better stability of the lead borate glass than the lead germanate one. In addition to DSC analysis, Infra-red spectroscopy, X-ray diffraction, atomic force microscopy (AFM) and transmission electronic microscopy (TEM) are used to characterize the substrate.

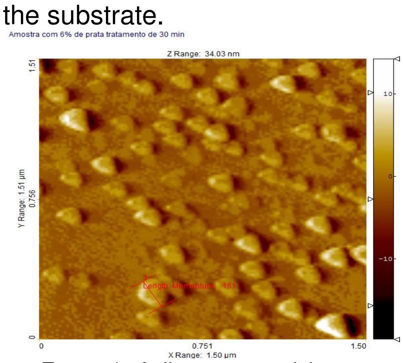

Figure 1: AFM image (1,5 x 1,5 µm, 34 nm Z range) of silver nanoparticles grown by reduction and diffusion of silver during 30 minutes of thermal treatment at T_g under air atmosphere.

[1] R. Schneider. Materiais híbridos formados por nanofilmes moleculares depositados sobre nanofilmes metálicos produzidos por processo bottom-up em substratos vítreos para uso como parte ativa de nanodispositivos, Master Degree dissertation, Universidade Federal de Pernambuco, 2008.
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