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Cu nanoclusters embedded in a glass host: A tunable nonlinear optical response, thermodynamic and dielectric behaviour

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Copper soda-lime glass nanocomposites were synthesized by an ion exchange method followed by thermal annealing in atmosphere. Ultraviolet-visible absorption spectroscopy and transmission electron microscopy confirmed the presence of Cu nanoclusters embedded in the glass matrix. The size of the Cu nanoclusters has been found to increase with increasing the annealing temperature and time. The particles size calculated from Mie theory, are in good agreement with the sizes measured from Transmission Electron Microscope (TEM). X-ray diffraction and high resolution TEM (HRTEM) results were systematically studied to investigate and determine the microstructure of the Cu doped Soda-lime glass. The chemical state of copper was further analyzed by X-ray photoelectron spectroscopy. Time-of-Flight Secondary Ion Mass Spectrometry and Rutherford backscattering spectrometry measurements were used to confirm the diffusion of Cu nanoclusters in the glass matrix. Plasmonic and thermodynamic properties of the embedded Cu clusters have explained the in situ thermal growth and efficient distribution mechanism. An interdependence of entropy, enthalpy and Gibbs free energy has been developed in relation to an activation energy of 8.04 kJ/mol. The NLO properties of the embedded Cu nanoclusters were further investigated with the Z-scan technique at 800 nm wavelength by executing both open and closed aperture methods to understand the behavior of the nonlinear absorption and nonlinear refraction traces, respectively. The frequency response of the dielectric constant, $\epsilon\hat{}$‘, and dielectric loss, tan (δ), has also been studied. Dielectric constants with higher values on higher thermal treatments were obtained which may be a result of the nanoclustering of Cu atoms. The above mentioned properties illustrate the potential application of this glass in the field of nonlinear optics, especially in optical limiting and contrast enhancement.

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