

Chapter 6

Summary and outlook

Owing to the outstanding optical properties and growing demand on miniaturization of integrated optics, metal nanostructures become beyond all comparison to break a sub-diffraction limit in creation of integrated circuits and optical elements. Thus, studies of the plasmonic materials remain a hot, active and expanding field of science and technology. Moreover, manufacturing of novel nanocomposites, micro- and nanodevices with specific features require development of powerful and flexible techniques to control and optimize their structural and optical properties. In this context, studies of the laser assisted modifications in the composite glass with Ag nanoparticles presented in this work demonstrate a simple way to manipulate the shape and distribution of the metal clusters, which in turn define the alterations of optical properties.

For instance, excitation of the spherical single Ag nanoparticles embedded in soda lime-glass by polarized fs laser pulses close to the SP resonance results in formation of uniformly oriented oblong silver clusters. Moreover, the orientation perpendicular or parallel to the laser polarisation is defined by the laser peak pulse intensity used for irradiation. Thus, pulse intensities slightly above the modification threshold lead to the elongation of the silver nanoparticle parallel to the laser polarisation. On the other hand, increase in the peak pulse intensity in one order of magnitude results in spheroids aligned perpendicular to the laser polarization. The temperature effects, luminescence studies of the modified samples as well as relaxation dynamics measurements indicate the SP assisted photoemission of electrons and ionization of the silver nanoparticles resulting in growth of silver cation content in vicinity to the cluster. Moreover, experimental data indicate ionization and formation of colour centers in the glass matrix (apparently close to the surface of metal nanoparticle) accompanying the cluster modifications upon exposure to fs laser pulses. According to the acquired experimental results a mechanism of the shape modifications was proposed.

However, there are many questions, which still need additional investigations. One of them is that up to now we have very poor information concerning a time scale of dichroism formation in the composite glass. In order to clarify this fact, the polarisation dependent pump-probe experiments are required. On the other hand, the contribution of glass matrix in the modification processes should be thoroughly studied. In turn, according to the proposed model, the threshold of the induced modifications is defined by injection of photoelectrons in the glass matrix. Hence, the energy manifold of the host matrix should strongly affect the tunnelling

of electrons and apparently the modification threshold. Thus, the fs laser induced modification of Ag nanoparticles should be studied in glasses with various cationic compositions.

Other effects were demonstrated in the system with aggregated Ag nanospheres upon irradiation with fs and ns laser pulses near to the SP resonance. For instance, exposure of the compact packed metal clusters to intense fs laser pulses reveal a formation of oblong metal clusters aligned parallel to the laser polarization, which are responsible for the induced dichroism in reflection spectra. Detailed analysis of the experimental data clearly testifies that observed modification occurs due to junction of the contacting clusters in direction to the laser polarisation caused by strong dipole-dipole interactions. In turn, the wavelength dependence of the induced modifications was demonstrated and could be associated with excitation of different collective modes. However, this assumption needs additional investigations.

On the other hand, excitation of the aggregated Ag nanoparticles with the ns laser pulses at 527 nm near to the SP resonance produces high thermal inhomogeneities in the surface region and results in the ripening of the periodical chain-like silver structures distributed in the glass. The periodicity about 500 nm and development of the observed structures in multi-shot regime allowed us to suppose formation of the so called Wood's structures caused by interference between the light scattered by the induced inhomogeneities and the incident laser beam. The exposed region demonstrated strong alterations in the reflectivity caused by the induced structural modifications in thin upper glass layer with aggregated nanoparticles. However, these are only the first results and observed effects should be extensively studied in the future.

In conclusion, proposed techniques could find many applications in development of different 3D polarization and wavelength selective microdevices such as polarizers, filters, gratings, RGB and DWDM devices, optical and plasmonic embedded circuits, and optical data storage devices.