Surface-Enhanced Photophysical Phenomena in Surface Metal-Amorphous Semiconductor Composite

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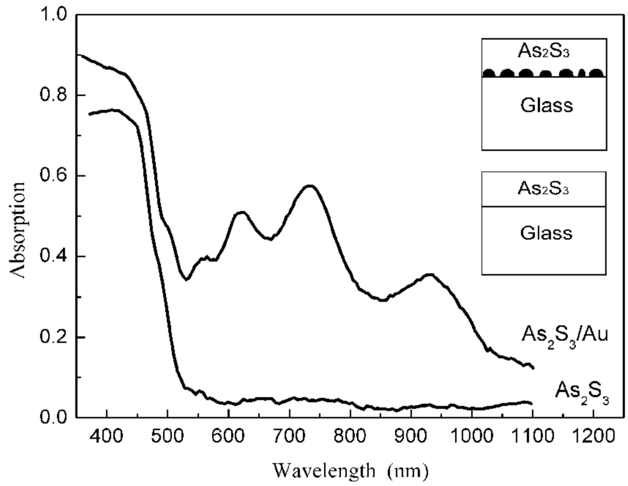
It is known that the enhancement of the electric field in the vicinity of a metallic nanoparticle resulting from the excitation of eigen oscillations in the electron gas (surface plasmons) leads to the enhancement of many photophysical phenomena. Composites belong to a class of functional materials where variations of the effective dielectric function of heterosystem and the optical properties of the material are possible in the wide range [1]. Surface composites are created typically based on plasmon-carrying materials (metals, conducting oxides) with the structures with reduced dimensionality (nanoparticles, nanowires and thin films) deposited on the surface of the semiconductor or insulator. The main idea of surface composites is a realization of significant electromagnetic interaction in the near-field and in the far-field regions. Such interaction leads to various surface-enhanced photophysical phenomena, such as surface-enhanced infrared absorption (SEIRA), Raman scattering (SERS), tip-enhanced Raman scattering (TERS), photo- or electroluminescence (SEEL), generation of electron-hole pairs and, accordingly, photoelectric current of barrier structures etc.

We have fabricated single and multicomponent layered structures, which consist of granular (gold) nanoparticle film and chalcogenide (As_2S_3) layers on glass substrates. Morphology and structure of composites were investigated with AFM, TEM and SEM techniques. Optical properties were investigated with reflectance/transmittance spectroscopy of polarized light at several angles of incidence in the 400–1100 nm spectral range.

Spectroscopic investigations with transparent substrates allow us to obtain total absorption spectra $A(\lambda)=1-R(\lambda)-T(\lambda)$ of layered structures. In figure it is shown that beyond the fundamental absorption edge of the chalcogenide ($\lambda_g \approx 450$ nm) the absorption in the Au/As_2S_3 structure becomes much more complicated in comparison to the case of pure chalcogenide film on a glass. Apparently, the surface enhanced absorption of light in the region of transparency of the semiconductor is caused by the interaction of surface plasmons (near field) and interference modes in a Fabry-Perot like cavity (virtual modes) [2]. Since light passes many times across the near-field region of metal nanoparticles, the absorption coefficient attains a level comparable to that in the case of fundamental band to band absorption.



Chalcogenide glasses display the highest photoinduced effects among other materials and their photosensitivity does not involve chemical reactions. Photo-induced transformation processes, as some laser-stimulated changes of optical parameters in amorphous chalcogenide films (As_2S_3, As_2Se_3 etc.), are used for optical memory and recording, fabrication of photonics elements, direct laser writing of buried optical waveguides etc. Because of excitation of localized (surface) plasmons in metal nanoparticles accompanied by near-field enhancement is used for enhancement of various photophysical phenomena, it can be assumed that photo-induced transformation processes in chalcogenides also can be influenced by this way [3].

Thus, we have observed another surface enhanced photophysical phenomenon similar to such long familiar effects as the enhancement of the infrared absorption or Raman scattering by adsorbed molecules in the presence of a rough metallic surface or colloidal metal particles. This effect could be used for development of new active elements for opto- and nanoelectronic devices (sensors, photodetectors, solar cells etc.), where the excitation of surface plasmons or surface plasmon-polaritons is used. Also, results obtained enable further selection of optimized structures for optical recording.

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