Investigation of Optical Properties of Diamond Like Carbon Thin Films with Embedded Silver Nanoparticles Employing Spectroscopic Ellipsometry

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Abstract

Nowadays there is an increased interest in localized surface plasmon resonance (LSPR) of metal nanoparticles. At first and most commonly, LSPR of gold nanoparticles were investigated, because of its high response and stability [1]. However, gold possesses high absorption, which causes lower sensors sensitivity [2]. Thus new materials started to be investigated: silver [3], palladium [4], copper, platinum, nickel, tin, yttrium, aluminium [1]. Sensor applications is not the only field, where nanocomposites of metal nanoparticles in a matrix can be utilized. Potential fields of application are solar cell efficiency enhancement, perfect absorbers, photochemical reactions, antibacterial films and others [3, 5, 6].
Spectroscopic ellipsometry is an optical non-destructive measurement technique. It is commonly used to determine refractive index n and thickness of thin films d, but it can also provide results about extinction coefficient k, volume concentrations of materials in a composite and many more [7]. The main drawback of this technique is that it requires building an optical model, which subsequently requires some initial knowledge about the film. Mixtures of two or more materials (e.g. composites) have to be described using Effective Medium Approximation (EMA). Known materials are described by dispersion values from database, while unknown – by assigning dispersion laws with certain varied parameters. The actual properties of the film are derived through fitting simulated Ψ and Δ functions to experimentally measured. The goodness of fit is described by coefficient of determination R2 and root mean square error RMSE [8].

In this work, the investigation of nanocomposite thin films, consisting of diamond like carbon matrix with embedded silver nanoparticles (DLC:Ag), is presented. Thin films with different silver content were deposited employing magnetron sputtering on two different substrates: fused silica and silicon. DLC:Ag on fused silica were used for investigation of absorption spectra. The spectra were obtained employing AvaSpec-2048 (Avantes) UV-VIS-NIR spectrometer. DLC:Ag on silica were used for investigation with scanning electron microscope (SEM, FEI Quanta 200 FEG) and energy dispersive X-ray analysis (EDS, Bruker). Optical properties of all samples were investigated employing variable angle rotating compensator

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spectroscopic ellipsometer GES5-E (Semilab). 7 different angles of light incidence were used: 45 deg. – 75 deg. (step 5 deg.). The dispersion graphs of ellipsometric parameters Ψ and Δ were registered at wavelength range of 190-900 nm. Theoretical model was created and fitted to experimental data using Spectroscopic Ellipsometry Analyzer (SEA, Semilab) software.

Before fitting, experimental data was smoothed using build-in SEA function. 2-layer optical model was created to explain the thin film. Bruggeman EMA was chosen for DLC:Ag mixture. DLC was described by Cody-Lorentz dispersion law and silver was described by n&k values from database. Simulated Annealing fitting algorithm was chosen. Fitting results were in good agreement with experimental data: coefficient of determination reached 0.98 and root mean square error was up to 1.66. It was found out that the thickness of sample with 14.1 at% silver is 43.5 nm and is similar to what was expected. Its silver volume concentration is 22 % and refractive index at 632.8 nm is 1.56. The dispersion graphs for the thin film were also derived. The average size of nanoparticles is 3.5-5.1 nm.

Keywords: spectroscopic ellipsometry, sensor applications, nanocomposites, diamond like carbon, silver nanoparticles.

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