High refractive polymer materials based on the silicon nano- and micro-particles.

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Abstract— For developing THz technologies transparent materials with controllable refractive index are requested. We create such materials by incorporation of micro-and nano-particles of high refractive semiconductors into a transparent polymer. With THz time-domain spectroscopy composite materials based on nano-and micro-particles of silicon are investigated. The ultimate achievable value of absorption, refraction and scattering, as well spectral tuning due to laser illumination are discussed.

Keywords—nanoparticles; silicon; terahertz; refraction; scattering; plasma frequency

I. INTRODUCTION

Transparent and flexible materials with high refraction become highly requested for THz component development. Polymers are good candidates to achieve such an aim[1]. Moreover existing technologies of photopolymerization or extrusion of thermoplasts allow production of complex 2D and 3D systems. For compact THz devises bending waveguide elements and coupling sections for GaAs based photoconductive antennas are actual. To increase polymer refractive index we insert small particles with high refraction in it. Since particles size can be thousand times smaller than the wavelength, scattering losses could be negligible, if we manage to avoid agglomeration.

The other perspective semiconductor particles application is the possibility of new functionality of such composite material. Besides high refraction index we may produce gradient or periodical refraction distribution, to exclude reflection losses or to filter specific frequency. In other class of materials one may actively control transmission amplitude and phase by illumination of semiconductor particles with laser radiation. We tested polystyrene, polyethylene, Topas and OKM-2 as a polymer matrix with nano and micro particles of Si, Ge, GaAs, LiNbO3 as a high refraction index materials. For high particles concentration, large particle size or material inhomogeneity we still observe considerable scattering losses. We account for this type of losses as a Rayleigh scattering in a dense media (a quasi-crystalline approximation) [4]. Refraction is calculated with effective medium approximation [3]. Experimental measurements are done with standard THz-TDs setup, described elsewhere [2].

II. RESULTS

We have shown that for micro-particle size less than 10 microns, scattering losses became much smaller then material absorption. When we decrease particle size to 30 nm, we only increase overall particles surface with layer of SiO2 that has worth absorption and refraction values, moreover it is more difficult to obtain high volume concentration with nano-particles because of capillary effects. The advantage of the use of nano-particles one can obtain transparent composite material even for the visible wavelength, that allows to use laser radiation interference for periodical structuring polymer composite during photopolymerization. Effective diffraction grating induced in OKM-2 with nano-Si has been demonstrated. We also demonstrated THz transparency increase of nano-Si composite at laser illumination with 800 nm femtosecond laser radiation. For doped Si micro particles we can obtain tunable absorption maximum in spectral range of 0.1-3 THz, due to local plasmons excitation. We succeeded to increase refraction index value up two n=2.2, preserving moderate losses (below 2 cm-1 at 1 THz frequency), that correspond to about 50% of Si nano particles volume in PE. With this material we produce small hyperspherical lens, that allowed us to couple directly photoconductive THz emitter to a polymer waveguide.

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REFERENCES


