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Optical properties of photoresist in the terahertz range

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A B S T R A C T

To meet the urgent demand for terahertz band materials with the development of terahertz devices, we have identified the refractive index, absorption coefficient, transmittance and dielectric constants of photoresist from 0.25 to 1.0 THz for it is no any reactions in the THz band. The absorption coefficient is less than 3 m^{-1}. The refractive index of the unexposed sample and exposed sample range from 1.71–1.82 and 1.68–1.76, with the transmittance ranges of 81–92% and 77–89.5%, respectively. The results suggested that photoresist could be good candidate materials for terahertz photon devices. The new applications of photoresist were opened up and the THz material databases were enriched by this work.

1. Introduction

Terahertz wave falls between microwave and infrared wave in the EM spectrum. Compared with the common light source, terahertz pulse light possesses the transient, broadband, coherence, low-power and other peculiar properties. Furthermore the spectra of material in the terahertz band, such as transmission spectrum and reflectance spectrum, contain plentiful physical and chemical information. Therefore, it is quite significant to research the spectra of material in the band [1–5]. Most of the micro-nanostructures, such as photonic crystal, surface plasma and guide mode resonance grating have a wide range of applications in terahertz devices. And they would hold an important status in

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the future research in the terahertz field. However, few materials could be applied in the THz photonic devices. The development of THz photonic devices would be limited.

Photoresist is a light-sensitive material, consisting of the photoactive resin [10], the photosensitizer and solvent. The photo-curving reaction of photoactive resin could quickly take place once exposed in the UV radiation and visible light. It makes the solubility, affinity and other physical properties of the material changed obviously [6–8]. In the past decades, photoresist only played the copy and mask role in those micro-nanostructures. Mizue Mizoshiric discovered that marks increased in refractive index of chemically amplified photoresists induced by highly repetitive femtosecond laser irradiation without post-exposure baking treatment [9]. But there were still not any reliable THz parameters about photoresist.

In this paper, we focus on the optical properties of the photoresist in the terahertz band, and try to obtain a series of reliable data from it. The data demonstrates that the photoresist exhibits excellent optical properties at the terahertz range. And it establishes the base for the future study that the photoresist applies in the terahertz photonic devices.

2. Theory

The photoresist were obtained from commercial suppliers in Japan, produced by AZ Electronic Materials (Japan) K.K company. It is a sort of ultra-thick positive 'G-line' photoresist. The photosensitizer of the photoresist is the diazonaphthoquinone (DNQ) and the photoactive resin is the novolac resin. DNQ has a strong absorption in the range from 300 nm to 450 nm. The absorption bands can be assigned to n–π^* (S_0–S_1) and π–π^* (S_1–S_2) transitions in the DNQ molecule [11]. However, there will be no direct photolysis reaction under the IR irradiation due to the low photo energy. In fact, the THz photon energy, which is only milli electron volts, is much lower than the IR photon energy. So we can deduce that the photoresist does not have direct photolysis reaction in the THz range. It provides an evidence for the application of the photoresist in the THz range.

In the experiment, transmission terahertz time-domain spectrum system (Fig. 1) was employed to get the optical properties of the photoresist. The wavelength, pulse duration and repetition rate of the femtosecond pulse are, 800 nm, 100 fs, and 80 MHz, respectively. Then the terahertz wave will be detected by the $\langle 1\,1\,0\rangle$ ZnTe crystal free electro-optic sampling technology. We got the signal $E(t)$ that is proportional to the electric field of the THz pulse. By Fourier transforming the signal $E(t)$ and combining the Fresnel formula, we got the refractive index n_r (Eq. (1)), the absorption coefficient α (Eq. (2)), and the real dielectric constant ε' (Eq. (3)) [12].

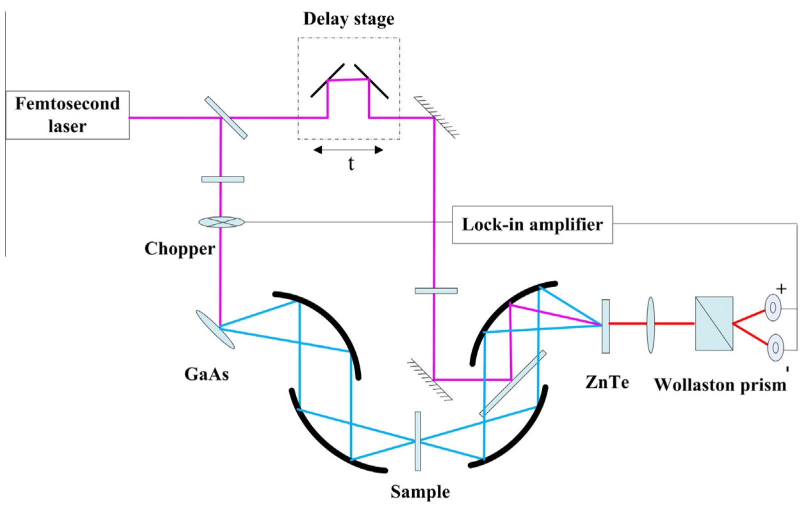

Fig. 1. The THz time-domain spectroscopy.