Imprinted Quarter Wave Plate at Terahertz Frequency

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Summary— We have imprinted artificial dielectric quarter wave plates (QWPs) on High Density Polyethylene (HDPE) for use at 2.6, 3.2 and 3.8 Terahertz. The grating period (Λ , Fig. 1) of the QWPs is 60 μm. An Inductively coupled plasma (ICP) etch process was used to create the silicon masters for the imprint. A maximum aspect ratio (grating height/grating width) of 7 was obtained.

Terahertz (THz) systems have recently received significant attention for applications in material inspection, security imaging, short range and high bandwidth communications [1]. In order to build such a system there is a requirement to make a wide range of THz components available. In this paper, we present design and characterization of quarter wave plates (QWPs) fabricated on HDPE. The design of the QWP is based on the theory of birefringence in an artificial dielectric [2]. The operating frequency of the QWP is dominated by the grating depth while the fill factor (a/Λ, Fig. 1) also has an important role. In this paper, we present QWPs imprinted on 1 mm thick HDPE sheet using silicon masters. The dielectric constant of HDPE (2.4) is small therefore a relatively deep grating depth (>200 μm) is required for a QWP at THz frequencies (< 4 THz). We have used two imprinted plates back to back for each QWP. This imprinting technology is simple, efficient and low cost since many plates can be imprinted from the one master.

A cross-sectional view of the HDPE QWP (2 imprinted plates, back to back) with the geometrical parameters is shown in Fig. 1. The total grating depth required for each operating frequency depends on the dielectric constant, fill factor and the operating medium [2,3]. A single mask process was used to fabricate the silicon masters. A 1 mm thick, single side polished silicon wafer was used as the master. Fabrication of the masters has previously been described [3]. Two masters were produced using an ICP etch process for 45 min (A) and 30 min (B) respectively at a silicon etch rate of ~3.7 μm/minute. Subsequently the QWPs were imprinted on HDPE using an Obducat nanoimprinting tool. During imprinting, the temperature was first increased to 140 ° C then a 5 bar pressure was applied for 5 min. The pressure and temperature were then reduced to 3 bar and 60 °C respectively for another 3 min. In the final step the pressure was fully released and the sample cooled to room temperature. The quality of the imprinted grating and repeatability of the process was very good. SEM images of the imprinted grating are shown in Figs. 2 (A) and 3 (B). The aspect ratio of the imprinted sample A is 7, better than the work published in [4]. The imprinting process is simpler than the process shown in [4].

The QWP samples were measured using a Bruker IFS 66v/S Fourier Transform Infrared (FTIR) spectrometer. The experimental set up and the definition of polarizing factors are presented in [3]. Fig. 4 shows the polarization factor $P(f)$ as a function of frequencies for QWPs in three configurations, i.e. A+A, A+B, B+B. The operating frequencies of the QWP for each configuration are 2.6, 3.2 and 3.8 THz respectively. The dielectric constant of HDPE is close to air so the reflection loss due to index mismatch is very small. This reduces the overall transmission loss of the QWPs.

References

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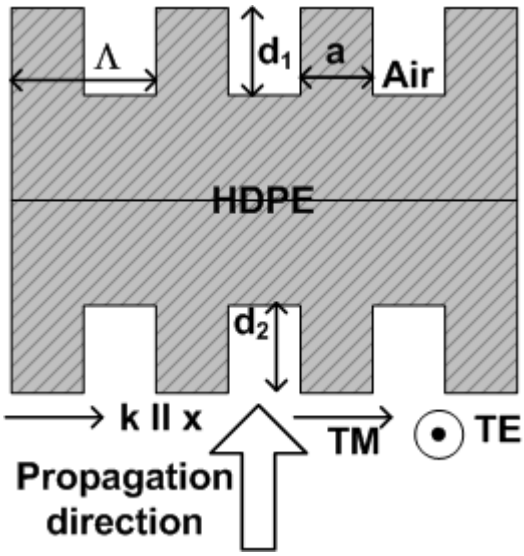

Fig. 1. A cross-section view of the quarter wave plate (2 plate back to back). The device is made of a vertical grating with alternate refractive index η_s (HDPE) and η_a=1 (air). The total grating depth is $d=d_1+d_2$. The grating direction is k.

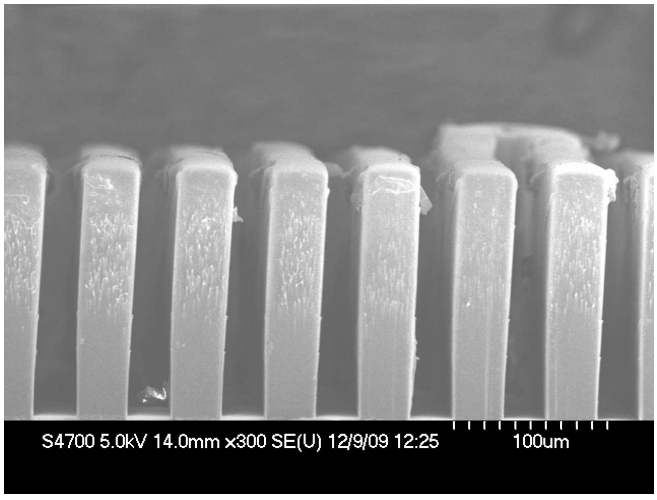

Fig. 2. A scanning electron Microscope (SEM) image of the imprinted plate A. The grating depth is 165 μm.

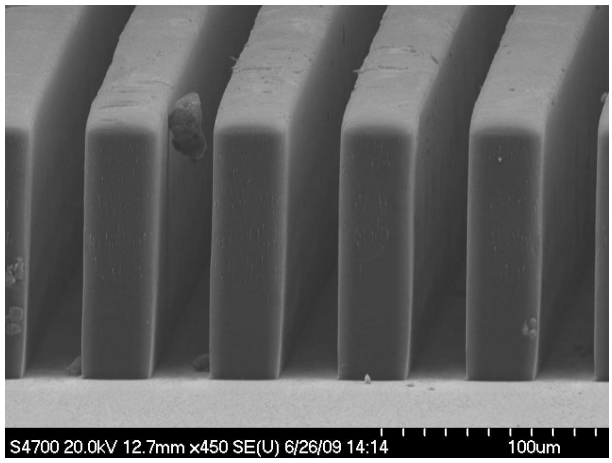

Fig. 3. A SEM image of the imprinted plate B. The grating depth is 115 μm.

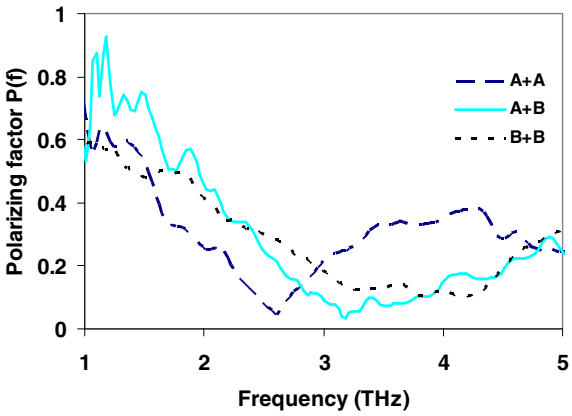

Fig. 4. Polarizing factor *P(f)* of QWPs in three configuration.