INTRODUCTION

Recently imaging with pulsed terahertz (THz) radiation is actively studied aiming for various applications [1]. Most of THz imaging systems with pulsed radiation are based on the terahertz time-domain spectroscopy (THz-TDS), by which spectroscopic information is obtained from the time-domain THz waveform signals [1-4]. When the THz-TDS imaging is used in the reflection scheme, it is also possible to detect layered structures inside of the imaged object using the reflections at the layer boundaries, in a similar way with the optical coherence tomography (OCT) [5-8]. Since the object is usually raster scanned to obtain the images with the THz-TDS imaging system [1, 4-7], the scanning speed is a critical problem, especially for a high-resolution imaging system. If the two-dimensional electro-optic (2D-EO) sampling is used in the imaging system, the data acquisition time can be dramatically shortened [4, 9]. In this paper we report a reflection-type THz-TDS imaging (THz tomography) system using the two-dimensional electro-optic (2D-EO) sampling.

PROCEDURE FOR EXPERIMENT

A tomographic imaging system has constructed based on the two-dimensional electro-optic sampling in the reflection scheme. The block diagram of THz tomography system is shown in Fig.1. A large-aperture photoconductive antenna was used as the emitter. The collimated THz beam was irradiated to a region of the sample after passing through the first high-resistivity silicon beam splitter. The reflected or scattered THz waves from the sample were reflected by the Si beam splitter to the direction of the detector. The reflected THz wave formed an image on to a ZnTe crystal plate by a pair of polyethylene (PE) lenses. A collimated probe beam was combined with the THz wave by using the second high-resistivity silicon beam splitter. A 2D-EO sampler was constructed by a ZnTe crystal and a polarizer with nearly zero bias alignment. A C-MOS digital camera with 128x128 pixels acquired the 2D-EO images. The observable region was 30-mm in height and 24-mm in width. Therefore, the number of depth profile data taken was 16384. The acquisition of such large amount of data in a short time is a very hard task for the raster-scan type imager. However, the 2D-EO THz tomography system was able to make a two-dimensional depth scan within 6 minutes for 256 sampling points with a 20-micrometer step.

EXPERIMENTAL RESULT

Tomographic images were obtained for test samples by using our THz imaging system. The wave front of THz beam has a spherical shape. The time-shifts due to the wave front deformation was determined from the reference waveform measured without the sample and compensated in constructing the tomographic images. The tomographic image was generated from the THz amplitude waveforms by using image processing software. Fig. 2 schematically shows the structure of a test sample, which consists of stacked silicon and vinyl chloride plates. The tomographic image is shown in Fig.3, which clearly reveals the inner-structure of the sample.

![Fig. 1. Block diagram of reflection-type THz 2D-EO imaging system. Laser source is the femto-second laser (fs-laser) with regenerative amplifier. Two parabolic mirrors are expanding the diameter of THz beam to 40 mm. The polyethylene lens optics has the scale ratio of 2:1. C-MOS camera is synchronizing with the repetition rate of fs-laser. Thick short lines at the corner of the laser beam represents mirrors and beam splitters.](image)

![Fig. 2. Outline of the sample. The vinyl chloride plate is a substrate for the Si plate. The thickness of Si plate is 0.65 mm. The dimension of the sample is H11.5-mm x W9 mm.](image)
DISCUSSION

Since the THz tomographic image shown in Fig. 3 was not compensated for the time delay of the THz wave due to the high refractive index of silicon, the interface between the first and the second Si plate is shown to be located much deeper than the surface of the second Si plate not covered by the first Si plate and the surface of the vinyl chloride plate not covered by the Si plates in Fig. 3. Therefore, the second Si plate surface has a rectangular hole as an artifact. For the test sample the refractive indices of Si and Vinyl chloride are known, the image can be corrected for the refractive index without difficulty. However, since we usually don’t know the refractive indices of the materials consisting of the imaging target in advance, the correction for the refractive index is difficult. This is also the reason why the correction for the refractive index distribution is not usually made in the OCT image in the near-infrared region [8, 10]. Since the refractive indices of materials in the THz region are sometimes very large (such as those of semiconductors), the image distortion due to the refractive index inhomogeneity in the THz tomographic imaging is more serious problem than in other frequency regions and need to be addressed in the future researches.

CONCLUSION

We constructed the THz tomographic imaging system based on the reflection-type 2D-EO sampling method. The inner-structures of the sample were successfully identified with the tomographic image that was taken within 6 minutes. The image acquisition time and the image quality can be further improved by using a more efficient emitter and a higher resolution camera. The THz tomographic imaging system is potentially useful for the quality inspection of products in industries, for example, in the drag manufacturing.

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REFERENCES


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