Terahertz imaging with micro-bridge structure detector array and 2.52THz far infrared laser

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***Abstract*—A room temperature operating terahertz (THz) detector with low thermal conductive micro-bridge structure is presented using metal thin film as THz wave absorber. Vanadium oxide is acted as thermal sensitive material and |TCR| of the film is ~2%/K. The detector array is fabricated on silicon substrate with read-out integrate circuit. THz wave transmission imaging could be obtained with the micro-bridge focal plane array and 2.52THz far infrared CO_2 pumped laser.**

I. INTRODUCTION

TERAHERTZ detector array with microbolometer structure is a useful active THz imaging method and indicates many characteristics, such as real-time imaging, operating at room temperature, array format and small bulk. Based on vanadium oxide thermal sensitive material, the THz imaging arrays have reported by NEC and INO companies and indicates potential application in non-destructive evaluation imaging [1,2].

In this paper different pixel size microbolometers are simulated with MEMS software and fabricated with the same semiconductor process recipe. Optimized microbolometer parameters were used to design THz detector array on CMOS read-out integrate circuit substrate. The image result of the focal plane array with CO_2 laser THz source radiation was presented.

II. SIMULATION

Normal structure of the microbolometer consisted of one suspended multi-layer membrane and two long supporting legs, and was packaged in vacuum environment to reduce thermal conduction. The membrane with antenna pattern or metal thin film could absorb incident THz radiation and then change the temperature of multi-layer films membrane of the micro-bridge. Suppose that the environment temperature was 20 ^{o}C and the radiation power intensity of terahertz wave was 2×10^{-13} W/μm^2. The micro-bridges were irradiated under the radiation intensity for one second, and temperature changing map of micro-bridge were simulated by Intellisuite software [3]. The results indicate temperature of membrane is very uniform and the maximum temperature increasing value is 50.8 mK, as shown in Fig.1.

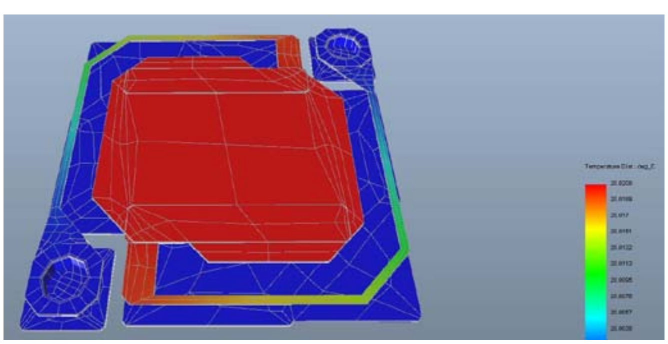

Fig. 1. Temperature distributing map of simulated micro-bridge cell.

III. FABRICATED OF MICRO-BRIDGES

Over ten photomask patterns were designed to fabricate the terahertz detector array with micro-bridge structure. The preparing processes included plasma-enhanced chemical vapor deposition, DC magnetron sputtering, photolithography, reactive-ion etching, plasma treating, solution etching, et al.

Different pixel size and supporting leg width of micro-bridges were designed and fabricated with the same semiconductor process [4]. In order to obtain the micro-bridge deformation of those fabricated structures, three dimension images of designed microbolometers were obtained using laser scanning confocal microscope. The scanning area is 256μm ×192μm for all cell structure and listed in Fig.2. The cell size from type (1) to (5) is 50*50μm^2, 75*75μm^2, 100*100μm^2, 125*125μm^2 and 150*150μm^2. In the same cell dimension, leg width in (b) cell was bigger than that of (a) cell.

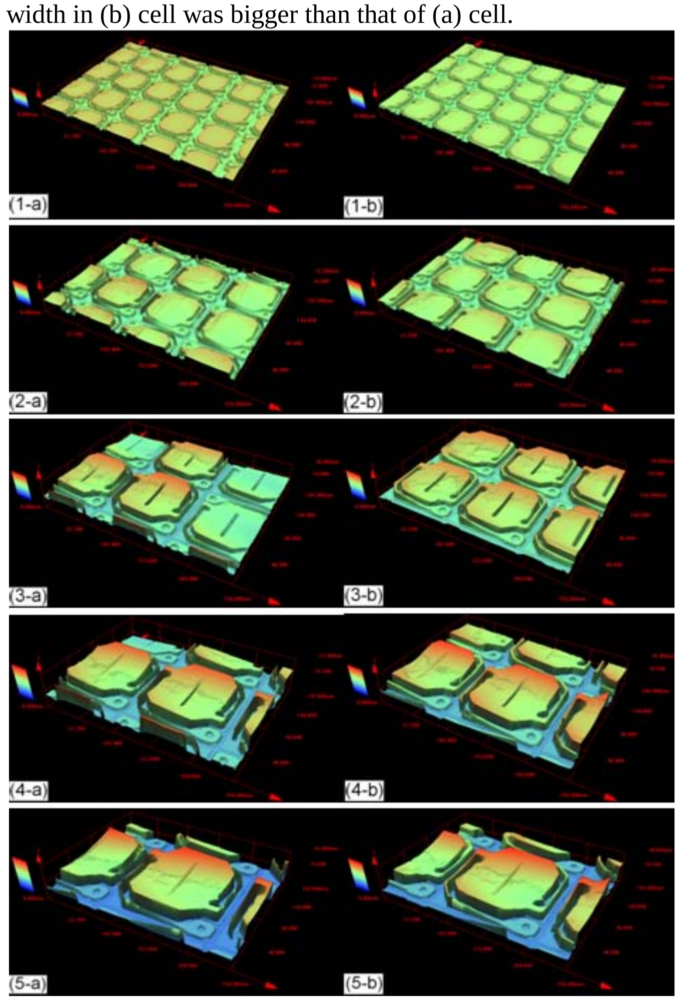

Fig. 2. Three dimension laser scanning confocal microscope images of different kinds of microbolometers, the cell size from type 1 to type 5 is 50μm, 75μm, 100μm, 125μm,150μm, the scan area is 256μm×192μm.

There is nearly no deformation for the small size micro-bridge (type 1, 50×50μm^2), and obvious deformation of membrane or supporting leg in type 5 microbolometer (150×150μm^2). The strip hole in some bigger size membrane was used to release the sacrificial materials under the membrane, which didn't affect the deformation of micrbo-bridge. From the same size micro-bridge cell pattern, the leg width indicates weak effect to the structure deformation, but the internal stress of multi-layer membrane film does. So it's important to control the thin film inner-stress of membrane, such as dielectric layer, thermal sensitive layer, absorber layer, et al. Comparing with other size of micro-bridge, type 2 (75×75μm^2) is suitable for detector array because of bigger membrane area and low deformation.

IV. RESULTS

The micro-bridge focal plane array (FPA) was bonded on ceramic substrate by gold wires and packaged in metal shell with high resist float zone (HRFZ) silicon as transmission window. The THz imaging system was setup with the FPA, THz source, driving PCB board and data display software, which was shown in Fig.3. High power terahertz laser (FIRL 100, 2.52 THz radiation, methanol gas laser pumped by a high power CO_2 laser) was used as THz radiation source [5].

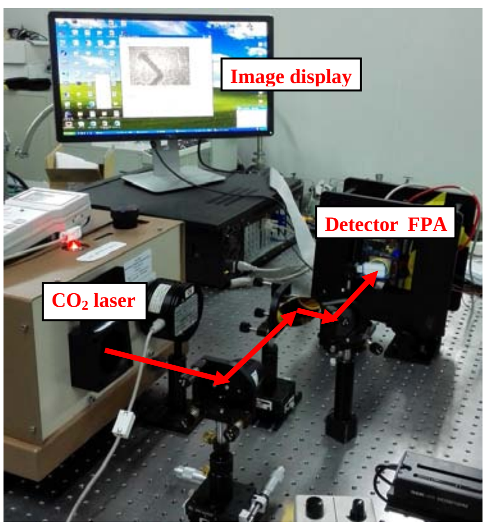

Fig. 3. THz image system with detector FPA and THz radiation source

As present in Fig.3, the THz radiation arrived at the FPA after reflected by several gold coat mirrors, penetrating two layers of label paper and HRFZ Si window. One curving hobnail was pasted between two layers of label paper, and profile of the nail could be clearly seen on the display screen as shown in Fig.3, which indicated that the FPA could detect those THz radiation intensity transmitted through the label paper.

Another imaging of the system was shown in Fig.4 with the fabricated THz FPA, which was the image of watermark in RMB. Because of the paper thickness difference, the invisible water mark in visible light environment could be easily exhibited with THz radiation and detector array. But there are obviously interference fringes in the image. From Oda's analysis [6], the interference fringes include fine fringes and coarse fringes. The fine fringes result from interference generated by two widely separated sources by an optical cavity effect, while the coarse fringes come from short-distance interference. Precise determination of the fringes would require further investigation in a future experiment and the improvement about definition of THz image should be done in the following works.

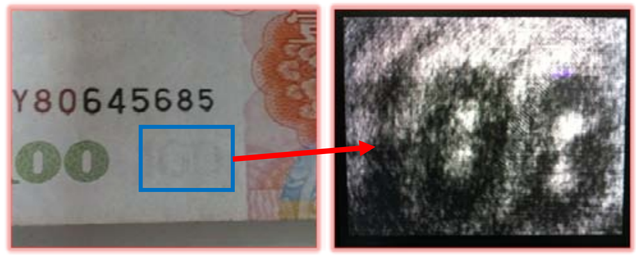

Fig. 4. THz image of watermark in RMB with the fabricated THz FPA.

V. SUMMARY

Different cell sizes of microbolometer structure THz detector were designed and fabricated. The transmission imaging of fabricated detector array were presented with 2.52 THz radiation source, and further improved about detector should be done to get high definition image.

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