CMOS-SOI-NEMS Transistor (TeraMOS) for Terahertz Imaging

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Abstract: We report a novel THz sensor, based on several leading technologies: THz photonics, CMOS-SOI and NEMS. By integrating the TeraMOS sensor with thermal antenna, we expect to achieve a breakthrough in uncooled Terahertz passive imaging.

1. Introduction

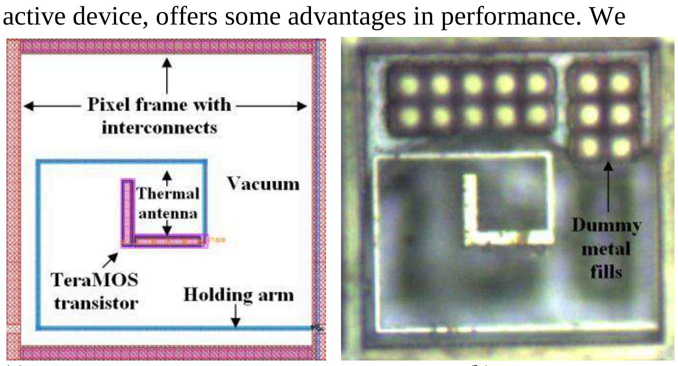
The Terahertz (THz) band of the electromagnetic spectrum extends from the upper edge of microwaves to the infrared, within 10^{11} to 10^{13} Hz. THz radiation is non-ionizing and the associated power is low, hence it is considered as safe. At the same time, the THz wavelength is penetrating. The combination of penetrating yet safe radiation can be used for new and extraordinary applications, such as medical imaging, security/surveillance imaging, and spectroscopic applications.

THz imaging can be classified into passive and active. In passive imaging the blackbody radiation, which is emitted spontaneously by all bodies according to their temperature, is detected [1-3]. In active imaging the target is illuminated by some external sources and the reflected radiation is detected [4]. Passive imaging offers considerable advantages compared to active imaging: it does not introduce health concerns, it doesn't require expensive THz sources and it can't be intercepted, thus offering covert surveillance. This study pursues the development of uncooled passive THz sensors in cost-effective technology, based on CMOS-SOI-NEMS. The sensing pixels are fabricated in a matured 0.18µm CMOS-SOI technology [5]. The nanomachining is performed by post processing, using the CMOS metallization layers as built-in masks, following the process developed at Technion - CMOST.

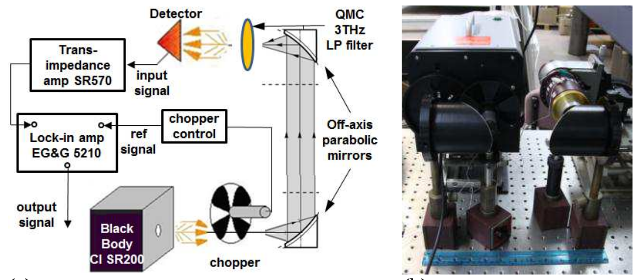
2. The TeraMOS sensor and the “thermal antenna”

The TeraMOS sensing pixels are formed by the combination of an antenna, which collects efficiently all the incident THz radiation, and a thermal sensor, which is sensitive to slight variations of the surrounding temperature. When positioned in a focal-plane array, the antennas form a periodical structure that interacts with the radiation on a specific wavelength, according to the Frequency Selective Surface (FSS) theory [6]. Acting as a band-stop filter, while radiation at the selected wavelength is absorbed, the remaining spectrum can propagate beyond the array.

Classical antennas receive electromagnetic waves, which induce currents within its area. In contrast, the antennas reported here are dubbed thermal antennas because of their most characteristic feature: being made of a resistive layer, they directly absorb the THz waves and convert them into heat. The temperature increase is detected by a thermal sensor, which may be a bolometer, a forward-biased diode or a transistor. The latter, being an active device, offers some advantages in performance. We adopted a thermally isolated transistor, TeraMOS, with a diode-like connection, which is operated above the ZTC-Zero Temp Coefficient of the transistor [7]. The layout of the pixel is shown in Fig. 1.



(a) (b)
Fig. 1. THz sensing pixel (a) schematic view of the layout and (b) an optical image after the NEMS nano-machining.



(a) (b)
Fig. 2. Optical measurement system (a) schematic diagram (b) photo.

3. Packaging

After the post-processing, the FPA is packaged in a sealed Dewar where a ~1Pa vacuum is created. The antenna array is backed by a "$\lambda/4$" grounded reflector to form a resonant cavity, improving its efficiency. The optical window on top of the Dewar is made of quartz.

4. Characterization with a Blackbody and THz Filters

A measurement approach, shown in Fig. 2, resembling the natural operating conditions of passive sensors is based on a cavity blackbody operating in the 300-1200°C range. Since at these temperatures the emission peak lies in the IR range, a THz LP filter, with a sharp cutoff at 3THz was used to remove the unwanted radiation [8]. Current responsivity R_i~0.5[A/W] and noise of 10^{-24}[A^2/Hz] @ 30Hz are measured at room temperature on pixel of Fig. 1, using a TeraMOS transistor with W/L=4µm/80µm.

The NEP is ~7.8 [pW/$Hz^{1/2}$] and NETD ~1.25K. The goal is to obtain NETD of ~ 0.5-1K.

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5. References

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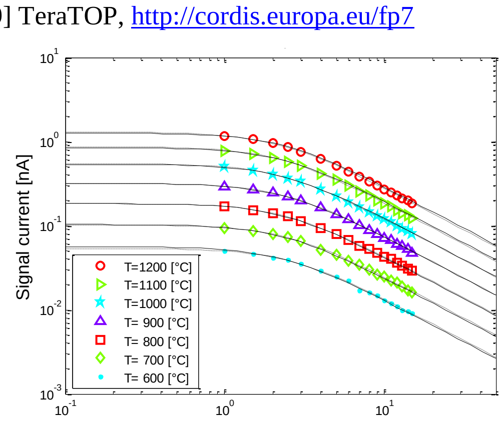

Fig.3: Measured data - signal current vs. chopper frequency, yielding responsivity and thermal time constant.