Nanocarbon materials for sub-THz thermomechanical bolometry

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1. Introduction

Imaging in the THz and sub-THz frequency range has been revealed as a strongly impacting technology to several fields ranging from security, quality control, in-vivo diagnostics and astrophysics [1]. In this research context, constrains for field applications and/or integration with existing technologies favour the use of uncooled (operating at room-temperature), fast detectors arranged in focal-plane arrays configuration, where an image "snapshot" can be acquired without the need for mechanical scanning.

Among the others, the concept of thermomechanical bolometers (TMB) has been recently introduced for far-infrared detection [2]. The basic concept of TMC devices relies on the frequency shift of the eigenfrequency of a mechanical resonator upon illumination-induced heating. Interesting metrics have been measured in preliminary trampoline resonator devices made of a 300/100nm Si_3N_4/Au bi-layer and measured with optical interferometry, with Noise-Equivalent-Power as low as 80 pW/sqrt(Hz) and roughly 20 Hz operating speed under a 140 GHz source illumination [2].

2. Advanced TMBs

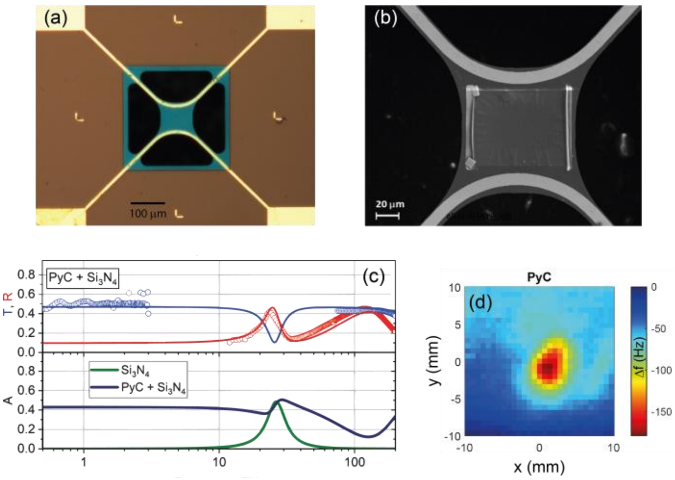

Fig. 1. (a): Microscope image of a typical TMB. (b): SEM of the PyC absorber integrated in the TMB. (c): Tranmission and reflection spectra of a Pyc film on Si3N4. Bottom panel shows estimated absorption obtained adding a 18 nm PyC film on the bare silicon nitride. (d): Beam profiling of the 140 GHz source using a PyC-TMB.

The basic device concept can be further improved by developing all-electrical read-out schemes and by enhancing the TMB absorption, which was estimated in the first generation devices to be around 3% at 140 GHz. While the first issue has been addressed by adding electrical contacts (see Fig. 1 (a)) and exploiting the electromotive voltage generated by mechanical vibrations in a static magnetic field [3], the latter requires a careful engineering to avoid that bulky absorbers could be detrimental to the device performances, which rely on maintaining a high mechanical quality.

To this end, we have developed a strategy to integrate ultra-thin carbonic materials within the TMB. Our choice considered Pyrolized Carbon (PyC) due to the easiness of controlling its absorption spectrum by tuning the film thickness. A typical TMB device hosting a ~18 nm PyC film is shown in the Scanning Electron Micrograph of Fig. 1 (b). As expected, the presence of the PyC film greatly enhances the absorption in the range around 1 THz, as can be seen in the experimental data reported in Fig. 1 (c) and obtained for homogeneous coated and uncoated silicon nitride membranes [5]. Reaching a maximum absorption of 40 % with a minimally added mass, PyC films can benefit the sub-THz and THz TMBs performances, as can be seen by the sharp beam profiling image of Fig. 1 (d), obtained employed a PyC-TMB device.

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