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Development of a scalable nanotube-microbolometer technology

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Summary:
Fraunhofer IMS provides a manufacturing process for microbolometer based FIR-imagers (IRFPAs). Beside classical approaches with membranes of microbolometers thermally isolated by lateral legs, Fraunhofer IMS developed a manufacturing process for a thermal isolation realized by nanotubes. This approach benefits the scalability of pixel pitch, because of a pitch-independent thermal isolation. Latest progress in mechanical stability as well as a qualitative characterization of a demonstrator device with 17 µm nanotube-microbolometers on a 17 µm ROIC in QVGA-resolution will be presented.

Keywords: FIR-imager, uncooled imager, microbolometer, nanotubes, scalability, QVGA.

Introduction

Due to recent progress in pixel design of uncooled infrared imagers, pixel size decreased continuously from the latest state-of-the-art pixel size of 17 µm [1, 2]. To achieve the necessary thermal isolation of microbolometer membranes, Fraunhofer IMS developed a nanotube based electrical contact, which also acts as thermal isolation and advantageously, is independent from pixel size [3].

The use of a vertical thermal isolation by nanotubes allows to reduce the pixel size without redesigning the contact area. This opens up the path to a microbolometer technology which is scalable i.e. independent from pixel pitch. One key requirement for a scalable technology is stress management. The effects caused by stress become more prominent with increasing pixel size. Therefore, the technology will be discussed by microbolometers with 17 µm pixel pitch in this paper.

Mechanical Stability of Microbolometer Membranes

For nanotube-microbolometers the filling factor and therefore the absorption area can be increased to nearly 100 %. The microbolometer membrane has to incorporate several functionalities like temperature sensing, absorption, and electrical connection. Since all these functions cannot be covered by one material the membrane is realized as multilayer stack made of metallic, insulating and sensing material with different mechanical properties. Especially for large membranes compared to small nanotube contacts this can cause highly bent membranes, which can result in membranes touching the substrate causing a thermal bypass and therefore insensitive pixels (Fig. 1).

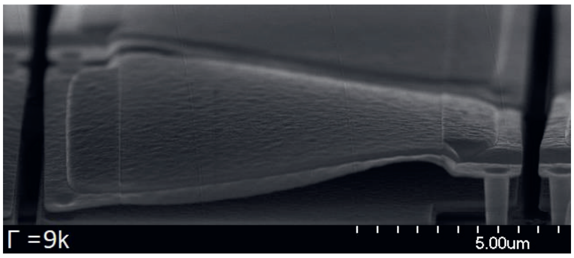

Fig. 1. Highly bent microbolometer membrane.

A set of mechanical test structures was used to evaluate the intrinsic membrane stress of the multilayer material systems (compare Fig. 2).

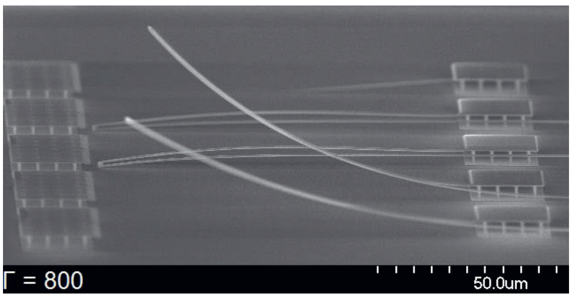

Fig. 2. Long-Short test beams for intrinsic stress measurement.

The lateral deflection of the Long-Short test beams displays the intrinsic mechanical stress of the multilayer stack, whereas the stress gradient is indicated by the vertical curvature of the beams [4, 5].

Intrinsic material stress can be influenced only in a limited way due to process limitations by deposition and patterning techniques. Therefore, the ratio between single layer thicknesses was adapted based on the results of the mechanical test structures. Optimized layer thicknesses avoid large stress gradients over the material stack and result in a smaller out-of-plane deflection.

Nanotube-Microbolometer

A SEM picture of a microbolometer array with improved material stack resulting in a negligible deflection is shown in Fig. 3.

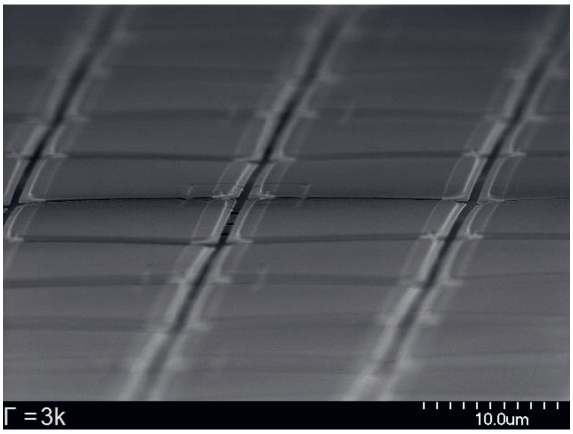

Fig. 3. QVGA-IRFPA of 17 µm nanotube microbolometers.

For qualitatively analyzing the technology a QVGA-IRFPA with 17 µm microbolometers, a digital readout integrated circuit and a chip-scale vacuum package was fabricated. Its performance is given by a test scene in Fig. 4.

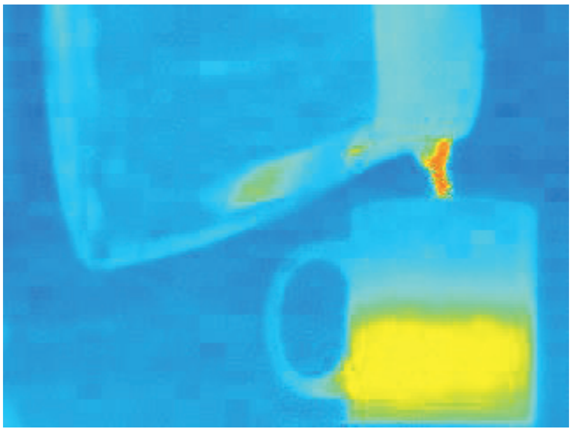

Fig. 4. FIR test picture of hot water flowing in a coffee mug. Image is shown uncompensated and without pixel correction. NETD of the IRFPA is estimated to 230.1 mK with only 2 electrical defect pixels in the QVGA-array.

The filling level of a coffee mug and also the reflection of the mug at the metallic surface of the thermal jug can be demonstrated.

Conclusion

The mechanical stability of the membrane, which was presented at the upper scaling limit of 17 µm pixel size, constitutes a necessary condition for a further enhancement of the nanotube-microbolometer technology.

Minimizing the mechanical stress of the membrane also reduces the mechanical load on the nanotubes. This allows to decrease the wall thickness of the nanotube to improve the thermal isolation and thereby reducing the NETD.

The presented nanotube-microbolometer technology features a simple scalability towards smaller pixel sizes without changing the elemental fabrication process. Therefore, microbolometers with a nanotube contact could be pushed towards the optical resolution limit [6] in the FIR-regime at 5 µm pixel size.

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