Epitaxial p+pn+ vertical short diodes for microbolometers

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***Abstract*—In LWIR band, pn diodes represent an attractive solution for thermometers in microbolometers. In this paper, epitaxial short p^+pn^+ diodes were studied at 303-353 K. A TCC at 4.6-6.2 %/K and a noise dominated by ficker noise were measured. Finally, a thermal resolution between $2.10^{-3}\,K$ and $5.10^{-2}\,K$ was obtained at 303 K. It offers promising performances for future microbolometers.**

Keywords—pn-diode, silicon, thermal sensors, LWIR, TCC, flicker noise, thermal resolution, epitaxy

I. Introduction

The Long-Wave Infrared (LWIR) band, covering the wavelengths from 8 µm to 14 µm, is a region of the light spectrum used for thermal imaging sensors. It offers a high contrast in low visible light conditions and therefore interests in multiple applications : military, rescue, medical, spatial, automotive emergency breaking (AEB) for instance. In this wavelength range, uncooled thermal detectors as microbolometers are used. Their thermometers are usually made of a semiconductor resistance, commonly vanadium oxides (VO_x), amorphous silicon (a-Si) and titanium oxides (TiO_x). They feature a relative thermal response ranging from -1.5 to -3.3 %/K and a very low noise at low frequencies [1]. As an alternative to classic semiconductor resistances, forward biased silicon pn diodes offer several advantages : a compatibility with CMOS technological processes and a relative thermal response at 4-7 %/K for currents ranging from 1 nA to 1 µA. In addition to previous works on silicon diodes for bolometers [2][3][4], we investigated the performances of vertical short diodes made with epitaxial silicon junctions.

II. Fabrication

Initially, 50-nm Silicon-On-Insulator (SOI) wafers produced with Smart Cut are used. Starting from the SOI substrate, successive epitaxies by RTCVD are made in order to obtain p^+pn^+ diodes. Once the epitaxies are completed, the shape and size of the diodes are fixed by dry etching. The sizes range from 1 to 10 µm (Z). A first contact is created. Then, the structure is put face to face and bonded onto a second wafer. Finally, a second contact is achieved by etching the silicon and the Buried oxide of the original SOI wafer. In the structure, we admit different types and sizes (C) for the contacts that are displayed on Table 1. A schematic cross section of the structure of the diodes is represented on Figure 1.

III. Results and Discussion

At 303-353 K, electrical characterizations are done using B1500A Semiconductor Device Parameter Analyzer to extract the Temperature Coefficient of Current (TCC) : $TCC = \frac{1}{I}\frac{dI}{dT}$. Figure 2 presents these results at 303 K. The TCC has a similar evolution for all the diodes and is in agreement with previous works [2]. At 303 K and 0.6 V, it takes a value between 4.6 and 6.2 %/K. The Power Spectral Density (PSD) of the current noise S_i is measured using a Dynamic Signal Analyzer HP35670A. We observed that S_i is dominated by flicker noise (Figure 3) and proportional to I^k with 1< k < 1.66 (Figure 4). Our hypotheses are that the noise comes from the bulk and corresponds to different sources of noises (mobility fluctuations 1/f noise and generation-recombination noise) related to the epitaxial processes [5]. We calculate the thermal resolution (ΔT_{min}) of our diodes (K) : $\Delta T_{min} = \frac{i_n}{TCC\times I}$. i_n is the root mean square (RMS) current noire (in A) of S_i. At 303 K and an integration time τ_{int}= 60 µs, a ΔT_{min} between 2.10^{-3} and $5.10^{-2}\,K$ is found for currents at 10^{-9}-10^{-5} A (Figure 5). For the same current range and at 300 K, *Fournol et al.* found a ΔT_{min} between 6.10^{-4} and $5.10^{-3}\,K$ [2] and *Corcos et al.* between 8.10^{-3} and $5.10^{-2}\,K$ [3].

IV. Conclusion

Epitaxial p+pn+ short diodes were successfully fabricated and characterized at 303-353 K. The thermal resolution ΔT_{min} of the diodes were estimated. We obtain a value between 2.10^{-3} and $5.10^{-2}\,K$ for bias currents ranging from 10^{-9} to 10^{-5} A at 303 K. It shows promising performances for future microbolometers.

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Table 1 : Characteristics of studied diodes

Name	Z (µm)	C (µm)	Number of contacts
D1	1	0.5	1 x 1
D2	2	0.5	1 x 1
D3	6	0.5	1 x 1
D4	6	5.1	7 x 7
D5	10	9.1	12 x 12

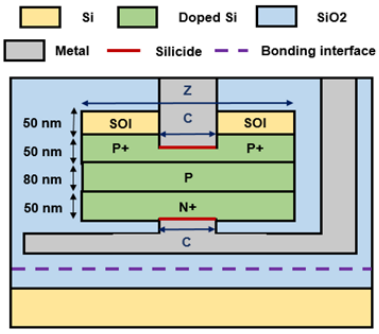

Figure 1 : Schematic cross section of the structure of the diodes.

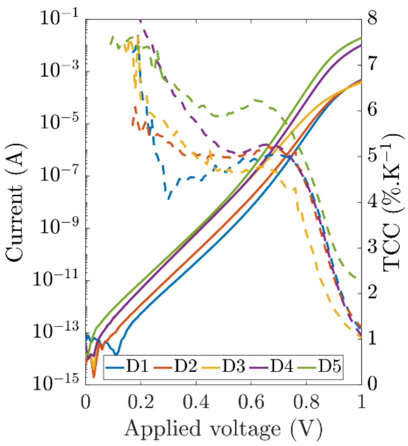

Figure 2 : IV characteristics (solid line) and TCC (dashed line) of the diodes as a function of the applied voltage at 303 K.

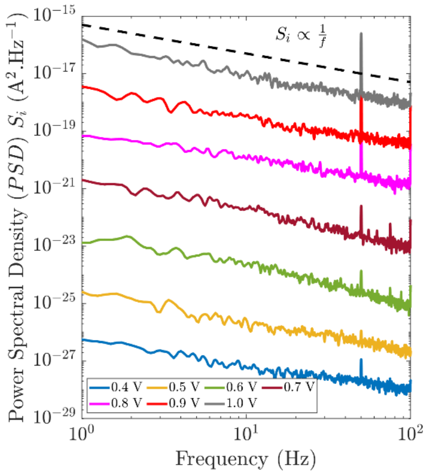

Figure 3 : PSD of the current noise (Si) of D1 for different applied voltages as a function of the frequency (Hz) at 303 K.

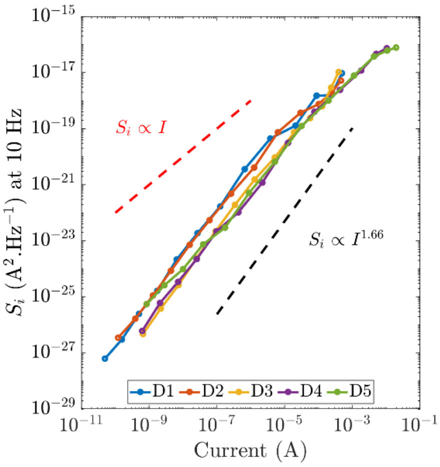

Figure 4 : PSD of the current noise (Si) as a function of the current (A) at 303 K and 10 Hz.

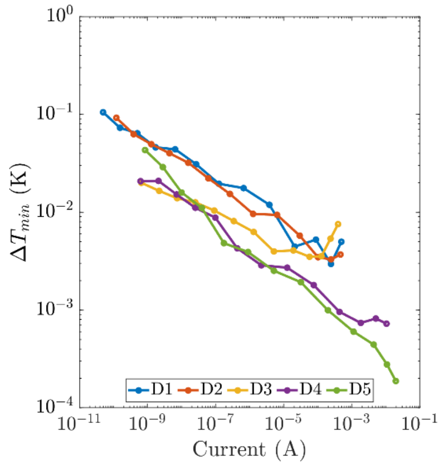

Figure 5 : The thermal resolution ΔTmin as a function of the current (A) at 303 K.