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A-9-1 (Invited) Uncooled Infrared Focal Plane Arrays Using Micromachining Technology

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1. Introduction

Benefited by micromachining technology, uncooled infrared focal plane array (FPA) technology has made remarkable progress in the last decade. Many applications that require long-life, small-size and low-cost infrared systems have emerged through the introduction of uncooled infrared cameras into the market. This paper reviews the role of micromachining technology in uncooled infrared FPA development and describes an uncooled infrared FPA which can be manufactured with a Si-LSI compatible process technology.

2. Micromachining for Uncooled Infrared FPAs

Figure 1 illustrates the operation of a thermal infrared detector used in uncooled infrared FPAs. Infrared rays are absorbed in the detector, which is thermally connected with a low thermal conductance to the heat sink (the substrate), causing a temperature rise (or a temperature fall) at the detector. A temperature sensor in the detector generates a signal according to the temperature or temperature change.

The responsivity of the thermal infrared detector is determined not only by the sensitivity of the temperature sensor but also by the thermal conductance of the link. Although the ultimate performance is determined by the fluctuation of heat transfer from the detector, current performance of uncooled FPAs is at a level far from this theoretical limit, and the noise equivalent temperature difference (NETD) is directly proportional to the thermal conductance. Surface micromachining technology has made it possible to achieve thermal conductances of around 1×10^{-7} W/K for uncooled infrared FPAs, and has brought about drastic improvement in performance. Using vanadium oxide (VO_x) as bolometer material, various micromachined FPAs have been successfully developed to date [1]. Such uncooled FPAs have achieved NETDs of less than 0.1 K with f/1 optics, which is ample performance for most commercial applications.

3. SOI Diode Uncooled Infrared FPA

Although microbolometer FPAs with VO_x have many attractive features when compared with early hybrid uncooled infrared FPAs, productivity is limited because VO_x is not used in current Si-LSI production lines. We have been developing an alternative technology that is fully compatible with the current Si-LSI [2]. Figure 2 shows the schematic illustrations of our pixel structure. In our pixel, forward-biased single-crystal pn diodes on a silicon on insulator (SOI) wafer are used as a temperature sensor. Thermal isolation is performed by the structure that contains the SOI diode sensor on the buried oxide suspended by two support legs. Since, for the structure shown in Fig. 2 (a), a fraction of incident light is absorbed at the detector, an infrared absorber that covers almost the entire pixel area is attached to the detector through several pillars. This structure offers the advantages of low noise, high uniformity, and large fill factor.

Figures 3 shows the micromachining process for the SOI diode uncooled infrared FPA. An amorphous Si film is used as a sacrifice layer so as to release the whole structure with a single etching step.

We have developed a 320 × 240 element uncooled infrared FPA using the technology described above. Specifications and performances of the developed FPA are summarized in Table 1. Examples of thermal images are shown in Fig 4.

4. Conclusions

Micromachining technology has been playing a crucial role in the uncooled infrared FPA field. Making the best use of this technology, we have developed a fully Si-compatible uncooled infrared FPA.

References

[1] M. Kimata, *Sensors Update* (ed. H. Baltes et al.), **4**, 53 (1998).
[2] T. Ishikawa et al., *Proc. SPIE*, **4130**, 152 (2000).

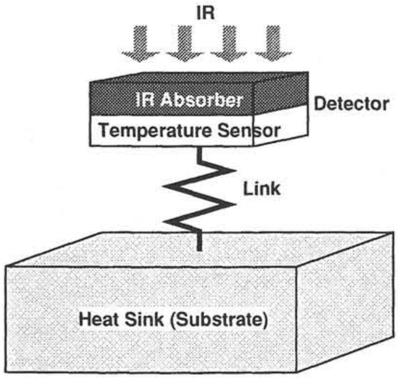

Fig. 1 Operation of thermal infrared detector.

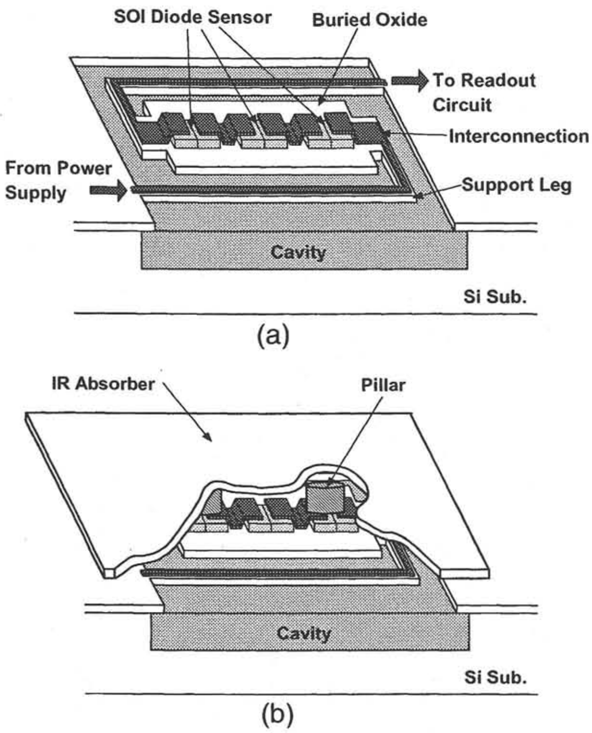

Fig. 2 Pixel structure of SOI diode uncooled infrared FPA, shown without (a) and with (b) IR absorber.

Table 1 Design specifications and performances.

Array Size	320 × 240
Temperature Sensor	Forward-biased SOI Diodes (×8)
Pixel Size	40 μm × 40 μm
Fill Factor	90%
Chip Size	17 mm × 17 mm
Spectral Band	8 – 12 μm
On-chip Amplifier	Gate Modulation Integrator
Si Process	1 Poly-Si and 2 Metal 0.5 μm CMOS
Micromachining Process	Single Step Surface and Bulk Process
Thermal Conductance	1×10^{-7} W/K
Thermal Time Constant	17 msec
Responsivity	930 μV/K @f/1, 300K
Noise	110 μVrms
NETD	0.12 K @f/1, 300K
Responsivity Nonuniformity	<0.2% (σ)

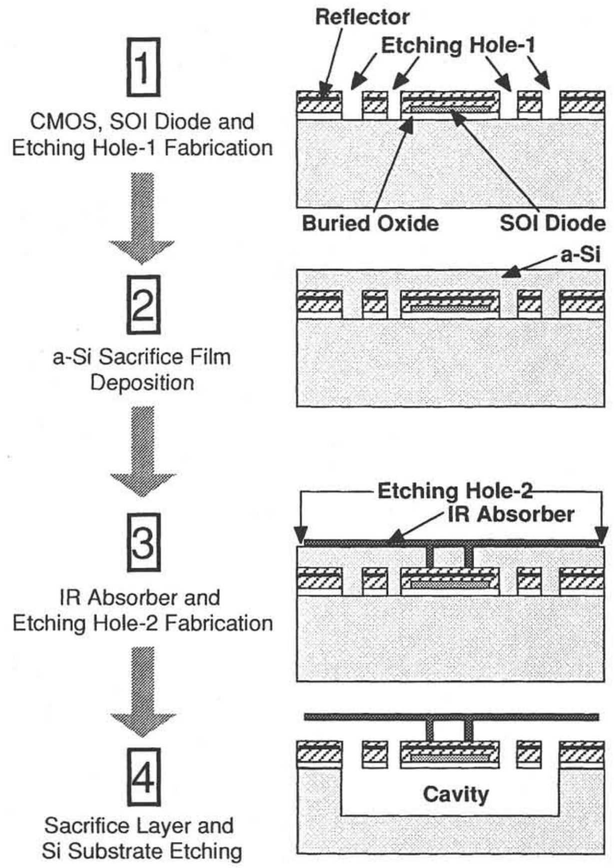

Fig. 3 Micromachining process for SOI diode uncooled infrared FPA.

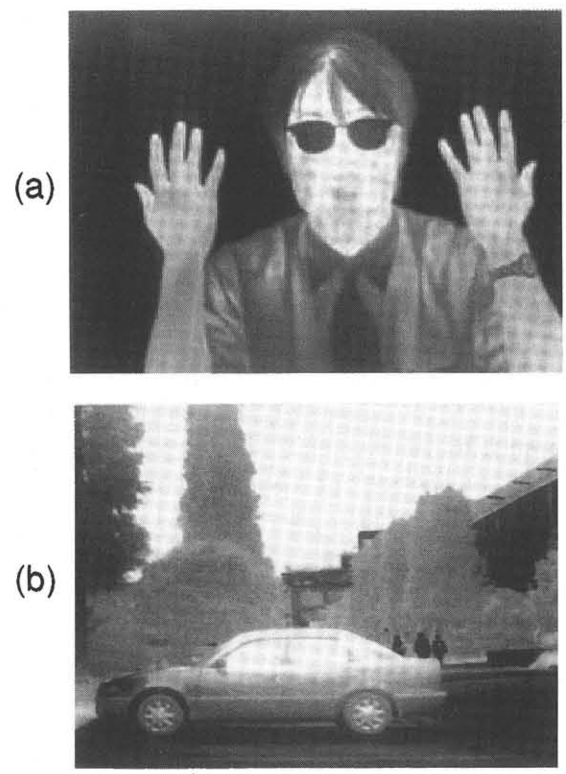

Fig. 4 Examples of thermal images with SOI diode uncooled infrared FPA. White is hot for (a), and black is hot for (b).