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Advances in Uncooled Focal Plane Arrays

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Abstract

An uncooled infrared focal plane array (IRFPA), which is a tool for night vision and thermography, is an integrated microelectromechanical systems (MEMS) device with thermal infrared detectors. Since uncooled IRFPAs are manufactured by Si-based technology and can be operated at room temperature, uncooled infrared cameras are available at affordable prices. Since the announcement of the first high-performance uncooled IRFPA in 1992, the technology has been progressing toward the theoretical performance limit. MEMS technology has been contributing to uncooled IRFPA development by enabling high thermal isolated structures. Although various MEMS-based uncooled IRFPAs have already been proposed, only two continue to prosper: resistance bolometer and silicon on insulator (SOI) diode uncooled IRFPAs. In these devices, the pixel pitch is reduced to near the diffraction limit of optics and the spatial resolution is increased to a level compatible with high vision. Thus, the technology is approaching a plateau phase and attention is now directed toward business expansion. Although the market size for uncooled IRFPAs today is relatively small, considerable growth is predicted over the next few years and is expected to increase to 6.5 million units in 2025. In this paper, the evolution of microbolometer and SOI diode uncooled IRFPAs is explained in connection with thermal conductance reduction using MEMS technology. Technologies for cost reduction and some promising applications are also introduced.

1. Introduction

Advances in infrared focal plane arrays (IRFPAs) have been contributing to thermography technology by enhancing temperature and spatial resolutions. Although cooled IRFPAs are used for applications in which extremely high sensitivity and high frame rate are indispensable, uncooled IRFPAs are available for a wide range of thermography applications. The pixel pitch and spatial resolution of uncooled IRFPAs have reached 12 µm and full high-definition levels, respectively. In parallel with performance improvement, remarkable cost reduction is also proceeding. This paper discusses the evolution of uncooled IRFPAs and technologies for cost reduction, and introduces some promising applications.

2. MEMS-based uncooled IRFPA technology

Uncooled IRFPAs detect infrared rays by thermal detectors, which convert the infrared energy into thermal energy and detect infrared rays as the temperature changes. The introduction of MEMS (microelectromechanical systems) technology plays an important role in enhancing the responsivity of uncooled IRFPAs by reducing the thermal conductance between the detector structure and the substrate.

After the successful demonstration of a high-performance MEMS-based uncooled IRFPA with a resistance bolometer (microbolometer) in 1992 [1], uncooled IRFPA technologies have been developed with various temperature-sensing methods [2], such as thin-film pyroelectric, bi-material, thermo-optical, and diode bolometer, as alternative technologies to the microbolometer. Although most emerging technologies have already been abandoned, diode bolometer on an SOI (silicon on insulator) substrate (SOI diode) technology [3] survives. Figure 1 shows two successful pixel structures: microbolometer and SOI diode pixels. The thin and narrow support legs in both structures effectively reduce the thermal conductance between the freestanding detector structure and the substrate.

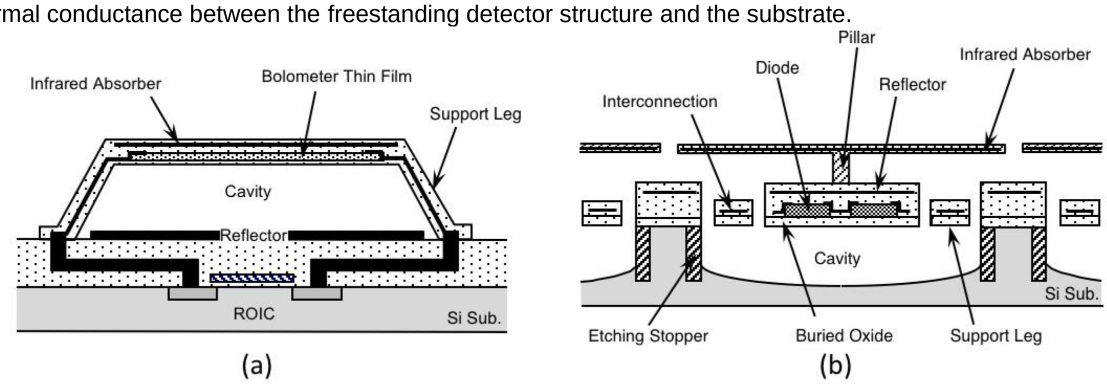

Fig. 1: *Pixel structures of microbolometer (a) and SOI diode (b).*

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3. Advances in uncooled IRFPAs

Pixel-pitch reduction contributes to higher spatial resolution, cost reduction of IRFPAs, and miniaturization of infrared cameras. Pixel size has been reduced from 50 µm to 12 µm in the past 20 years [4]. In spite of about a 1/20 reduction in the pixel area, new-generation devices with smaller pixel pitches have the same NETD (noise equivalent temperature difference) as the previous generation by reducing the thermal conductance. Figure 2 summarizes the relationship between the pixel pitch and thermal conductance for reported uncooled IRFPAs [5]. The trend shows that the thermal conductance is proportional to the 2.7 power of the pixel pitch, which means that the pixel area reduction is fully compensated by the thermal conductance reduction with advanced MEMS technologies.

The pixel-pitch reduction enables larger integration of pixels to obtain higher spatial integration. Uncooled IRFPAs with a full high-definition format are already available [6]. Smaller pixel-pitch technology is also applied to smaller format IRFPAs with around 10-k pixels. Thermography cameras using such small-format IRFPAs are selling at prices lower than 1,000 dollars. Cost lowering of uncooled IRFPA production is accelerating also by introducing wafer-level vacuum packaging technology, integrated ROIC (readout integrated circuit)/MEMS wafer process, and enlarging wafer size.

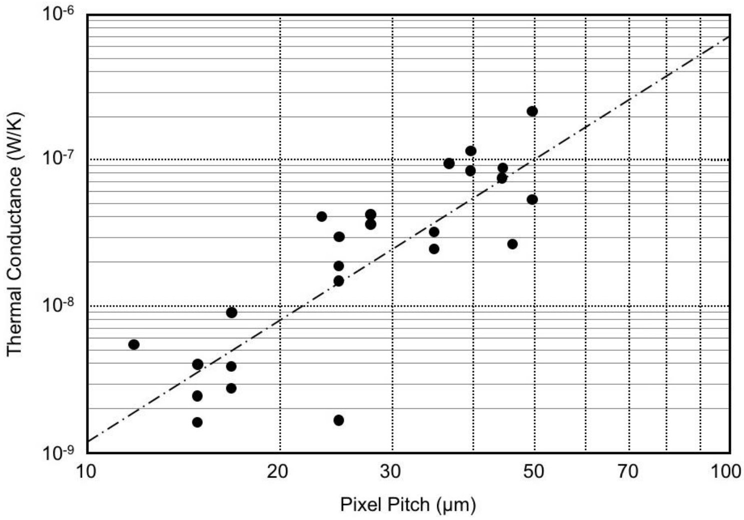

Fig. 2: *Reduction of thermal conductance in pixel-size reduction [5].*

4. Expansion of IR imaging business

Techno Systems Research forecasted that the shipment number of uncooled infrared cameras will increase from 1 M units in 2018 to 6.5 M units in 2025 [7]. This forecast is far beyond the trends of past increases. Although traditional infrared imaging applications such as predictive maintenance, industrial measurement, security, and research will retain a large share in the revenue, night vision systems for automobiles and infrared cameras for PDAs (personal digital assistants) drives this shipment number in the infrared imaging market. Since these growing applications are very cost sensitive, much more reduction in cost can be expected. Enlarging the total infrared imaging is believed to have positive effects on traditional application fields as well.

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