Advanced techniques improve life of IR detectors

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Vacuum monitoring with novel pressure sensors enhances long-term stability and calibration in uncooled, mid-IR detector assays.

Packaging is one of the most costly steps of manufacturing microdevices such as microelectromechanical and micro-optoelectromechanical systems (MEMS/MOEMS). It needs to protect the device, permit necessary interactions with the environment, ensure reliability, and support optimum performance. However, packaging is often neglected in the early stages of new microdevice design, leading to cost increases in the final item. To develop a viable product, both the device and the package should be designed as a whole, including the sensors for calibrations during its lifetime.

Uncooled IR microbolometers require a vacuum atmosphere below 10mTorr to operate at their highest sensitivity. The bolometer response depends on the scene temperature as well as the package’s internal pressure and temperature. To minimize cost, real estate, and power consumption, temperature stabilization is typically not provided to the packaging. Hence, long-term, high-sensitivity operation of IR bolometers requires calibration of in-package pressure and temperature. A low-cost, accurate means to measure pressure without being affected by the operating temperature is needed.

We have developed a low-cost, low-temperature hybrid vacuum micropackaging technology for microbolometer detector arrays (see Figure 1).1–3 Diced windows of material selected based on the wavelength range of interest and using known good microbolometer dies are bonded to a ceramic frame wafer that provides for window openings and evacuation ports. A typical material is antireflection-coated silicon float zone for the 8–12 μm spectral window. Assembly is performed using low-cost, typical integrated-circuit packaging equipment in a standard clean-room atmosphere. The microcavities are subsequently sealed in vacuum after an evacuation step at a pressure of approximately 10−6 Torr. Our micropackaging approach, which we call ‘chip-to-wafer’ assembly or hybrid micropackaging, reduces cost because of minimal use of expensive antireflection-coated IR-transmitting window material, assembly of only known good dies, and the use of standard, low-cost packaging equipment. Furthermore, the separation of the assembly and sealing steps obtains one of the lowest base pressures reported in the literature (less than 10mTorr) without needing expensive getter materials to remove traces of gas that are commonly used in other vacuum-packaging techniques. An equivalent leak rate of 4×10−14 Torr L/s for storage at 80°C was obtained without getter. Even with such a low flow, the long-term stabilization of residual pressure variations affects the IR bolometer’s sensitivity and calibration. We have developed temperature-insensitive MEMS pressure sensors that allow real-time measurement of package pressure above 1mTorr. The pressure sensors can be integrated with IR bolometers in a

Figure 1. The micropackage dimensions dictated by the chip size are 9.7×10.5×2.3mm³. The package cavity, with a volume of 60μL, is made of a 1mm-thick, laser-machined ceramic spacer bonded on one side to the MEMS chip and on the other to an antireflection-coated, silicon IR window. Hermetic solder seals ensure vacuum integrity.

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Figure 2. Scanning-electron-microscope image of the bolometric pressure sensor. The suspended platform supporting the vanadium oxide-coated thermistor is at the center. The supporting arms are serpentine-shaped to minimize thermal conduction from the suspended platform to the substrate. The rising pillars provide the electrical connection to the reading circuit and lift the platform approximately 2.5\(\mu\)m above the substrate.

die-level packaging process or microfabricated simultaneously on the same die.

The pressure sensors are located in a suspended-platform thermistor device that operates as a Pirani pressure gauge. A scanning-electron-microscope image of the sensor is shown in Figure 2. When the thermistor is electrically excited and heated, its temperature at equilibrium is a function of applied electrical power and of thermal transfer to the environment. The gas is part of this environment. The heat transferred from the thermistor to the environment is a function of the gas pressure, which is measured by heating the device using electrical excitation, measuring the temperature of the thermistor’s suspended platform, and estimating the thermal conduction to the gas. The gas pressure is estimated from the thermal conduction after proper calibration. The design of the pressure sensor is optimized to ensure that thermal conduction is dominant over other pressure-independent thermal effects. This has the advantage of maximizing the sensor sensitivity, and allows measurement of pressures as low as 1mTorr with less than 10% uncertainty, improving to \(\pm 2\)% above 7mTorr. The suspended platform is covered by vanadium oxide, which acts as thermistor and allows precise measurement of the temperature. The vanadium oxide is compatible with our IR microbolometer’s microfabrication. It has received attention as a thermally sensitive layer material because of its large temperature coefficient of resistance as high as 2\% per degree Kelvin near 20\({}^\circ\)C. The pressure-sensor reading method is important to minimize the dependence of pressure measurement on environmental-temperature variations. An innovative reading method provides a pressure measurement dependent on environment temperature as low as 0.7\%\(/{ }^\circ\)C. Complex reading-circuit or temperature control of the packages are not required, making the pressure sensor well adapted for low-cost, high-volume production and integration with IR bolometer arrays.

In conclusion, the long-term stability of MOEMS sensors and low-temperature micropackaging techniques open the way to exciting space-based and terrestrial applications, such as compact and low-cost IR and terahertz imaging for defense and security systems. We are currently developing low-temperature-compatible high-efficiency getters for further improvement of the lifetime of our micropackages for IR detectors. We expect that the pressure inside the microcavities will be maintained below 10mTorr during the device lifetime (typically 10 years).

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References