Multispectral plasmonic perfect absorbers integrated with room-temperature VO_x air-bridge bolometers

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***Abstract*— Room-temperature microbolometer arrays with sensitivity in narrow wavelength bands for spectral imaging in the mid-wave and long-wave infrared are described. The approach is based on vanadium-oxide air-bridge bolometers that are integrated with plasmonic resonant absorbers to maintain response speed without adding processing complexity.**

Keywords—infrared, bolometer, MEMS, vanadium oxide

I. Introduction

Usual infrared detectors are only crudely wavelength selective by being designed for broad atmospheric transparency windows. These are the Mid-Wave IR (MWIR) and Long-Wave IR (LWIR) bands, corresponding to 3-5 and 8-12 μm wavelengths, respectively. The MWIR is of interest for imaging hot targets, such as engines and rocket plumes. The LWIR is valuable for night-vision and imaging of targets closer to ambient temperature, such as humans.

Currently marketed uncooled LWIR detectors include a VO_x microbolometer with 17 μm pitch, 30 mK NETD, and a 10 ms response time [1]. The D* value is well into the 10^9 √Hz/W range. State-of-the-art is 12 μm pitch with a 40 mK NETD and 10 ms response time [1]. Cheap (~$250) low-resolution, wafer-level-packaged FPAs are available from a catalog (FLIR Lepton, Seek Camera). At the other end are expensive high-definition cameras, where costs are mainly driven by the large fast optics rather than by the FPA. Achieved absorptance is near unity for these microbolometers across the LWIR, and speed-responsivity trade-off is nearly optimized. Further pitch reduction is expected, to 10 μm, and NETD may be reduced to 10 mK using doped-polycrystalline VO_2. This will result in detectors that are nearly thermal-fluctuation-noise limited, as opposed to the present situation where Johnson noise dominates. Then the detectors will have reached fundamental theoretical limits for microbolometers (~D* = 10^{10} √Hz/W), where further R&D aimed at improving standard figures of merit will experience strongly diminished returns.

Microbolometers in their current form have sufficient sensitivity for 90% of the existing applications. Large companies (DRS, Raytheon Vision Systems, FLIR, and Northrop Grumman) dominate that market. For small companies and academic research, it is still worth exploring niche applications. One such possible application is spectral sensing, where narrow-band wavelength selectivity is integrated directly into the detector. An opportunity is to distinguish targets based on subtle differences in emissivity spectrum, which can arise due to the effects of sharp molecular absorption features. For instance, it may be possible to identify factories based on spectral emission from waste gases. To perform such spectral discrimination now would require considerable fore-optics and spectroscopic instrumentation, such as gratings or interferometers.

II. Methods

An opportunity is integration of selective absorbers with microbolometers [2,3]. As selective absorbers, we consider plasmonic resonators, in which sharp strong absorption bands are created at design-tunable wavelengths using subwavelength metal and dielectric structures. The specific thermal infrared detectors considered are air-bridge microbolometers fabricated from semiconducting vanadium oxide VO_x, which has a high temperature coefficient of resistance (TCR).

The resonant absorbers comprise metal squares on dielectric on metal ground plane, where all dimensions are sub-wavelength. The optical properties of such structured films have been the subject of intense fundamental research by AFRL, ourselves (e.g. [4-8]), and others. The operational wavelength is design tunable. For the same small dielectric thickness, the resonant wavelength is roughly proportional to the dimension of

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the metal square. The precise wavelength depends also on dielectric thickness, and the selectivity is degraded if there is strong dielectric dispersion [7,8].

The resonators add thermal mass that can noticeably slow the bolometer response [3]. This paper reports progress on a design that integrates the plasmonic absorber into the bolometer to minimize both mass and processing complexity [2]. Materials were chosen to facilitate processing and to avoid dielectric dispersion at the operating wavelengths.

III. RESULTS

Fig. 1 presents an optical microscope image a VO_x air-bridge bolometer, which is the central 40 μm x 40 μm square connected by conducting arms to bond pads outside the frame. The region surrounding the bolometer is bare silicon, which will be isotropically etched to undercut the bolometer and create an air bridge. The patterned top-layer of an integrated subwavelength pattern of IR absorbing structures is observed as the small squares on top of the bolometer.

Fig. 2 presents a scanning electron microscope (SEM) image of fully undercut and released bolometers. These were prepared without the resonant structures for comparison.

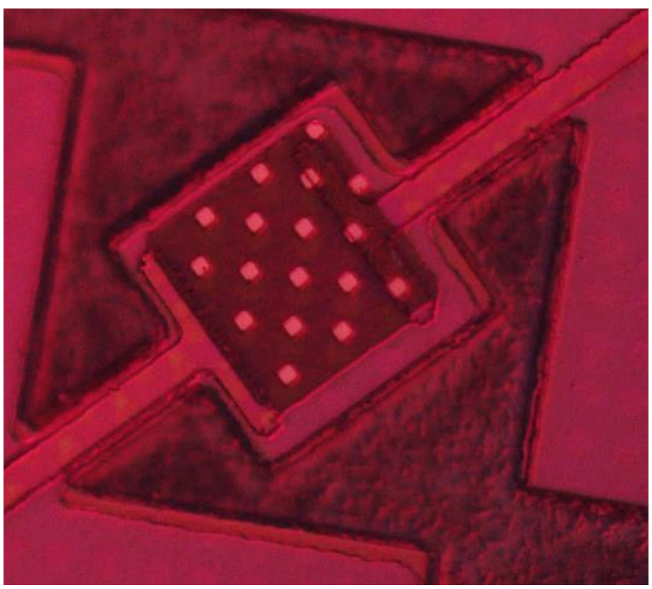

Fig. 1. Optical image of bolometer before undercut etch. Patterned resonant absorber structures on top of the VO_x active region.

IV. DISCUSSION

Bolometers have been completed with different absorber patterns to give different spectral response. Test results, including spectral photoresponse, speed, and noise measurements are underway. Results will be presented pending approval by AFRL.

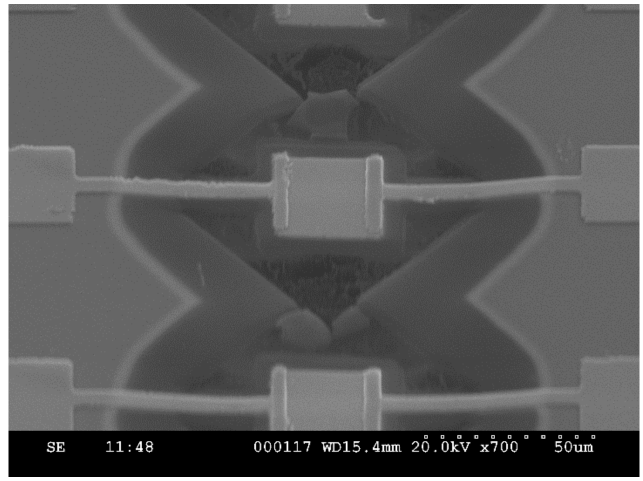

Fig. 2. SEM image of released air-bridge bolometers after undercut etch.

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