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Characterization of uncooled bolometer with vanadium tungsten oxide infrared active layer

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Abstract

A surface micromachining uncooled infrared detector with an optimized vanadium alloy oxide layer is fabricated, based on low temperature annealing of V–W alloy oxide layer. Vanadium oxide is a promising material for an uncooled bolometer, due to its high temperature coefficient of resistance at room temperature. An infrared active layer is needed to be with the reflective layer to enhance its IR absorption.

Test bolometers are successfully fabricated and then are radiated by an IR laser source at various power levels with a chopper in a frequency range of 1–500 Hz. The responsivity and the noise of the test bolometer are measured and the detectivity is calculated. From the results, the calculated detectivity is 1.1×10^7 cm Hz$^{1/2}$ W^{-1}. Bolometer detectivity can be increased further if the noise in the device is reduced.

Keywords: Uncooled bolometer; Vanadium oxide; Vanadium tungsten oxide; Detectivity; Micromachining

1. Introduction

Uncooled infrared (IR) detectors have been developed with tremendous efforts in recent years due to many military and civilian applications such as thermal cameras, night vision cameras, thermal sensors, surveillance, etc. The IR detectors are generally divided into two types: photon detectors and thermal detectors. The photon detectors have high signal to noise ratio and very fast response. However, the photon detectors require cryogenic cooling system, which is very bulky, heavy and expensive. The recent advances in micromachining technology allow fabricating sensitive thermal detectors. The thermal detectors are operated at room temperature without the need of the cooling system. This offers decrease in power consumption and system cost, which makes it possible to apply for the hand-held infrared camera applications.

Methods of making thermal detectors are based on three common approaches, namely, bolometers, pyroelectric and thermoelectric effects. A bolometer employs a characteristic of thermal sensitive layer as it changes its sheet resistance according to the change of the temperature (the larger the resistance change, the higher the temperature coefficient of resistance (TCR), so the higher of sensitivity). Many materials have been used for IR active layer of bolometer such as metals (Au, Pt, Ti, etc.) [1,2], semiconductors (VO_x, amorphous silicon, etc.) [3,4]. Semiconductor active layers show higher TCR (5–10 times) compared to that of metals.

In the past, many papers reported the use of vanadium oxide [3,5,6] as IR active layer for bolometers including methods of deposition, condition for annealing. This is the first time we used new vanadium alloy oxide to fabricate bolometers. Even though, the new material is yet to have higher performance characteristics compared with vanadium oxide layer, its low cost processing and high TCR promotes a good opportunity to be a competitive material for uncooled infrared detectors.

In this paper, bolometers were fabricated using new IR sensitive V–W–O layer. Devices were then measured bolometer figure of merits. Test devices show the maximum detectivity of 1.1×10^7 cm Hz$^{1/2}$ W^{-1}.

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2. Background theory

Performance levels of bolometers are expressed in terms of device figure of merits such as responsivity (R_v), noise equivalent power (NEP), detectivity (D^*), and temperature coefficient of resistance [7]. Responsivity represents the amount of output signal per unit of input radiant power:

$$R_v = \frac{S}{EA_d} \tag{1}$$

where S is the signal measured at the output of the amplifier, E is IR radiation intensity, and A_d is device active area.

NEP is the IR radiation power generating a signal output equal to the rms noise output (signal to noise ratio (SNR) equal to 1):

$$\text{NEP} = \frac{\overline{Vn}}{R_v} \tag{2}$$

Detectivity (D^*) is defined as the SNR normalized with respect to noise bandwidth and detector active area:

$$D^* = \frac{\sqrt{A_d \Delta f}}{\text{NEP}} = \frac{R_v\sqrt{A_d \Delta f}}{\overline{Vn}} \tag{3}$$

The thermal time constant τ is the ratio of thermal capacitance C to thermal conductance G of the device, written as:

$$\tau = \frac{C}{G} \tag{4}$$

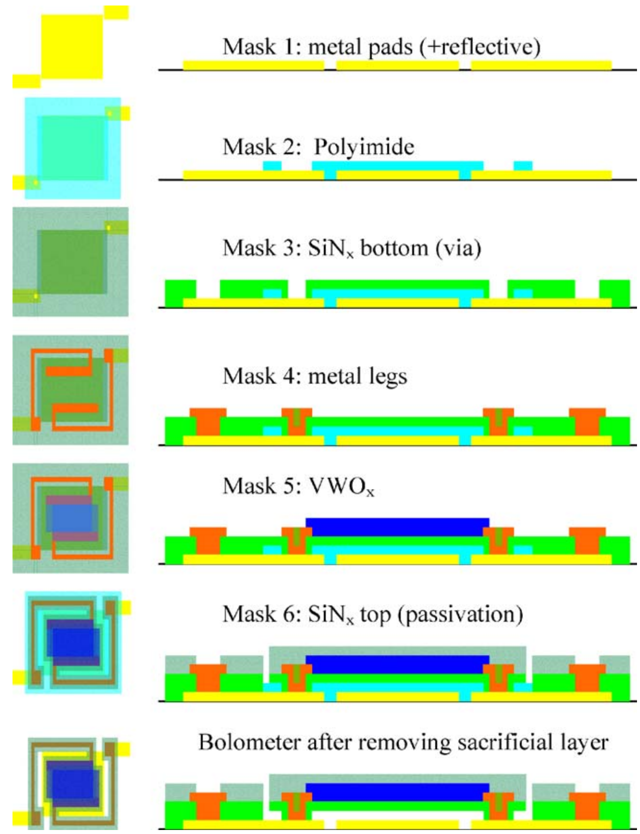

Fig. 1. Fabrication steps of a bolometer.

3. Device fabrication

Test bolometers are fabricated with a device size of 70 μm × 70 μm, which has a fill factor of 49%. Bolometers are built on silicon substrate based on MEMS surface micromachining technology. The sacrificial layer is PI2610, which is an HD microsystems' polyimide. The bolometer structure is based on the suspended microbridge-style, which is to provide thermal isolation for the uncooled infrared detectors. Bolometer fabrication steps are outlined on Fig. 1. And a scanning electron microscope (SEM) picture of the bolometer is shown in Fig. 2.

A metal pad layer of Cr/Au with a thickness of 200/1200 Å is sputtered on a LPCVD nitride-coated silicon wafer. Patterns are prepared by utilizing wet etching for electrical connections and reflective mirrors. A thin polyimide PI2610 layer is spin coated and cured in an oven at 300 °C for 30 min, which finally gives polyimide a thickness about 2.3 μm. RIE using CF_4 and O_2 gas mixtures with thick resist AZ9260 as a mask is used to pattern the polyimide layer.

A 3000 Å thick supporting layer of silicon nitride (SiN_x) is PECVD deposited. Vias are opened for electrical contacts, followed by 1000 Å of Cr layer and 200 Å of gold layer. These layers are used for the electrical contact for an IR sensitive layer, vanadium tungsten oxide (VWO_x). A 400 Å thin layer of VW alloy is deposited by a conventional RF sputter. This

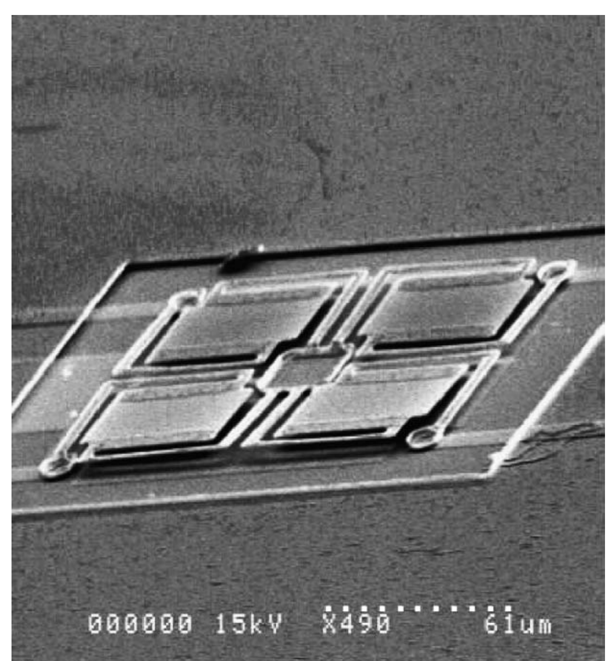

Fig. 2. Scanning electron microscope (SEM) image of fabricated bolometers.