ACKNOWLEDGMENTS

This work is supported partially by the Young Scholar Foundation of Nanjing University of Science & Technology, the Excellent Young Teachers Program of Moe, PRC, and the Natural Science Foundation of China under contract no. 60271005.

REFERENCES


© 2003 Wiley Periodicals, Inc.

ANTENNA-COUPLED VOx THIN-FILM MICROBOLOMETER ARRAY

F. J. González, M. Abdel-Rahman, and G. D. Boreman
School of Optics/COREL
University of Central Florida
4000 Central Florida Blvd.
Orlando, FL 32816-2700

Received 17 January 2003

ABSTRACT: Two-dimensional arrays of log-periodic antenna-coupled microbolometers were fabricated using VOx and Nb thin films as bolometric materials, which have different temperature coefficients of resistance. Noise, response, and angular characteristics of both types of microbolometer arrays were measured and compared. VOx-based devices presented a 4.5× better response and 5.5× better signal-to-noise ratio than Nb-based devices. Radiation patterns show that a further increase in response can be obtained by better matching the VOx bolometer to the antenna elements. © 2003 Wiley Periodicals, Inc. Microwave Opt Technol Lett 38: 235–237, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.11024

Key words: microbolometer; vanadium oxide; antenna-coupled detectors

1. INTRODUCTION

Two-dimensional arrays of antenna-coupled microbolometers are used as fast infrared detectors that can be integrated into commercial readout integrated circuits (ROICs) [1], however, their measured responsivity is lower than the required for commercial infrared imaging applications [2]. The voltage responsivity of a bolometer is given by [3]:

\[ R = \alpha \cdot |Z_{\text{bias}}| \cdot V_{\text{bias}} \]  

where \( \alpha \) is the temperature coefficient of resistance of the bolometer, \( V_{\text{bias}} \) is the dc bias voltage across the device, and \( Z_{\text{bias}} \) is the thermal impedance of the device. The temperature coefficient of resistance (TCR) is the material parameter used to quantify the temperature \( T \) dependence of the resistance \( R \) of the material and is defined as

\[ \alpha = \frac{1}{R} \frac{dR}{dT}. \]

As we can see form Eq. (1), the TCR of the bolometric material is directly proportional to the responsivity of the detector; therefore, the choice of the thin-film heat-sensitive material is an important factor in achieving good response from the microbolometers. A thin films of sputtered Nb, which has a TCR close to 0.003 K⁻¹, was used as bolometric material in [1]. Vanadium is a metal with a variable valence forming a large number of oxides which have a very narrow range of stability [4], films of vanadium oxide (VOx) consisting of a mixture of various oxides present a TCR \( \approx 0.02 \) K⁻¹ and have been used in the past to fabricate microbolometers [5]. Films of stoichiometric VO₂ with TCRs greater than 0.05 K⁻¹ and a more involved deposition process have also been reported [6]. In this paper the performance of a VOx-based antenna-coupled microbolometer is evaluated and compared to a Nb-based device.

2. METHOD

Two-dimensional arrays of log-periodic-antenna-coupled microbolometers with a 50 μm \( \times \) 50 μm pixel area were used in this study.
at 12 kHz, while the VOx-based devices presented a
response, and angular measurements were made on both sets of
antenna coupled detectors

The response of the antenna arrays to 10.6
m and an irradiance of 25 W/cm² at the focus. Noise,
response, and angular measurements were made on both sets of
wafers using the procedure described in [1].

The 2D arrays of microbolometers presented an average dc
resistance of 1.2 ± 0.1 kΩ for the Nb-based detectors and 450 ±
500 for the VOx detectors. The measurements were made at a bias
voltage of 300 mV.

3. RESULTS

The response of the antenna arrays to 10.6 μm radiation was
measured, and the Nb-based detectors gave a polarization depen-
dent signal of 5.1 ± 1 μV while the measured response of the
VOx-based devices was 22.5 ± 2.5 μV, which corresponds to a
4.5× increase in response. Figure 2 shows the noise frequency
spectrum measured with an HP3585B spectrum analyzer. The
Nb-based devices had a noise voltage spectrum of 54.3 ± 2.7
nV/√Hz at 12 kHz, while the VOx-based devices presented a
noise voltage spectrum of 44.3 ± 2.0 nV/√Hz at the same
frequency. This represents a 5.5× increase in signal-to-noise ratio
of the VOx-based devices over the Nb-based ones.

Figure 3 shows the measured angular patterns of the Nb-
based devices and the VOx based devices, the radiation char-
acteristics for similar antenna array configurations show that the
impedance at the feed does alter the electromagnetic character-
ts of the antenna array; in this particular case, the Nb-based
array presents a more directive pattern than the VOx-based
detector, which indicates that the impedance of the Nb patch is
better match for the individual log-periodic elements of the
array. The thickness of the VOx bolometer can be varied to
better match its impedance to the antenna elements and obtain
a further increase in response.

4. CONCLUSIONS

We have measured the response, noise, and radiation patterns of
Nb-based and VOx-based 2D arrays of log-periodic antenna-cou-
ded microbolometers. The VOx-based devices present a response
4.5× higher and a 5.5× better signal-to-noise ratio than the
Nb-based devices. Measured radiation patterns showed that the
gain in response and in signal-to-noise ratio can be further in-
creased by better matching the impedance of the bolometric de-
tector to the antenna elements, which would yield an increase in
response closer to the 5–10× expected due to the better TCR of
VOx as compared to Nb thin films.

ACKNOWLEDGMENTS

This work was performed in part at the Cornell Nanofabrication
Facility (a member of the National Nanofabrication Users Net-
work) which is supported by the National Science Foundation
under Grant ECS-9731293, its users, Cornell University and In-
dustrial Affiliates.

This material is based upon research supported by NASA grant
no. NAG5-1308.

REFERENCES

1. F.J. González, M.A. Gritz, C. Fumeaux, and G.D. Boreman, Two
dimensional array of antenna-coupled microbolometers, Int J Infrared
and Millimeter Waves 23 (2002), 785–797.
2. S. Sedky, P. Fiorini, K. Baert, L. Hermans, and R. Mertens, Character-
ization and optimization of infrared poly SiGe bolometers, IEEE Trans
Electron Devices 46 (1999), 675–682.
impedance model of electrostatic discharge effects on microbolometers,
4. H. Jerominek, F. Picard, and V. Denis, Vanadium Oxide films for
Abstract: This paper presents magPEEC, a new 3D electromagnatic modeling technique that extends the existing PEEC approach to analyze arbitrary conductor-magnet structures by accounting for fictitious magnetized currents on a magnetic material surface. Applications for magnetic-cored/layered spiral inductors demonstrate validity and accuracy of magPEEC. Possible solutions to improve RF IC inductors using magnetic cores are discussed. © 2003 Wiley Periodicals, Inc.

1. Introduction
Nowadays, magnetic materials have been widely used to make electro-magnetic (EM) devices such as micro electro mechanical systems (MEMS) and on-chip spiral inductors for RF IC applications to improve inductance and quality factor. Inductors using magnetic films operated at multi-GHz frequency have been reported [1]. It is impractical to analyze these structures with magnetic films or cores by using existing full-wave approaches, such as finite-difference or finite-element methods, due to their computational deficiency. The simulation approaches given in [2] and [3] have limited applications due to their 2D nature. A new simulation program called Fastmag, was reported in [4], which can only deal with structures with magnetic materials separated from electrical conductors and is not suitable for true 3D structure simulation due to the equivalent loop-structure mesh cell used. PEEC approach was firstly proposed to model 3D multi-conductor systems in [5], which was later extended to include dielectrics [6]. The PEEC method allows for calculations being reduced to static calculations by neglecting retardation, while still maintaining high accuracy analogous to the full-wave methods [6]. This paper presents a new modeling technique, called magPEEC, which extends the PEEC approach to analyze arbitrary 3D electro-magnetic structures that permits conductors to be outside, touching or inside magnetic materials—a desired feature for modeling many sophisticated electro-magnetic structures.

2. magPEEC: Magnetic Materials Included
For an arbitrary 3D EM structure with conductors and magnetic materials, currents are distributed in three regions, that is, conductor bodies carrying bulk currents outside magnetic materials (denoted as region α), conductor-magnet interface carrying surface currents (denoted as region β), and magnetic surfaces carrying surface currents without contacting conductors (denoted as regions γ). By using fictitious magnetized currents on a magnetic material surface, the magnetic problem is equivalent to the free-space problem. The real conductive currents and fictitious magnetic current densities at a point i are denoted as $\mathbf{J}_i(\mathbf{r})$ and $\mathbf{J}_i^m(\mathbf{r})$, respectively. The total equivalent current density denoted as $\mathbf{J}_i$ is based on the equation $\mathbf{J}_i = \mathbf{J}_i(\mathbf{r}) + \mathbf{J}_i^m(\mathbf{r})$. For each mesh cell mentioned in this paper, the total through currents through it due to $\mathbf{J}_i$, $\mathbf{J}_i^m$, and $\mathbf{J}_i$ are denoted as $I_i$, $I_i^m$, and $I_i$, respectively.

Region α is discretized into $N_x$ filament cells, as shown in Figure 1(a). Related parameters for the $i^{th}$ filament cell include current flowing direction $\mathbf{n}_i$, through electrical voltage $V_i$, filament bulk $B_i$, current crossing area $A_i$, and current flowing length $D_i$. Regions β and γ are discretized into $N_y$ and $N_z$ panel cells, respectively, as shown in Figure 1(b). Related parameters for the $i^{th}$ panel cell in region $x$ (with $x = \beta, \gamma$) include current flowing direction $\mathbf{n}_i$, panel’s normal direction $\mathbf{n}_i$, through electrical voltage $V_i$, panel area $S_i$, surface current crossing width $W_i$, and current flowing length $D_i$. For convenience, the normal direction is defined as pointing from b side to a side of the panel, as shown in Figure 1(b). $\mu_n^\beta(\mathbf{r})$ and $\mu_n^\gamma(\mathbf{r})$ are the permeabilities of both sides, with $\mu_n^\beta(\mathbf{r})$ and $\mu_n^\gamma(\mathbf{r})$ the corresponding relative permeabilities. Current densities over these cells all are assumed locally constant.

Analogous to problems of currents distributed in free space, the magnetic vector potential is obtained as follows: