Fabrication of Antenna-Coupled Metal-Oxide-Metal Diode Thermal Infrared Detectors Using In-Situ Oxidation

Badri Tiwari[a], Gergo Szákmany, Jeffrey Bean, Gary H. Bernstein, Patrick Fay, and Wolfgang Porod

Center for Nano Science and Technology, Department of Electrical Engineering, University of Notre Dame, Notre Dame, IN 46556 USA

We report the fabrication of antenna-coupled metal-oxide-metal diodes (ACMOMDs) that detect long-wavelength[1] infrared (LWIR) radiation. These sensors are designed to detect LWIR radiation for uncooled thermal imaging applications. These devices consist of a half-wavelength dipole antenna and a nonlinear junction, which is a metal-oxide-metal (MOM) diode in this case. The antenna captures LWIR radiation and the resultant antenna currents are rectified using the asymmetric-barrier MOM diode. These detectors operate at room temperature without cooling or biasing, have a small footprint of 10 μm x 10 μm, and offer CMOS compatible fabrication.

We have previously reported a type of ACMOMD that was fabricated using a single electron beam lithography (EBL) step[2]. However, the Al/AlO_x/Pt ACMOMDs presented in this work are fabricated with two separate EBL steps and an intermediate oxide-processing step. This new approach allows for additional degrees of freedom in the device design that are not possible with a single-step EBL device such as the modification of device geometry and ability to consider a wider array of metal and insulator materials. Each EBL process is followed by metallization in an electron beam evaporator and a liftoff process. Al is used to define one antenna arm, while Pt defines the other half of the antenna. The overlap between the Al and Pt lines is separated by AlO_x, of thickness ~20 Å, which forms the MOM diode tunnel barrier. The composition and tunneling properties of the native oxide of Al, which grows after the aluminum metallization, is dependent upon ambient laboratory conditions and hence difficult to control. Therefore, a Kaufman ion-source is used to remove this unwanted AlO_x and then the oxide is regrown through an in-situ controlled-oxidation process. An electron micrograph of a fabricated device is shown in Figure 1.

Current-voltage (I-V) and infrared (IR) measurements have been performed to characterize these ACMOMDs. A 10.6 μm CO_2 laser was used for IR characterization. The polarization-dependent IR response of an Al/AlO_x/Pt device is shown in Figure 2; the expected cosine-squared antenna response is observed, confirming that detection is due to the dipole antenna. Current responsivity is 0.95 mA/W and a signal-to-noise ratio (SNR) of 15 dB was measured for these devices. The rms incident laser power required to produce SNR of unity, referred to as noise equivalent power[3] (NEP), was calculated to be 3.47 nW. Specific detectivity (D*), which normalizes NEP with respect to effective detector area and measurement bandwidth[3], was calculated to be 2.13×10^6 $cm{\cdot}Hz^{1/2}{\cdot}W^{-1}$.

---

[a] E-mail: btiwari@nd.edu

[1] J. Miller, *Principles of Infrared Technology*. New York: Van Nostrand Reinhold, 1992.

[2] J. Bean, B. Tiwari, G. H. Bernstein, P. Fay, and W. Porod, to appear in Jan/Feb 2009 *J. of Vac. Sci.Tech. B*.

[3] Dereniak, E.L. and G.D. Boreman, *Infrared Detectors and Systems*. New York: John Wiley & Sons, Inc., 1996.

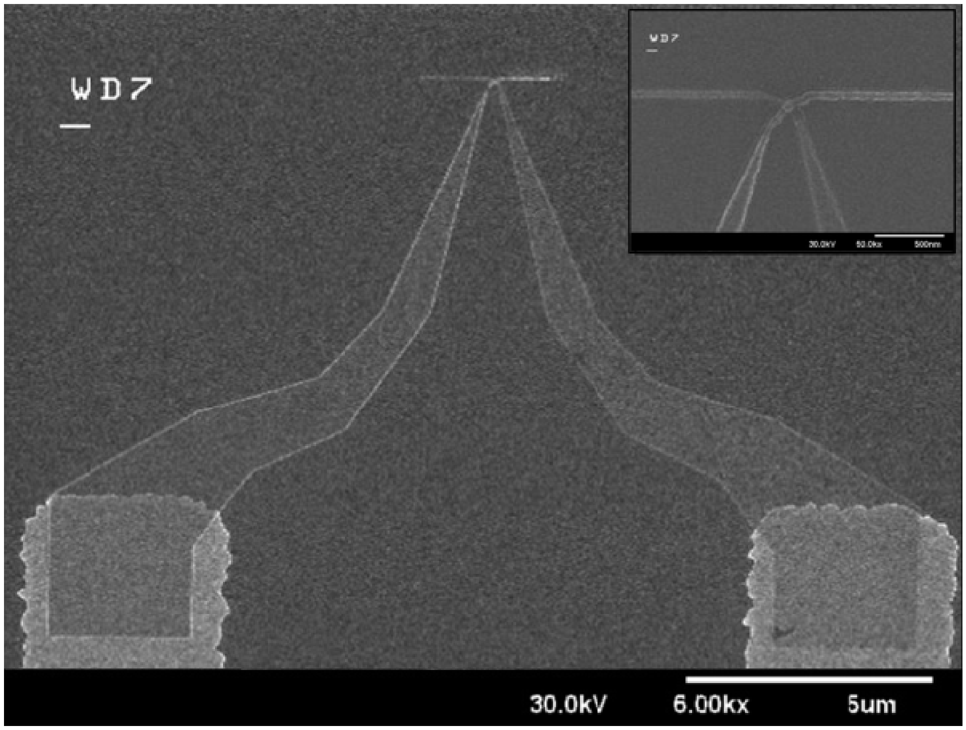

Figure 1: Scanning electron micrograph of an Al/Al_2O_3/Pt ACMOMD. The antenna length is 3.1μm. The inset micrograph shows the 50 nm x 50 nm overlap area where the MOM diode is formed.

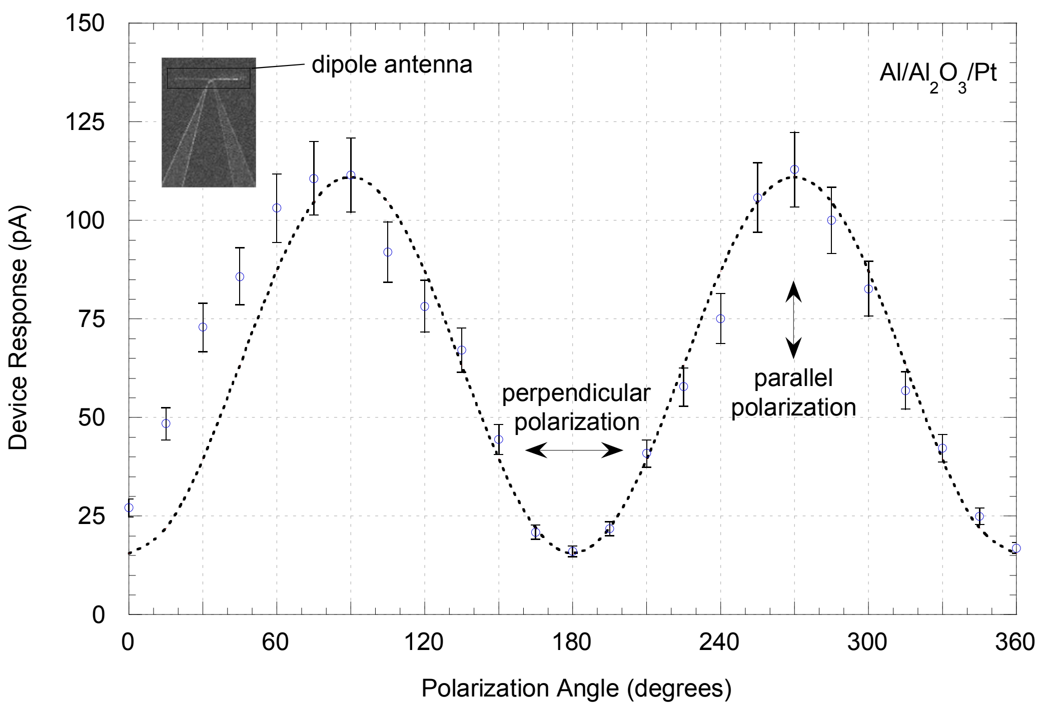

Figure 2: Polarization response of an Al/AlO_x/Pt two-step lithography ACMOMD. The electric field of the incident radiation is parallel to the antenna at 90° and 270°, where the maximum response was measured. The polarization ratio for this device, which is the ratio of the maximum response to the minimum response, is about 7.