Thin Film Antenna Coupled Conductor-Barrier-Conductor (CBC) Diode Implementation Using E-Beam Proximity Correction for Light Detection

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Antenna-coupled metal-oxide-metal (MOM) diodes have been used as detectors for high frequency electromagnetic waves up to the visible range owing to their high speed response. The physical structure of the device can be summarized in two parts. The first part is the antenna (in our case, a dipole bow-tie antenna) where the incident light is coupled forming an AC signal. In order to allow for the detection of the incident light, this coupled signal is rectified in the second part of the device**,** which is a tunnel junction that converts the AC signal formed across its barrier into a DC signal.

The first generation CBC diodes were first reported in 1966 as point contact MOM diodes working at millimeter and sub-millimeter wavelengths and then improved to enable the detection at infrared and visible ranges in the following years[1]. These devices are composed of a metal wire acting as an antenna and an MOM diode formed at the sharp tip of the wire touching the oxidized surface of another metal. First generation MOM diodes lacked the stability and reproducibility due to their mechanical properties as a result of that the second generation thin-film MOM diodes were implemented by integrating the antenna and the tunnel junction on a substrate. Although integrated devices brought stability and reproducibility, since their performance was restricted by integrated circuit fabrication technology, their progression had to follow the evolution in lithography. Second generation antenna-coupled MOM diodes were first implemented by photolithography and then e-beam lithography, which improved their performance by increasing the frequency range of the detectable light from microwave to visible.

In this letter we would like to present the third generation antenna-coupled CBC diodes. These third generation devices are fabricated by patterning doped polysilicon using e-beam lithography instead of using metal to form the antenna and the tunnel junction. This novel approach to the CBC diodes offers some advantages. First, since the performance of the tunnel junction is strongly dependent on the physical dimensions of the barrier**,** such as the area and the thickness, working with poly enables the fine control of these parameters through the application of different nano-fabrication techniques. Second, having the antenna part of the device made of polysilicon provides modulation of the carriers through the incident light which enables the device to be used as a light tunable antenna.

Specially developed nano-fabrication techniques are applied to the design and the fabrication of antenna-coupled CBC tunnel junctions. First of all, silicon substrate is prepared by depositing **a** 60nm thin nitride layer on top of the oxidized surface in order to create perfect isolation between the substrate and the subsequently deposited, 60nm thin, doped polysilicon. Secondly, the device pattern is formed by the e-beam proximity effect correction software[2], (developed by Peckerar et al.) in order to obtain a clear and accurate result. Proximity effect correction supplies us with a fine control of the barrier thickness and area at the tunnel junction. Next, the dose modulated pattern is formed by e-beam lithography (Raith e_line) on the substrate through a negative e-beam resist (HSQ). Reactive ion etching (RIE) is run to transfer the pattern into the poly layer. After stripping the resist, recursive oxidation of the sample in boiling water and oxide etching in Buffered Oxide Etchant (BOE) process is performed in order to allow for atomic level control of the junction area. In between this recursive processes the dimensions of the junction are measured through SEM in order to provide feedback. The electrical properties are checked with HP4156B semiconductor parameter analyzer and probing station at room temperature.

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[1] C. Fumeaux, W. Herrmann, F. K. Kneubühl**,** and H. Rothuizen, Infrared Physics & Technology 39(1998)123–183

[2] M.Peckerar, D. Sander, A. Srivastava, A. Foli, and U. Vishkin, J. Vac. Sci. Technol. B 25 2288 (2007)

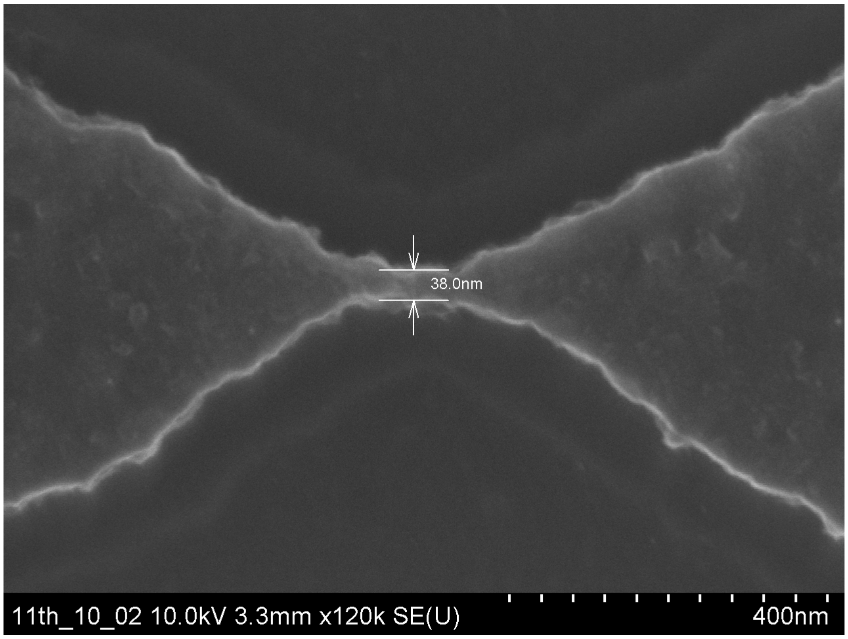
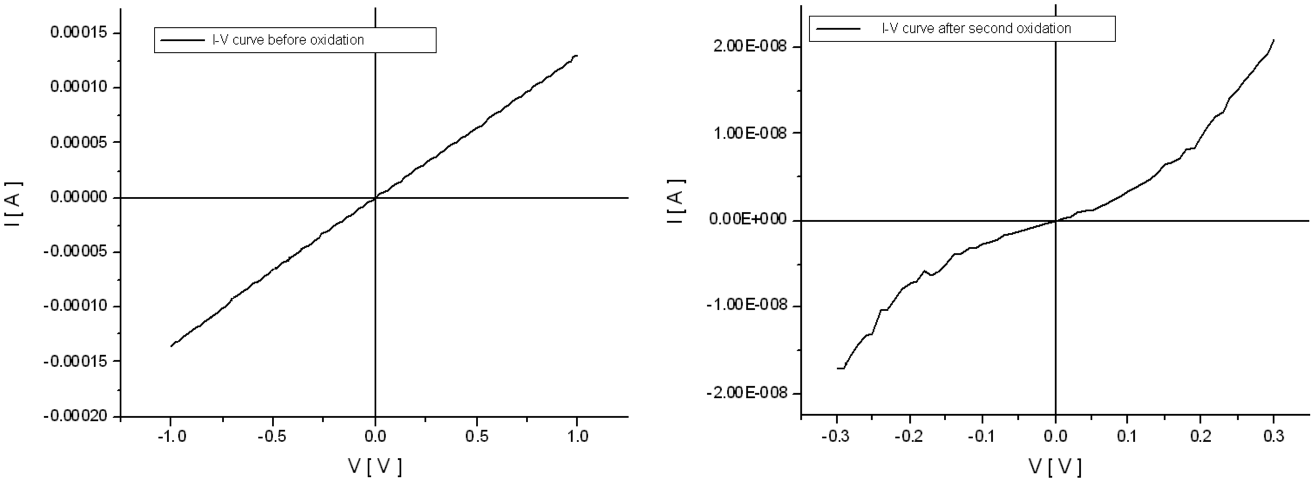


Fig 1: Bow-Tie structure created by e-beam lithography. Device is patterned on 60nm thin, doped polysilicon later. The narrowest part is measured as 38nm forming a junction area of 2280nm^2. Image is taken by Hitachi SU-70 SEM.



(a) (b)

Fig 2: Electrical I-V measurement plots at room temperature: (a) I-V sweep before any oxidation process applied. It is clear that the oxide barrier hasn’t formed yet so the device shows only resistive characteristics. (b) I-V sweep after applying oxidation and oxide etching process twice. The device shows nonlinear I-V characteristic proving the operation of a tunnel junction.