Metal-Insulator-Metal Diodes Fabricated on Flexible Substrates

David Etor, Linzi E. Dodd, David Wood, and Claudio Balocco
School of Engineering and Computing Sciences, Durham University
South Road, Durham, DH1 3LE, United Kingdom.

***Abstract*—The fabrication and testing of metal-insulator-metal (MIM) diodes on a flexible substrate for microwave and mm-wave applications are presented. The diodes utilized octadecyltrichlorosilane (OTS), which self assembles and provide a thin, pin holes free insulator. Preliminary electrical analysis shows that the diodes have a typical zero bias resistance of approximately 80 kΩ, zero-bias curvature coefficient ($\gamma_{\_ZB}$) of approximately 5.5 V^{-1}, and voltage responsivity of 3.1 kV/W at a frequency of 1 GHz, and are produced with over 90% device yield. The fabrication process is simple and cost effective, environmentally friendly, and demonstrates the possibility of roll-to-roll volume manufacturing of MIM diodes.**

I. INTRODUCTION

The metal-insulator-metal (MIM) diode is a fast switching rectifier, which consists of a thin dielectric layer sandwiched between two metal electrodes, with current flowing between the electrodes depending on the bias voltage polarity and the difference in the metal work functions [1].

The main challenge in the fabrication of a MIM diode is with the dielectric deposition; a very thin dielectric has to be used (only a few nm thick), corresponding only to a few atomic layers. This often results in a defective layer, with a large number of pin holes, short-circuiting the diode terminals and drastically reducing yield. To overcome this problem, a MIM diode in which the insulator self-assembles in a monolayer onto a metal surface has been developed [2]. The diode used an octadecyltrichlorosilane (OTS) self-assembled monolayer (SAM), which consists of carbon chains strongly packed together (pin-hole free) with an overall thickness of approximately 2 nm

In this work, polyimide (PI) has been used to form a 7.5 µm thick flexible substrate upon which Ti/OTS/Pt MIM diodes with junctions approximately 10 x 10 µm in area were fabricated. Polyimide is a high molecular weight and fully aromatic material, which is formed from polyamic acid precursors dissolved in an N-methyl-2-pyrrolidone based solvent carrier. The fabricated MIM structures are suitable for applications where a large-area manufacturing process on a flexible substrate is of paramount importance, such as in large area focal-plane arrays (FPAs), as well as energy harvesting devices if the structure dimensions are optimized [3].

II. RESULTS

Both dc and microwave characterization show that the fabricated devices have strong asymmetry and non-linear *I-V* characteristics with a typical zero-bias curvature coefficient $\gamma_{\_ZB}$ of approximately 5.5 V^{-1}, and a voltage responsivity of 3.1 kV/W at a frequency of 1 GHz, which is consistent with the values reported for the same structure on a rigid glass substrate [2]. The devices were also found to have a zero-bias resistance of approximately 80 kΩ. The relatively low resistance was due to the thin (~2 nm) OTS insulator. Over 90% device yield was achieved. A picture of the fabricated devices can be seen in figure 1 (a). An AFM image of one of the devices is also shown in the figure (b), with the diode junction clearly visible.

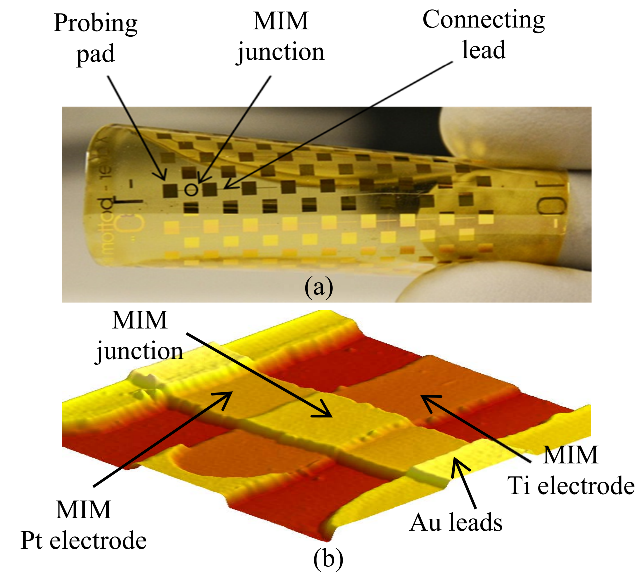

Fig. 1. Picture of fabricated Ti/OTS/Pt devices on PI substrate (a), with the devices' connecting leads and probing pads visible, and (b) an AFM image of one of the devices with the crossover at the middle denoting the diode junction.

III. SUMMARY

A high-yield, cost-effective fabrication process for MIM diodes with an OTS insulator on a flexible substrate has been demonstrated. The preliminary voltage responsivity is comparable to other state-of-art MIM diodes with conventional insulators. The flexible substrate enables the exploitation of ultra-fast rectifiers in applications such as large-area infrared and THz focal-plane arrays (which can be conformal to a non-flat substrate) as well as energy harvesting. The possibility of producing these MIM diodes with a roll-to-roll manufacturing process is currently being investigated.

REFERENCES

[1]. L.E. Dodd, S.A. Shenton, A.J. Gallant and D. Wood, "Improving Metal Oxide-Metal (MOM) Diode Performance via the Optimization of the Oxide Layer", J. Electron. Mater,Vol. 44, pp. 1361-1366, May, 2015.

[2]. D.Etor, L.E. Dodd, D.Wood, C.Balocco,"High-Frequency Metal-Insulator-Metal (MIM) Diodes for Thermal Radiation Harvesting," *IRMMW-THz Conf.* pp. 1-2, Hong Kong, August, 2015.

[3]. Y. Pan, C. V. Powell, A. M. Song, and C. Balocco, "Micro Rectennas: Brownian Ratchets for Thermal-Energy Harvesting", *Appl. Phys. Lett*. Vol. 105, 253901, December, 2014.