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Metal-Insulator-Metal Diodes Fabricated on Flexible Substrates

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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, 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.

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

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