Novel Low-Cost Ultra-High-Speed Diodes for Electromagnetic Energy Harvesting

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This work presents the fabrication of novel high-frequency low-cost metal-insulator-metal (MIM) diodes with the dielectric (insulating) layer formed using a chemical approach at low temperature, rather than using the more aggressive techniques typical of the semiconductor industry. This device is a useful component in a wide range of applications, including radio frequency identification (RFID), high frequency detectors and mixers, and electromagnetic energy harvesting as in (Y. Pan, C. V. Powell, A. M. Song, and C. Balocco, "*Micro Rectennas: Brownian Ratchets for Thermal-Energy Harvesting",* Appl. Phys. Lett. 105, 253901, 2014).

The MIM diode is a quantum device wherein a thin dielectric is sandwiched between two metal electrodes, and can operate at very high frequencies, well into the terahertz range, a promise first highlighted over thirty years ago (R. E. Drullinger, K. M. Evenson, D. A. Jennings, F. R. Petersen, J. C. Bergquist, L. Burkins, and H.U. Daniel, "*2.5 THz Frequency Difference Measurements In The Visible Using Metal-Insulator-Metal Diodes*", Applied Physics Letters, Vol. 42, No. 2, 1983, pp. 137-138). Electrodes with dissimilar work functions are thought to cause an asymmetric tunnel current to flow through the dielectric with respect to the polarity of the electrodes. The asymmetry can further be increased by maximising the work function difference between the two electrodes (E. W. Cowell III, N. Alimardani, C. C. Knutson, J. F. Conley Jr., D. A. Keszler, B. J. Gibbons, and J. F. Wager*, "*Advancing MIM Electronics: Amorphous Metal Electrodes*", Adv. Mater. 23, 2011, pp. 74–78). This increases the possibility of the diode to operate without the need for an externally applied bias.

The MIM diode is a popular device and has been produced using different fabrication techniques, with the most critical part of the fabrication being the definition of the insulating layer. Metal oxides are popularly used as the insulating layer by employing equipment like RIE, ALD, etc. (L. E. Dodd, A. J. Gallant and D. Wood, "*Controlled Reactive ion Etching and Plasma Regrowth of Titanium Oxides of Known Thickness for Production of Metal-Oxide- Metal (MOM) Diodes",* IET Micro and Nano Letters, vol. 8, 2013, pp. 476 478). The novelty in this work is the formation of the insulating layer via chemistry. The process developed for fabricating the diodes is very economical and efficient, and can be readily employed in the roll-to-roll commercial production of MIM diodes on flexible substrates. Results obtained from the DC and AC analysis of the devices are excellent when compared to others reported elsewhere.