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Terahertz Monolithic Integrated Circuits (TMICs) Array Antenna technology on GaN-on-Low Resistivity Silicon Substrates

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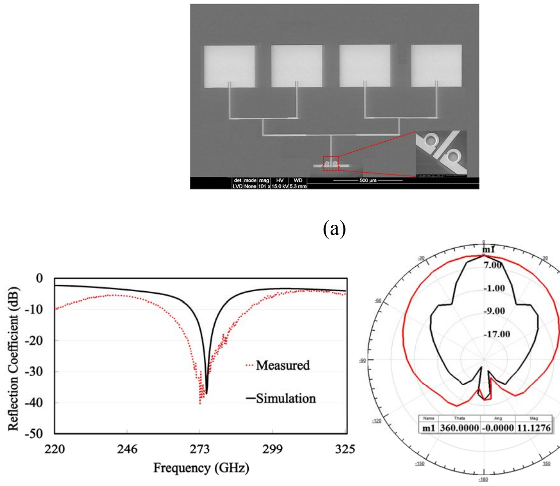
***Abstract*— In this paper, we have demonstrated a viable microstrip array patch antenna technology for the first time on GaN-on-low resistivity silicon (LR-Si) substrates (ρ < 40 Ω.cm) at H-band frequencies (220-325 GHz). The developed technology is compatible with standard MMIC technology with no requirement for high temperature processes. To mitigate the losses presented by the substrate and to enhance the performance of the integrated array antenna at THz frequencies, the driven patch is shielded by silicon nitride and gold layer in addition to a layer of benzocyclobutene (BCB). The demonstrated 4×1 array integrated antenna showed a measured resonance frequency in agreement with our simulation at 0.27 THz; a measured S11 as low as -41 dB was obtained. A directivity, gain and radiation efficiency of 11.2 dB, 5.2 dB, and 20% respectively was observed from the 3D EM model for a 5 µm BCB inset. To the authors' knowledge, this is the first demonstration of a THz integrated microstrip array antenna for TMIC technology; this developed technology is promising for high performance III-V electronic material on low resistivity/high dielectric substrates.**

I. INTRODUCTION

THz technology has many applications in imaging and sensing, spectroscopy, astronomy and communications. The short wavelength of THz frequencies allows for unique spectral interaction with matter and can achieve high resolution imaging [1]. Recent interest in new emerging applications is motivated by advances in high-speed semiconductor devices and nano-technology; which has enabled the advent of TMIC [2]. The advantage of using III-Nitride based material devices, such as higher power density and power added efficiency makes it more suitable than other material systems such as GaAs, InP or Si. The potential use of GaN HEMTs grown on LR Si offers the advantage of cost-efficiency and large diameter wafers making manufacturing of GaN-on-LR Si potentially competitive with existing high-resistivity (HR) Si and SiC technologies.



(a)

(b)

(c)

Fig. 1. 4×1 array antenna (a) SEM image (b) Measured and simulated reflection coefficient (c) Plot of directivity pattern

At frequencies above 220 GHz, designing high-Q passive components, including integrated antennas, introduces additional challenges as the wavelength becomes comparable with the substrate thicknesses [3]. To capitalize on the advantages of GaN on LR Si for millimeter-wave and THz applications, a technology with minimal substrate coupling is required. Insertion of a low-loss/low dielectric constant layer of BCB as an insulator has proven to be a successful technique for substrate coupling reduction [4]. Here we report on the design, fabrication, and characterization of integrated 4×1 array antennas on GaN-on-Low resistivity silicon using BCB as an insert layer.

II. MODELLING AND ANTENNA TECHNOLOGY

3-D full-wave Ansys HFSS® software was employed to design the integrated THz array antennas. Optimization of structure geometrics and heights was performed by way of simulation for better performance and to ensure the suppression of RF energy dispersion introduced by the conductive Si substrate. The array antenna was fabricated using optical lithography and all the steps required to fabricate the transmission media and antenna are compatible with standard MMICs technology.

The reflection co-efficient of the fabricated antennas was measured with an Agilent VNA/220-325 GHz OML heads and using LRRM calibrations on ISS standard substrate.

III. RESULTS

The simulated and measured reflection coefficient of the 4×1 array antenna is shown in fig 1. Here, the observed reflection coefficient was as low as -37 dB and -41 dB for simulated and measured respectively. The measured reflection coefficient shows a -10 dB bandwidth of 32 GHz from 259 GHz to 291 GHz, presenting a relative bandwidth of 11.6%. The directivity and gain of the suggested 4×1 array antenna was as high as 11.2 dB and 5.2 dB respectively. Further results on single microstrip patch, power divider performance and optimization of BCB height will be provided in the extended paper.

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