The First 0.15um MHEMT 6”GaAs Foundry Service: Highly Reliable Process for 3 V Drain Bias Operations

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Lattice matched InAlAs/InGaAs/InP HEMTs have performance advantages over more commonly used GaAs PHEMTs due to the high electron velocity and carrier density. However, manufacturing these devices at high production level is difficult due to the limited size, high cost, and brittle nature of the InP substrate. Growing InAlAs/InGaAs structures metamorphically on GaAs substrates can overcome these substrate issues. However, the ultimate acceptance of MHEMT in commercial application depends upon its providing higher performance compared to other technologies at the same cost. In order to address the needs for both high performance and low manufacturing cost, for the first time, an highly reliable 4 mil 0.15 um MHEMT process has been developed on six inch GaAs substrates with high yield and reproducibility for both power and noise applications.

1-DC and RF Characteristics: The DC and Pulse I-V characteristic of WIN 0.15um MHEMT, as shown in fig.1, is free of any kink and surface trapping phenomena. WIN 0.15um MHEMT has $I_{ds,max}$ of 550mA/mm and g_m-peak of 700mS/mm an off-state gate-drain breakdown of 13V. Fig. 2 shows the tight distribution of PCM DC characteristics of 3 lots from two epi-wafer vendors. ft of 120GHz at V_{ds} of 1.5V and 140GHz at 1V drain bias are typically achieved. This process shows very high capability for production with similar manufacturing cost compared to GaAs PHEMT. In fact, the 6-inch MHEMT process is 95% similar to our fully qualified 6-inch 0.15um PHEMT.

2-Noise Performance: The devices showed an excellent noise figure of 0.6dB and associated gain of 10dB at 26GHz and 0.9dB with gain of 8dB at 40GHz. The MHEMT exhibited a 0.3dB noise figure improvement with 2dB more gain compared to WIN 0.15um LN PHEMT. The noise performance of WIN

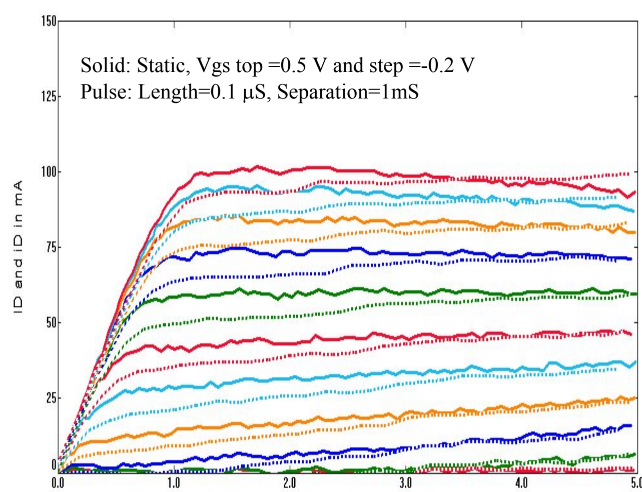

Fig.1: Pulse I-V of 0.15 um MHEMT showing kink and trapping free devices.

0.15um MHEMT makes it very suitable for low noise amplifiers to W-band for radio links and low cost MMICs for automotive radar at 77GHz. California Institute of Technology, CA, evaluated the MHEMT or 4-8 GHz cooled MIC LNA.

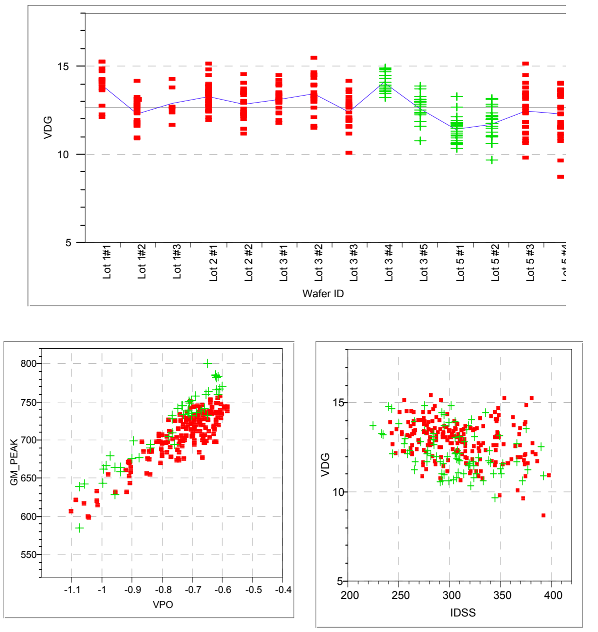

Fig.2: Distribution of gm, Vp, V_{DG} and I_{dss} from wafer to wafer and batch to batch with Epi wafers from two vendors.

The LNA consists of a low noise 0.15um MHEMT as the first stage and 0.1 um InP HEMT for second gain stage. Fig. 3 shows a noise temperature (K) of a MIC LNA at RT and 11K. The LNA has demonstrated an extremely low noise figure at RT of 0.46dB. When cooled to 11 K, the noise temperature is extremely low - 4.4K - at 4-8GHz. This is the first demonstration of a cooled LNA using MHEMT devices. The MHEMT did not show any trap symptom at 11 K.

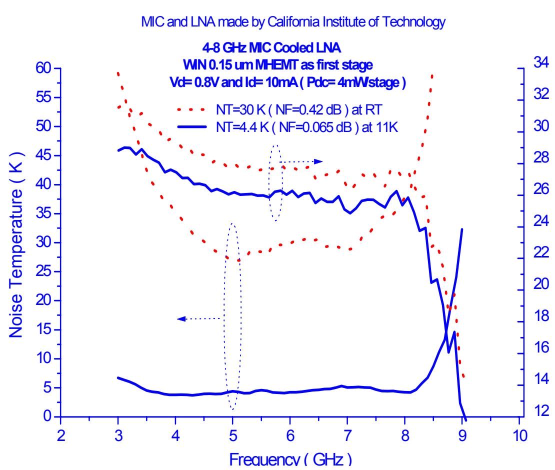

Fig.3: 4-8 GHz LNA, using WIN's 0.15um MHEMT first stage, giving average noise temperature of 4.4K 11K. LNA made and measured by California Institute Technology.

Centellax Corp. (USA) designed TIAs which were biased as Electro-Absorption Modulator driver (EAM) at V_{dd}=4.5 V and I_{ds}=120 mA for OC-768 also using the 0.15 um PHEMT, as shown in fig.4-b. The same design is used with WIN's 0.15um MHEMT and the results show a gain improvement of 2dB across the entire frequency band and a 10-12GHz improvement in the amplifier bandwidth with the MHEMT (see fig. 4-a). These results demonstrate that the MHEMT technology is superior for an amplifier requiring gain, bandwidth, linearity, low noise and high dynamic range, when compared to both 0.15um GaAs Low Noise and Power PHEMTs. This makes the 0.15um MHEMT an excellent choice for both 40G/s Fiber-Optic Communications and 77GHz automotive radar applications.

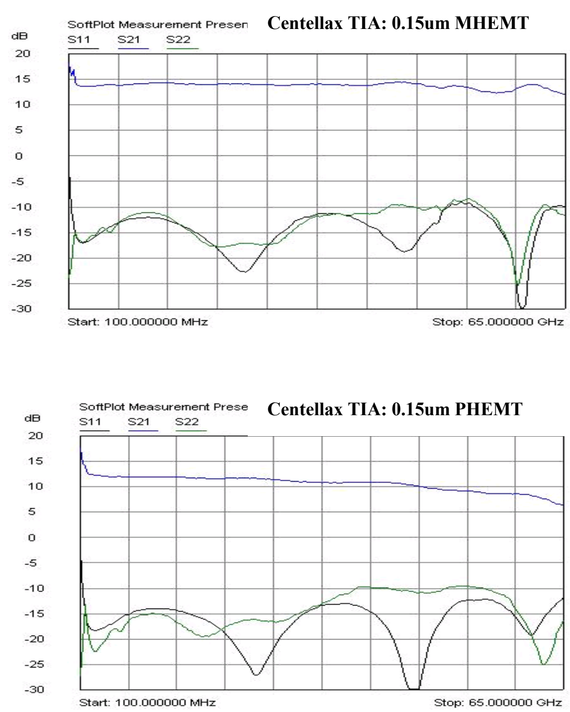

Fig.4: TIAs biased as EMA driver at V_{dd}=4.5V and I_{ds}=120mA for MHEMT (a) and PHEMT (b). Centellax performed TIA design and measurement.

3-Power Performance: As shown in fig. 5, load pull power measurement at 29GHz of a 0.15um unit cell MHEMT (2x75um) has demonstrated P_{1dB} of 330 mW/mm with linear gain of 14.2dB and PAE of 53% at V_{ds}=3V. In constrast, at Vds=3V, WIN's 0.15um power PHEMT shows P_{1dB} of 260mW/mm with 13dB gain and of 43% PAE. Compared to the power PHEMT, the MHEMT provides ~10% more efficiency and ~1.5dB more gain, demonstrating an excellent potential of power MHEMT for very high efficiency and high gain applications.

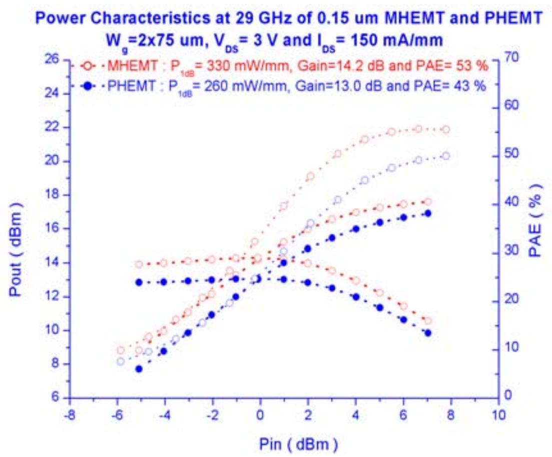

Fig.5: Load Pull Power measurement at 29 GHz showing the advantage of MHEMT to the PHEMT Power process at 3V and MMW frequencies.

4-Device Reliability: Our 3-temperature DC life test at 3V drain bias shows projected MTTF of 3e7 hours at T_{ch}=125C with an activation energy E_a of 1.72eV, as shown in fig. 6. Three-lot reliability is on going and no device early failures have been observed during the accelerated life test. This is the first demonstration of reliable 0.15 um power MHEMT.

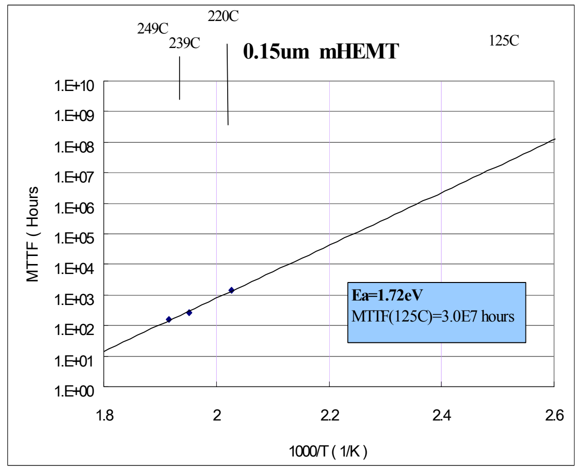

Fig.6: First demonstration of reliable power MHEMT at 3V drains bias with E_a of 1.7eV and MTTF of 3e7 hours at T_{ch} of 125 C.

In conclusion, we have demonstrated 6" GaAs wafer with high performance 0.15um Metamorphic HEMT technology. High yield and reproducibility have been achieved across 6-inch GaAs wafers. Good reliability at 3V drain bias has also been demonstrated. This is the first successful demonstration of 0.15um MHEMT technology on 6"GaAs substrates for foundry service.

