Pico-second Laser epitaxy for GaN regrowth

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Though there are some reports on the epitaxy using Femtosecond and Nanosecond Laser, there is no trial using Picosecond Laser with higher repetition frequency. The motivation come from the fact that regrown n^+-GaN (Si or Ge doping) can drastically reduce the on-resistance (Ron) in power FET in low-voltage range [1]. Since GaN regrowth using MOCVD is an expensive and time consuming process, PLD regrowth, an alternative low cost technique, can offer very attractive advantages such as, reduced material consumption, low growth temperature, and simplified parameters to control growth conditions. In this work, a Picosecond Laser (Panasonic, Kuai-5V-5W: λ =1064nm, t_{pulse}=24ps, E_{pulse}=45μJ, repetition f=25-100KHz, and $E_{density}$=~2.3 J·cm^{-2}) was used to ablate liquid $Ga_{0.995}Ge_{0.005}$ alloy. Nitrogen radical gun (RF plasma set at 13.5MHz and 300W) was used. Substrate temperature was varied between 400 and 775°C under chamber pressure 2-20 × 10^{-3} Pa. Fig. 1 shows growth rate of Ge-doped GaN as a function of repetition frequency. A threshold repetition rate was observed to start GaN epitaxial growth. Growth rate is gradually reduced as substrate temperature increases. Ge-doped GaN crystal quality as assessed by XRD ω-2θ scan is shown in Fig. 2. Incorporation of Ge was confirmed as high as 3× 10^{20} cm^{-3} by SIMS, which well corresponds to the ratio of target material. Fig. 3 presents carrier concentration and mobility obtained by Hall measurements, where it can be seen the high carrier density, ~5.0×10^{19} cm^{-3}, which will lower the contact resistance of GaN power devices.

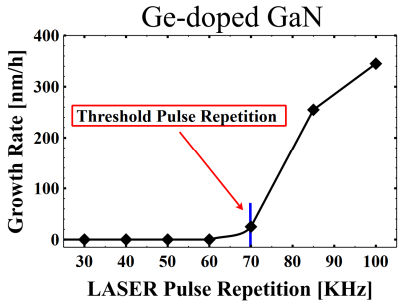

Figure 1 Ge-doped GaN growth rate at constant N^+ flow rate, ~650°C, at 1.15 J·cm^{-2} and 2.2×10^{-3} Pa.

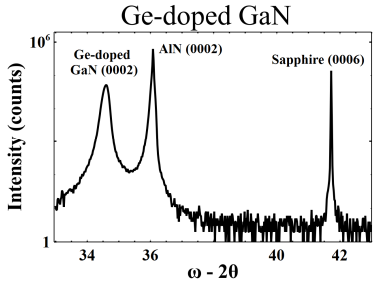

Figure 2 XRD ω-2θ scan of Ge-doped GaN grown on AlN/Sapphire template at ~650°C,~11×10^{-3} Pa, 2.3 J·cm^{-2} at 100KHz.

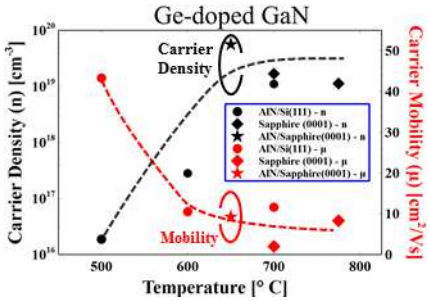

Figure 3 Carrier density and carrier mobility for Ge-doped GaN grown on AlN/Si(111) and AlN/Sapphire templates, and also on bare Sapphire substrates at 11-18 × 10^{-3} Pa, 1.35-2.3 J·cm^{-2} at 100KHz. Lines guide eyes.

References

[1] Suzuki A., et al. "Extremely low on-resistance Enhancement-mode GaN-based HFET using Ge-doped regrowth technique," pp. 11.1.1 - 11.1.4, IEDM, 2014.