Effects of N_2 or Ar Plasma Exposure on GaAs/AlGaAs Heterojunction Bipolar Transistors

C. H. Hsu[1], C.C.Chen[1], B. Luo[2], G. Dang[2], F. Ren[2], S. J. Pearton[3], C. R. Abernathy[3], J. W. Lee[4], K. D. Mackenzie[5] and Jay Sasserath[5]

1. Department of Chemical Engineering, Feng Chia University, Taichung, 407, Taiwan
2. Department of Chemical Engineering, University of Florida, Gainesville, FL 32611
3. Department of Materials Science and Engineering, University of Florida, Gainesville, FL 32611
4. Dept. of Optical Engineering, Inje University, South Korea
5. Unaxis USA Inc., St. Petersburg, FL 33716

HBTs are finding increasing applications in lightwave communication, networks, power microwave systems and wireless communication devices. The key processing steps in the fabrication of HBTs involve etching down to the base, sub-collector layers in order to deposit ohmic contacts on these layers and device passivation. While wet chemical etching has excellent selectivity for etching one material over another, it is generally unacceptable for maintaining good pattern transfer at emitter dimensions below ~ 2 μm, and increasingly dry etching is being employed, especially for manufacturing where yields are crucial. One of the most attractive plasma chemistries for fabrication of III-V HBTs is based on CH_4/H_2, which is a universal etchant for these materials and has good selectivity for GaAs over AlGaAs, and InGaAs over AlInAs, at low ion energies. There are two concerns with this gas mixture, namely ion-induced damage and hydrogen passivation of both acceptor and donor dopants within the exposed layer during etching. Sometimes N_2 or Ar can be added into Cl-based discharges to enhance the etch rates. N_2 can increase the Cl^- ion densities by increasing the Cl^- dissociation from BCl_3. Ar is added in the etching process to enhance the anisotropic etching through no-reactive ion bombardment during the etching process and stabilize plasma. In this study, we examined the effect of ICP N_2 plasma exposure on the dc characteristics of GaAs/AlGaAs HBTs. The plasma exposures simulate a worst-case for either an etching or a passivation process because the damage is allowed to be accumulated in our study, whereas in a real etching or deposition process at least part of the damaged region is being removed or passivated, respectively.

The HBTs were exposed to pure N_2 plasmas in a Plasma Therm 790 ICP system. The N_2 flow rate was held constant at 20 standard cubic centimeter per minute, with the process pressure varied from 2 m Torr to 5 mTorr. The 13.56 MHz power on the sample chuck was varied from 0 to 300 W, and 2 MHz ICP source power was varied from 200 to 1500 W. Plasma exposure time was varied from 20 sec to 1 min with GaAs sputter rates of about 250 Å/min. The base-collector reverse breakdown voltage and current gain were measured on the 90 μm diameter large area devices.

Figure 1 shows the changes in dc self-bias voltage on the sample chuck and HBT base-collector reverse breakdown voltage vs. the rf chuck power. Under a fixed ICP source power condition, the dc self-bias voltage is directly proportional to rf chuck power, as well as the ion energy. However, base-collector reverse breakdown voltage decreases continually with increasing rf chuck power. As dc self-bias voltage and hence ion energy increase, there are correspondingly more surface damages introduced, which causes As preferentially to be sputtered off from GaAs surface and leaves a Ga-rich semi-metallic surface. This Ga-rich surface leads higher leakage current and reduces the reverse breakdown voltage.

Figure 2 shows the effects of ICP power on sample chuck dc self-bias voltage and base-collector reverse breakdown voltage of HBTs. At low ICP power range, the ion density is proportional to the ICP power. As the ion density increased, the damage magnified. A similar surface dominant damage was observed. The base-collector junction became leakier and smaller base-collector reverse breakdown voltage was observed as the ICP power increased. However, there was a turnover of reverse breakdown voltage obtained when the ICP power was around 500W. This is due to higher ion density produced at greater ICP power condition, which suppresses the dc self-biased voltage and ion energy. Since the ion energy reduced at higher ICP power region, less damage on the HBTs should be obtained.

The effects of plasma exposure time and pressure on HBTs will be also presented in the meeting.

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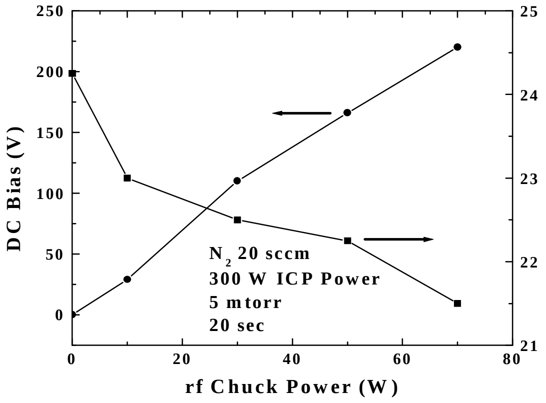

Figure 1. Base-collector reverse breakdown and the sample chuck self-bias voltage as a function of rf chuck power.

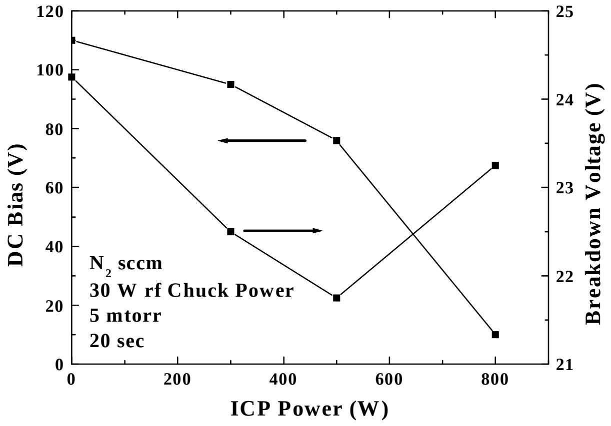

Figure 2 Base-collector reverse breakdown and the sample chuck self-bias voltage as a function of ICP source power.