Effect of Proton Radiation on dc And rf Performance of AlGaN/GaN HEMTs

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AlGaN/GaN HEMTs have potential applications in phased away radar mobile communications and high temperature electronics for aircraft and automobiles. The use of microwave for satellite transmission for broad-land data links and weather forecasting places a premium on the ability to withstand high radiation fluxes. In this work we report on the changes in dc and rf performance of AlGaN/GaN HEMTs exposed to 1MeV proton doses equivalent to either 10 or 100 years in low earth orbit. The devices suffer some significant degradation in their characteristics, but are still operational even at the highest dose.

The epi structures were grown on sapphire substrates by MOCVD. Ohmic contacts were formed by lift-off of e-beam evaporated Ti/Al/Pt/AU, which was annealed at 850°C for 30sec to minimize contact resistance. Schottky gates of e-beam deposited Ni/Au were formed by conventional optical lithography for 1.2µm gate lengths or e-beam lithography for shorter lengths. Mesa isolation was formed by ICP dry etching.

The Ids-Vds characteristics from a 1.2×200µm HEMT before and after proton doses of 5×10^{9} or 5×10^{10} cm^{-2} are shown in Figure 1. The projected ranged of the protons is ~12 µm and thus they penetrate the entire epi-layer structure. The maximum current decreases with increasing dose indicating either a decrease in carrier concentration in the channel or a decrease in electron saturation velocity. The change in slope of the curves at low bias also indicates decreases in carrier mobility or concentration. Note that the maximum Ids falls by only ~40% after a proton dose equivalent to 100 years low earth orbit. Similar results were observed over the entire range of gate length and widths.

Figure 2 shows typical HEMT transfer characteristics before and after proton irradiation. Note that V_{TH} shows minimal shift the peak gm occurs at the same bias after irradiation. There is an ~30% decreae in gm for the highest dose. Comparisons with AlGaAs/GaAs HEMTs of similar dimension showed that the nitride devices were approximately 5X more radiation hard as judged by the relative decreases in gm at a given dose. The forward current was decreased as a result of the proton-induced damage, which can be ascribed to a decrease in channel doping through the creation of deep level trap states. Sheet resistance measurements confirmed the decreases in sheet electron density in the irradiated devices. The decrease in channel doping was also evident in the increase V_B as a result of irradiation. The microwave performance was also degraded by the proton exposure, through the increase in channel resistance. This supports the notion that the main degradation mechanism is removal of conduction electrons by trap states in bandgap. The AlGaN/GaN HEMTs appear well-suited to applications requiring robust rad-hard characteristics.

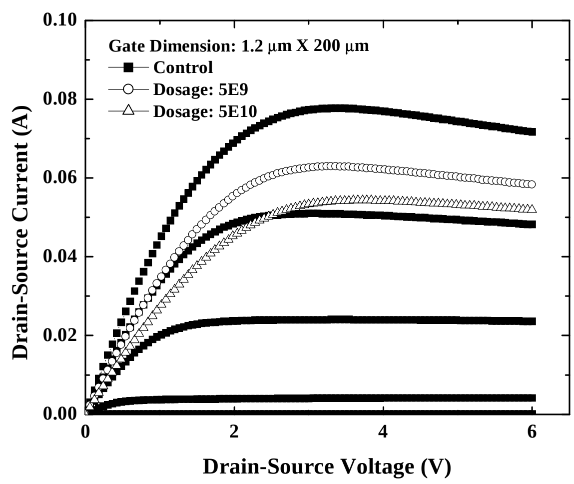

Figure 1. Ids-Vds before and after two different proton doses.

Figure 2. Transfer characteristics before and after proton irradiation.