Hot electron injection

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1 Reasons for hot electron injection

Hot electron injection allows electrons to be injected into a device through a narrow GaAs base region without significant relaxation.(Beton, Long, Couch & Kelly 1988). Traditionally, without hot electron injection, the energy of electrons is increased to the X band through large electric fields in the start of the drift zone. The area where this happens is a region which does not allow domain formation, and is known as the dead zone. It reduces the effective drift region length and acts as a parasitic resistance, reducing device efficiency (Neylon, Dale, Spooner, Worley, Couch, Knight & Ondria 1989).

Hot electron injection is the process of raising the energy of an electron into the X band before it enters the drift zone. This can be achieved by creating very large electric fields inside the semiconductor itself. In theory, Schottky barriers could be used, but there are problems with the metal-semiconductor interfaces. Planar doped barriers and graded gaps can be used more practically.

Using such techniques brings with it an additional benefit. The temperature of the electrons travelling across the junction will be set by the electron energy. This is typically equivalent to around 2000 K, so variances of 130 K required for the full military specifications will have relatively little impact (Neylon et al. 1989).

Hot electron injection is achieved by creating a heterojunction at the cathode of the diode. Generally, a layer of AlGaAs between the cathode contact and the active area. The electrons will gain energy when crossing the junction. An energy gain of around 0.25 eV is expected for $Al_{0.3}Ga_{0.7}As$ layers. A significant proportion of electrons will will be transferred from the Γ valley to the X valley because of this (van Zyl, Perold & Botha 1999).

Since this effectively reduces the dead zone, the RF power output of the device is increased. Also, smaller active areas can be created, allowing for higher fundamental frequencies to be employed.

2 Experimental results

During initial work on hot electron injection, 80 mW of power had been achieved at 90 GHz under exceptional conditions, with an efficiency of 2.4%. 50–60 mW at 94 GHz achieved reproducibly, giving a 1.6% efficiency on conversion from DC to RF power. It was theorised that with further enhancements such as grading the drift region to engineer the electric field throughout the device and placing the injector at the cathode, closer to the heatsink, that powers 100 mW at 94 GHz could be achievable (Neylon et al. 1989).

Since then, most people place the injector at the cathode as was suggested by this paper. Since then, diodes have been fabricated with multiple transit regions and multiple hot electron injection points. This effectively created multiple hot electron injection diodes in a single physical device. With this arrangements, RF powers of 160–178 mW were achieved at 73 GHz (van Zyl et al. 1999).

References

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