Comparison of the Noise Performance of NbTiN and NbN Hot Electron Bolometer heterodyne mixers at THz Frequencies

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Recently experimental data for the noise temperature of hot electron bolometers (HEB) based on NbTiN/AlN on high resistive Si have been obtained at 1.6THz. The noise, gain and IF bandwidth performance is compared to measured and extrapolated data for HEB on NbN thin films on Si with comparable device volume. In both cases, a hot spot model including Andreev reflection at the hot spot ends is applied. This yields IV curves, gain, noise and the IF bandwidth. These data are then compared with measurements. The parameters for NbTiN for a best fit to the experiments indicate a larger role of diffusion cooling (0.55 cm/s2 compared to 0.45 cm/s2 for NbN) at about the same electron-phonon interaction time (50ps compared to 40ps for a 35Å thick film). Due to the lower resistivity of NbTiN (a 4μm x 0.4μm x 35Å NbTiN device has 60Ω compared to 120 Ω in NbN), antenna matching requires that the optimum device length in terms of receiver noise performance is located at 4μm x 0.75μm (for a 60Å...70Å thick film) compared to a 4μm x 0.4μm (for a 35Å thick film). This increase in length results in an enlarged bias region where the device shows optimum noise properties (from 0.5mV to 2mV compared to 0.5mV to 1mV in shorter devices). The expected noise temperatures are about equal for NbTiN and NbN (500K receiver noise at 1.6T), measurements indicate 800K for NbN and 1200K for NbTiN. The gain figures indicate -12dB for NbTiN compared to -11dB for NbN, measurements yield -18dB for NbTiN and -12dB for NbN. This discrepancy may be explained by the presence of a AlN buffer layer detuning the antenna and therefore destroying the antenna pattern increasing the coupling loss between the laser and the mixer. Extrapolating the device resistances to zero device length indicates a residual resistance of 25Ω in most NbN devices. This increases the effective device length by 10% (corresponding to a current transfer zone under the antenna pads of 40nm). This effect seems more pronounced in NbTiN since the measured film resistance indicates a 50% reduction of the sheet resistance compare with

NbN. The actual measured device resistance for a 60Å NbTiN yields a sheet resistance which is identical to NbN at 30Å. Therefore the contact resistance may be up to 100Ω indicating a 400nm increase of the effective element volume. The measured IF roll-off frequency is 3GHz for a 65Å thick NbTiN film. This compares to 4.5GHz for a 35Å NbN (extrapolated to 2.5GHz at 65Å thickness) indicating that NbTiN may be intrinsically somewhat faster than NbN in line with initial expectations. Obviously more work has to be done for NbTiN devices to yield the same performance level as NbN devices. NbTiN HEB are located in the crossover region between phonon and diffusion cooling.