MgB_2 HEB Terahertz Mixers: Diffusion- or phonon- cooled?

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During the last few decades superconducting hot-electron bolometer (HEB) mixers have emerged as the most successful technology for extremely low-noise molecular spectroscopy observations at frequencies above 1 THz [1]. This is because, unlike SIS mixers, operation of HEBs is not limited by the superconducting gap and compared to Schottky diode mixers, their noise temperature is much lower. By far, the most extensively studied and used HEB mixers are based on phonon-cooled mechanism of non-equilibrium electrons. Despite of being state-of-the-art, the IF of NbN based phonon-cooled HEB mixers limits to 3-5 GHz due to about 12 ps of electron-phonon interaction time (τ_{eph}). While MgB_2 offers large IF bandwidth as a result of fast τ_{eph} (1-2ps) due to its higher Tc of above 30K [2], it is suspected that its low sheet resistance (one order of magnitude lower than NbN) has been problematic in optimizing the low noise temperature. In the alternative approach pioneered by Prober [3], the mixer element is a nanobridge and in this configuration, the dominant cooling mechanism for non-equilibrium electrons is outdifusion through normal metal contact pads. For such diffusion-cooled HEB mixers, material with lower sheet resistance and higher diffusion constant can be a suitable choice.

In retrospect, we investigated electron diffusion constant of MgB_2 ultrathin films grown in SiC substrate by hybrid physical chemical vapor deposition process and patterned in submicron bridges. Our results show that the ultrathin MgB_2 films has a diffusivity constant of ~ $5.0 cms^{-1}$, i.e. $\times 10$ compare to NbN ultrathin films, ~$0.5 cms^{-1}$. This higher electron diffusion constant in ultrathin MgB_2 films can have two benefits. One, compare to phonon-cooled MgB_2 HEB itself, the device size in diffusion cooled MgB_2 HEB can be reduceded to sub-micron size, thus, while ensuring an effective diffusion of non-equilibrium electrons, more uniform film surface can be utilized. On the other hand, due to larger diffusion constant of MgB_2, it is not necessary to reduce devices to too short i.e. nano bridges, as usually preferred in diffusion-cooled HEBs. Despite being very effective diffusion process in nanobridges, achieving a stable biasing is challenging due to the temperature distribution along the bridge. Also, too narrow bridges are likely to be susceptible to a direct detection. In this conference, we present a systematic study of superconducting properties and electron diffusion process in ultrathin MgB_2 films. We also discuss feasibility of utilization of low noise, high bandwidth diffusion cooled MgB_2 HEB mixers.

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REFERENCES

[1] T. de Graauw et al., “The herschel-heterodyne instrument for the far infrared (HIFI),” *Astronomy Astrophys.*, vol. 518, 2010, Art. no. L6.

[2] E. Novoselov and S. Cherednichenko, “Gain and Noise in THz MgB2 Hot-Electron Bolometer Mixers with a 30K Critical Temperature”, *IEEE Trans.THz.Sci.Technol.* vol. 7 (26) s. 704-710 (Nov. 2017)

[3] D.E. Prober, “Superconducting terahertz mixers using a transition edge microbolometer”, *Appl. Phys. Lett.* 62, 17 (1993).

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