# $MgB_2$ HEB Mixers with Nanopatterned Surfaces: Effect on the Noise Temperature and the LO Power.

Narendra Acharya and Sergey Cherednichenko*

Heterodyne receivers are capable of detecting and spectrally resolve fine structures of terahertz wave emission coming from interstellar medium, stars, and planets. For frequencies above 1THz, superconducting Hot-Electron Bolometer (HEB) mixers enable such heterodyne receivers on ground, air- and space based platforms.[1] For HEB mixers, ultra thin superconducting films are required with a ps-rate electron phonon interaction $\tau_{eph}$, and a fast phonon-to-substrate escape time $\tau_{esc}$ The resulting electron temperature relaxation time sets the upper limit for the utilizable Intermediate Frequency (IF). So far, such combination of properties has been observed in two materials. In NbN, with a critical temperature of 8-11K in thin films, $\tau_{eph}$ is about 12ps, and the maximum IF at 4-6GHz. In $MgB_2$, with a critical temperature of 30K in thin films, $\tau_{eph}$ is about 1-2ps, and the maximum IF is at 11-13GHz. Besides a wider bandwidth, $MgB_2$ HEB mixers are much less critical to the cooling, allowing for operation >10K (20K low noise operation has been reported [3])

Despite of obvious advantages offered by $MgB_2$ HEB mixers, there are two issues, which have to be resolved for efficient applications. Both of this issues are related to a rather low resistivity (hence, sheet resistance) of $MgB_2$ films, about a factor of 10 lower compared to NbN films. Even for 5nm thick $MgB_2$ films, the sheet resistance is in the range of 50-70 Ω/□, which requires the HEB bridges to have an aspect ratio $w/l \leq 1$ in order to keep the bridge resistance matched to the impedance of THz antennas (30-100Ω). On the other side, due to contact resistance (remember, that HEB mixers operate at a few THz), the width of the bridges has to be kept not too small in order to keep contact losses are low as possible. Earlier, we have observed that reducing the HEB width from 1μm down to 300nm the noise temperature is increasing. E.g. NbN HEB mixers have a width 2-4μm. With the first and the second constrains in mind, the optimized for the lowest noise $MgB_2$ HEB mixers would be e.g. 2μm×2μm. The LO power for HEB mixers is known to be proportional to the HEB area. Therefore, optimized for low noise, $MgB_2$ HEB mixers would require too high LO power.

Both authors are with the Department of Microtechnology and Nanoscience, Chalmers University of Technology, SE-412 96, Gothenburg, Sweden.

[2] corresponding author, serguei@chalmers,se.

In this study, we discuss artificial surfaces for $MgB_2$ films, such that the effective sheet resistance could be increased, and the aspect ratio w/l could be decreased. We achieve this effect by nano patterning $MgB_2$ films with a set of nano holes (see Fig.1). We vary the hole size and the patters (from 200nm to 20nm, and from an arranged order to a quasi-random).

We observe that both the critical temperature and the critical current are not affected by such patterning (comparing to reference non-patterned devices), whereas the sheet resistance can be tuned in a wide range (determined by the filling factor). On the conference, we will present results for both dc and THz characterization.

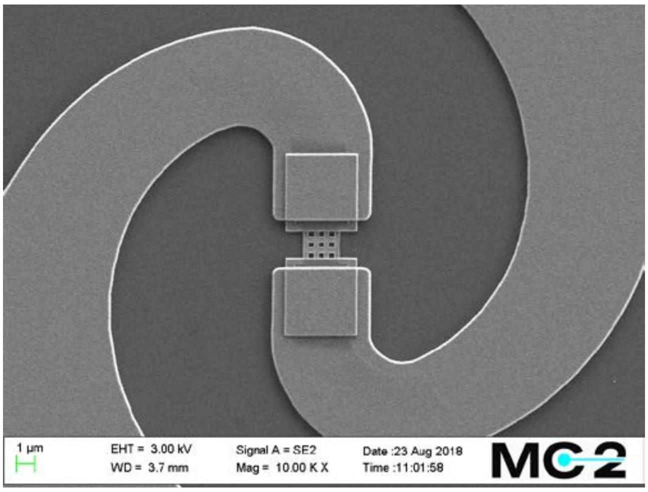


Fig. 1. Scanning Electron Microscope (SEM) image of a nano patterned $MgB_2$ microbridge, integrated with a gold spiral antenna. The microbridge size is 1.5μm×1.5μm.

## 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, “Low noise terahertz MgB2 hot-electron bolometer mixers with an 11 GHz bandwidth”, *Appl. Phys. Lett*. 110, 032601 (2017).

[3] 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)

NOTES: