MgB_2 thin film by HPCVD for THz HEB mixers fabrication

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Study of remote space objects in the terahertz (THz) range (0.1-10THz) allows for analysis of their chemical composition and dynamics manifested in Doppler-shifted spectral lines. In order to achieve high spectral resolution necessary for sub-mm astronomy observations heterodyne receivers are used. The most common devices for the heterodyne instruments in frequency range above 1Thz are hot-electron bolometers (HEB). Widely used NbN HEB mixers provide a high sensitivity (<10x the quantum limit) and an intermediate frequency bandwidth of 3-4GHz. However, for some astronomical observations even larger bandwidth is often required. Moreover, a requirement of cooling NbN HEBs with a liquid helium limits the instrument operation time which is especially critical for space-borne missions.

In order to improve the performance of HEB mixers novel materials are required. Recently, HEB mixers made from molecular beam epitaxy (MBE) grown MgB_2 films were successfully realized and tested. However, the great reduction of critical temperature (T_c) with MBE films thickness decrease has been observed, whereas for HEB mixers both a high T_c (resulting in a high operation temperature and a short electron-phonon interaction time) and a small thickness (resulting in a short photon escape time from the film into the substrate) are desirable. The hybrid physical chemical vapor deposition (HPCVD) method developed for MgB_2 thin film deposition [1] can provide ultra-thin superconducting films of a high quality. A T_c of 36K (almost the same as for the bulk) can be achieved with films as thin as 3nm by thinning down thicker films by ion-milling [2]. The use of HPCVD MgB_2 thin films in HEB mixer fabrication will push the bandwidth above 10GHz and operation temperature above 20K, where compact cryocoolers might be used.

In this presentation we will discuss the in-house custom built HPCVD system for MgB_2 thin film deposition: construction and the deposition process development and optimization. The process was optimized aiming to achieve the ultra-thin films with a T_c in the order of bulk value keeping them homogenous and smooth. The inhomogeneity and high roughness of films can significantly affect the HEB mixers performance if they are scaling down to submicron dimensions, e.g. by reduction of T_c or increase of device resistance and consequently mismatch with antenna. The film parameters (such as critical temperature, sheet resistance, critical current density) of obtained films were measured; morphology (AFM), structure (XRD) of the films were also analysed concerning HEB mixer performance.

1. X. X. Xi et al, “MgB_2 thin films by hybrid physical-chemical vapor deposition,” *Phys. C Supercond.*, vol. 456, no. 1-2, pp. 22-37, 2007.
2. N. Acharya et al, “MgB_2 ultrathin films fabricated by hybrid physical chemical vapor deposition and ion milling,” *APL Mater.*, vol. 4, no. 8, p. 086114, 2016.