Study of the effect of annealing temperature on low-temperature-grown-GaAs photomixers

Siddhant Chowdhury,* Joshua R. Freeman, Mark C. Rosamond, Reshma A. Mohandas, Manoj Kumar, Lianhe Li, Paul Dean, A. Giles Davies and Edmund H. Linfield

School of Electronic and Electrical Engineering, University of Leeds, Leeds, LS2 9JT, U.K.

*el08s2c@leeds.ac.uk

Introduction

Photomixers are compact sources of continuous-wave (cw) terahertz (THz) radiation that operate at room temperature. Compared to pulsed excitation schemes commonly used in terahertz time domain spectroscopy, narrowband THz generation using cw excitation provides several advantages – namely, better frequency resolution, higher spectral power density, and the possibility of frequency tuning [1, 2].

We present a systematic study of the effect of annealing temperature on the performance of photomixers fabricated on LT-GaAs substrates, with a broadband log-spiral antenna and interdigitated electrode design. The measured emission bandwidths are understood in terms of the material resistivity and carrier lifetime, measured using a photo-correlation technique.

Methodology and Results

LT-GaAs films were epitaxially grown by molecular-beam epitaxy on semi-insulating GaAs substrates and annealed ex-situ at temperatures between 500-625 °C. Ti/Au (10 nm/ 150 nm) was patterned, using electron-beam lithography, evaporation and lift-off, on the substrates to form three pairs of interdigitated electrodes (0.2 μm wide with a 1.6 μm gap), centred in a three-turn self-complimentary broadband log-spiral antenna. The photomixers were characterised by heterodyne excitation using two commercially available, fiber-coupled, frequency tuneable cw diode lasers operating at ~780 nm. The generated radiation was collected and focused on a GaAs-based TOPTICA Photonics photomixing receiver using a hyper-hemispherical silicon lens and two parabolic mirrors.

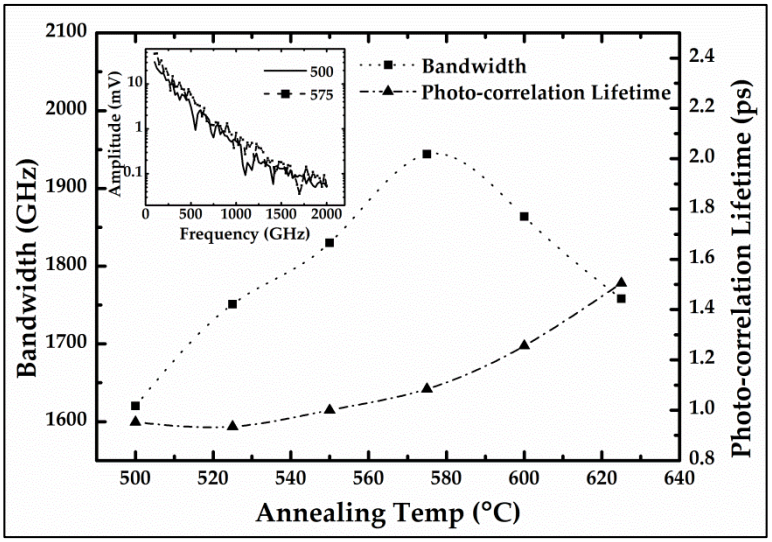

Fig 1: Comparison of bandwidth and photo-correlation lifetime of LT-GaAs photomixer at different annealing temperatures. (Inset) Heterodyne frequency response of two photomixers, annealed at 500 °C and 575 °C.

The bandwidth of the emitters was found to vary with annealing temperature due to changes in resistivity and carrier-lifetime of the material. Both the resistivity and carrier-lifetime increased with increasing annealing temperature. With increasing resistivity, a reduction in background noise lead to improved bandwidth but this was countered by an increase in carrier lifetime that acted to reduce the bandwidth. As such, the annealing temperature needs to be optimised to give high material resistivity and low carrier-lifetime for good CW performance. In this study, samples annealed at 575 °C were found to generate the highest bandwidths >1.9 THz, as shown in Fig. 1. In addition, photo-correlation measurements revealed a corresponding photo-correlation lifetime of 1.08 ps, as also shown in Fig. 1.

1. Preu, S., et al., *Tunable, continuous-wave Terahertz photomixer sources and applications.* Journal of Applied Physics, 2011. **109**(6): p. 061301.
2. Verghese, S., et al., *Generation and detection of coherent terahertz waves using two photomixers.* Applied Physics Letters, 1998. **73**(26): p. 3824-6.