Heterostructure-Based Photoconductive Terahertz Emitters

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Generation of THz radiation within a femtosecond mode-locked laser cavity using a photoconductive emitter was recently demonstrated [1]. The emitter is based on an AlGaAs/AlAs Bragg reflector with low-temperature-grown (LTG) GaAs. The LTG GaAs has two functions: as a saturable absorber and as an active photoconductive layer of the THz emitter. In order to achieve optimal emitter performance, we have focused on tuning the properties of LTG GaAs to maximise THz output power.

The THz emitter comprises a Bragg mirror stack made of the AlGaAs/AlAs layers and LT GaAs layer grown usually at 220 °C and annealed at 600 °C. The parameters of LTG GaAs strongly depend on the growth temperature and post-growth thermal history (i.e., annealing temperature and time). Changing growth temperature thus allows modifying the charge carriers' lifetime and mobility. In the standard LTG GaAs, the carrier lifetime is in the sub-picosecond range, while carrier mobility is about 30 times lower then in normal GaAs. Therefore, we have prepared a set of emitter structures with LTG GaAs grown at different temperatures between 220 and 350 °C.

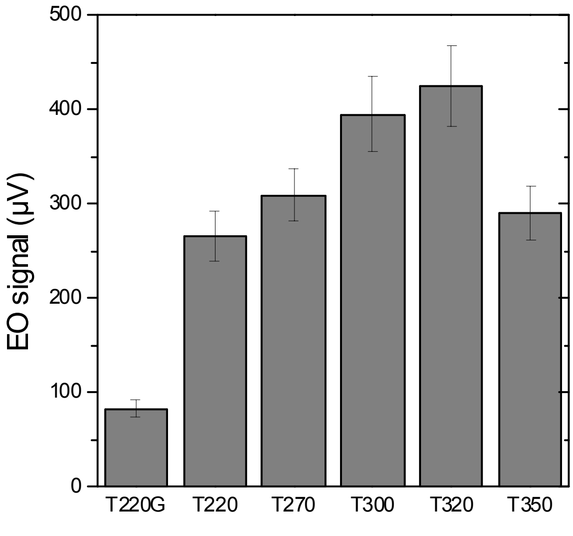

Fig. 1: Output THz radiation from LT/BR emitters with LTG GaAs layer grown at different temperatures. Emitters were biased at 150 V.

Figure 1 shows the output THz power from the emitter at a bias of 150 V. The efficiency of emitters increases with the LTG GaAs growth temperature, but for temperature of 350 °C efficiency already drops. The emitters are also compared to one labelled T220G (standard photoconductive THz emitter without Bragg mirror) exhibiting significantly lower THz emission efficiency. The gradual increase of emission efficiency with the LTG GaAs growth temperature is explained by a synergetic effect of longer lifetime and the higher mobility of charge carriers [2]. Final drop in THz emission efficiency is due to an enormously increased dark conductivity of the emitter.

Another problem that we have addressed is a fatal breakdown of the THz emitter when a certain optical power is exceeded. This breakdown is related to a local increase of the temperature of the emitter due to the deposited optical power. We have studied the thermal resistance of the emitter structures. An attenuated laser beam at 800 nm was focused to an area of about 100 µm in diameter. The local temperature was monitored by means of a deposited platinum strip. Figure 2 shows the thermal resistance we observed for four different emitters structures – LTG GaAs on GaAs substrate, with AlAs and AlGaAs/AlAs Bragg mirror stack, and SI GaAs substrate only. The LTG GaAs exhibits reduced thermal conductivity in comparison to the standard GaAs, therefore, all structures with LTG GaAs have a higher thermal resistance. The insertion of a thermally well conductive layer (AlAs or AlGaAs/AlAs) helps to reduce the overall device thermal resistance. In practice it means that the local temperature of the THz emitter can be reduced by more then 50 K when a convenient structure is used.

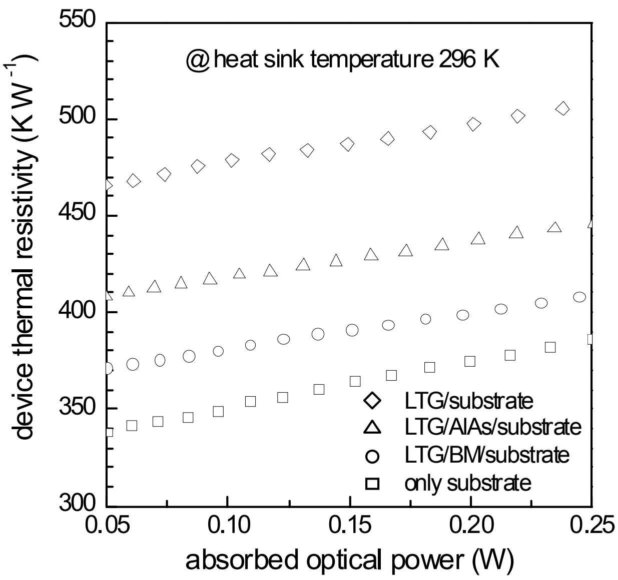

Fig. 2: Thermal resistance of THz emitters with different structure layout. The size of the focus was about 100 µm in diameter

In conclusion, we have improved the performance of the photoconductive THz emitter (i) by means of optimised parameters of the LTG GaAs active layer; and (ii) by improving the heat management of the emitter.

References

[1] J. Darmo, T. Müller, G. Strasser, K. Unterrainer, G. Tempea; “Terahertz emitter with an integrated semiconductor Bragg mirror”; Electron. Lett. **39**, 460-462 (2003).

[2] J. Darmo, J, Kröll, T. Müller, G. Strasser, and K. Unterrainer, “Cavity enhanced THz generation”, Terahertz and Gigahertz Electronics and Photonics III, part of the Photonics West Symposium Optoelectronics 2004: Integrated Optoelectronics Devices, San Jose, California, USA, 24-29 January 2004.