Low-Temperature-Grown Gallium Arsenide Photoconductors with Photoresponse reaching 25 mA/W under 1550nm CW excitation

C. Tannoury, M. Billet, C. Coinon, J-F. Lampin and E. Peytavit

Univ. Lille, CNRS, Centrale Lille, Univ. Polytechnique Hauts-de-France, UMR 8520 - IEMN, F-59000 Lille, France

***Abstract*— We show in this communication that photoconductors based on GaAs grown at low temperature can exhibit photoresponses as high as 25 mA/W under continuous-wave 1550-nm-wavelength illumination. It is achieved by using an optical Fabry-Pérot cavity in order to improve the external quantum efficiency and by decreasing the post growth annealing temperature down-to 450 °C.**

I. INTRODUCTION

Low-temperature-grown GaAs (LT-GaAs) photoconductors have been commonly used as THz sources or detectors in time-domain THz spectroscopy systems based on Ti:Sa mode-locked lasers operating around 800 nm. They have also been used as photoconductive switches to sample millimetre wave signals [1], as optoelectronic homodyne mixers in CW THz spectroscopy systems [2] and also as optoelectronic heterodyne mixers in THz detectors [3]. We have recently shown that LT-GaAs ultrafast photoconductors are able to operate at λ = 1550 nm, despite a photon energy E_{ph} ≈ 0.75 eV, i.e. lower than the energy gap of GaAs (E_g = 1.42 eV), by placing the LT-GaAs layer inside an optical resonant cavity [4]. These first results have been obtained by using a LT-GaAs layer grown at a temperature of 250±5°C and annealed at 580°C during 60 s. In this study, we show that photoresponses under CW illumination reaching 25 mA/W can be achieved by decreasing the post-growth annealing temperature down to 450°C.

II. RESULTS

The samples were fabricated using the following procedure: starting from a 450-µm-thick semi-insulating GaAs substrate, a 0.1-µm-thick GaInP etch-stop layer was grown by gas-source molecular beam epitaxy (GS-MBE) followed by a 500-nm-thick layer of low temperature grown (250 °C) GaAs. The GaAs wafer is subsequently cleaved into 4 pieces which are annealed at temperature T_A = 450°C, 500°C, 540 °C and 580 °C respectively. Four different samples (S_1, S_2, S_3, S_4) were then processed. On each one, the buried gold layer was obtained by bonding the LT-GaAs epitaxial layers onto 2-in.-diameter silicon wafers. This is done by using an Au-Au thermocompression layer bonding technique. To form an optical cavity (see Reference [4] for further details), a gold grating was patterned on the LT-GaAs layer by using electron lithography, electron beam evaporation, and lift-off techniques. Test structures for photocurrent measurement consist of a 60 × 55 µm^2 area optically opaque Au contact pad and a 60 × 75 µm^2 area grating of 300-nm-thick Au electrodes.

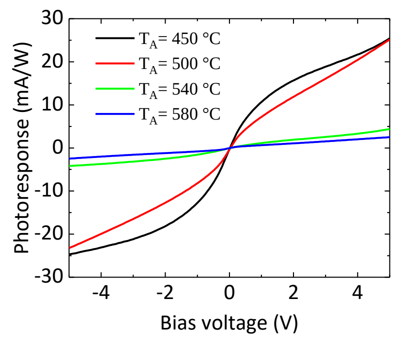

Fig. 1. Photoresponse-Bias voltage characteristics measured on optical cavity photoconductors fabricated using LT-GaAs layers grown at 250 °C and annealed at T_A= 450, 500, 540 and 580 °C.

First, the dependence of the dark resistivity ρ_d on the post-growth annealing temperature was evaluated by measuring the dark currents on the four samples as a function of bias voltage. Dark resistivities at zero bias voltage of around 200, 70, 150 and 15000 kΩ.cm have been obtained on the samples S_1, S_2, S_3, S_4 respectively. The photoresponse experiment was then conducted using a fiber coupled external cavity laser emitting at λ = 1550 nm. In Fig. 1 are shown the photoresponse (R) as a function of the bias voltage obtained with a CW optical power P_{opt} = 5 mW. It can be seen that at the maximum bias voltage, the samples S_1 (T_A = 450 °C) and S_2 (T_A = 500 °C) show a photoresponse 10 times larger than the sample S_4 (T_A = 580 °C). The increase of photoresponse is seen as a consequence of the increase of the optical absorption in the LT-GaAs layer due to a higher defect density. It has been shown that LT-GaAs photoconductors can be seen as a credible alternative to InGaAs-based ultrafast photoconductors for CW and pulsed THz optoelectronic application since they can potentially exhibit simultaneously a very high dark resistance and a high photoresponse under CW 1550-nm illumination.

REFERENCES

[1] G. C. Valley, "Photonic analog-to-digital converters.," *Opt. Express*, vol. 15, no. 5, pp. 1955–82, Mar. 2007.

[2] A. Roggenbuck *et al.*, "Coherent broadband continuous-wave terahertz spectroscopy on solid-state samples," *New J. Phys.*, vol. 12, no. 4, 043017, Apr. 2010.

[3] E. Peytavit, F. Pavanello, G. Ducournau, and J.-F. Lampin, "Highly efficient terahertz detection by optical mixing in a GaAs photoconductor," *Applied Physics Letters*, vol. 103, no. 20. American Institute of Physics, 201107, Nov. 2013.

[4] M. Billet, P. Latzel, F. Pavanello, G. Ducournau, J.-F. Lampin, and E. Peytavit, "Resonant cavities for efficient LT-GaAs photoconductors operating at λ = 1550 nm," *APL Photonics*, vol. 1, no. 7, 076102, Oct. 2016.