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Highly Resistive and Ultrafast Fe-Ion Implanted InGaAs for the Applications of THz Photomixer and Photoconductive Switch

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Abstract. We develop highly-resistive (*i.e.* low-carrier-density) and ultrafast Fe-ion implanted InGaAs layers for the applications of THz photomixer and photoconductive switch. The measured Hall mobility, sheet resistance, carrier density, and carrier lifetime of the optimized 1.2-μm-thick Fe-implanted InGaAs layer are 3.4×10^2 cm^2/Vs, 0.24 MΩ, 6.5×10^{14} cm^{-3}, and 0.13ps, respectively.

Keywords: terahertz, photomixer, InGaAs, photoconductive switch
PACS: 73.50.Pz(photoconductivity), 85.30.-z(semiconductor devices)

INTRODUCTION

Terahertz (THz) frequency sources have received considerable attention for their medical, agriculture, environmental, and security applications [1]. Over the past decades, significant progresses have been realized in the fields of THz time-domain spectroscopy (TDS) and frequency-domain spectroscopy (FDS) using photoconductive switch (PCS) and photomixer, respectively. Researches on both the PCSs and the photomixers have been mainly conducted using the low-temperature-grown GaAs (LTG-GaAs) due to its short carrier lifetime and high resistivity (*i.e.* low carrier density). Recently, there have been several reports on LTG-InGaAs or ion-implanted (IM) InGaAs that can act as a photoconductive material aiming at the connection between the THz and the well developed InP-based communication technologies [2, 3]. However, the InGaAs based photomixers have the critical problem of high dark current, which is not acceptable for efficient THz emission because of background thermal radiation as well as low thermal-damage threshold. Consequently, the reported THz powers from InGaAs-based photomixers are several ten times lower than those from typical LTG-GaAs photomixers. Therefore, more thorough studies on the material optimizations would be needed for achieving more efficient and widely-tunable InGaAs-based photomixers. In this work, we develop a highly-resistive (*i.e.* low-carrier-density) and ultrafast Fe-ion implanted InGaAs layer for the applications of THz photomixer and PCS.

FABRICATION AND RESULTS

An 1.2-μm-thick undoped $In_xGa_{1-x}As$ (x=0.53) epilayer was grown on a semi-insulating InP substrate at 650°C by using a MOCVD system. The as-grown wafer was split to several pieces which were implanted by Fe ions with various ion energy and dose conditions. Each as-implanted piece sample was further split to several pieces for various post rapid-thermal-anneal (RTA) processes. All the post RTA processes were conducted in H_2 environment in just 30 seconds. Figure 1 shows the Hall measurement data against the post RTA temperature for various implantation conditions. The black, red, green, blue, cyan, and magenta lines in Fig. 1 correspond to the Fe-ion energy / dose conditions of 2.3MeV / 2×10^{15}cm^{-2}, 2.3MeV / 1×10^{15}cm^{-2}, 2.3MeV / 6×10^{14}cm^{-2} + 0.7MeV / 2×10^{14}cm^{-2}, 2.3MeV / 3×10^{14}cm^{-2} + 0.7MeV / 2×10^{14}cm^{-2}, 3.0MeV / 2×10^{15}cm^{-2}, and 3.0MeV /

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$1x10^{15}cm^{-2}$, respectively. The Hall mobility increases with RTA temperature as shown in Fig. 1, which is consistent with the data in [3]. And the carrier density decreases with RTA temperature, which is also an expected phenomenon because of the curing of the shallow donor defects generated during implantation. As one can see in Fig. 1, the optimized Fe-ion energy, dose, and post-RTA temperature giving the lowest carrier density are 3.0 MeV, $1x10^{15}$ cm^{-2}, and 500°C, respectively. In the optimized condition, the measured Hall mobility, sheet resistance, and carrier density are $3.4x10^{2}$ cm^{2}/Vs, 0.24 MΩ, and $6.5x10^{14}$ cm^{-3}, respectively.

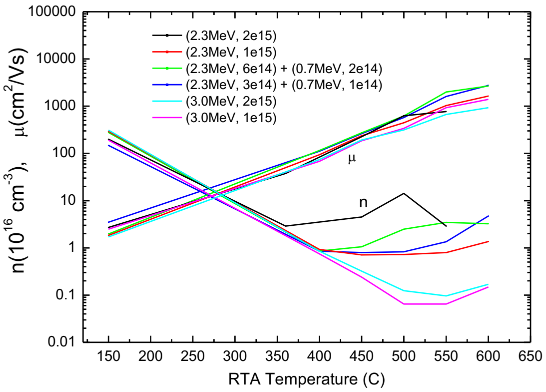

FIGURE 1. Hall data of the various Fe-implanted InGaAs layers.

The carrier lifetime was measured by using a time-resolved pump-probe time-resolved reflection spectroscopy (TRS). Figure 2 shows the result of the TRS experiment. The measured carrier lifetime is about 0.13 ps which is the lowest value ever reported.

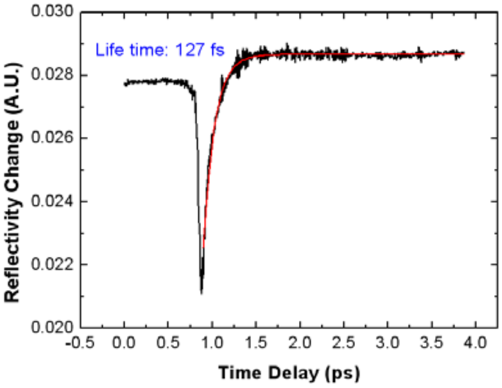

FIGURE 2. Result of the pump-probe reflection spectroscopy of the Fe-implanted InGaAs layer.

The details about electrical and optical properties of the Fe-implanted InGaAs layer will be presented in the conference. The fabrication of photomixers and PCSs with the Fe-implanted InGaAs layer is under way for efficient and broad-band THz generation.

CONCLUSIONS

We develop highly-resistive (*i.e.* low-carrier-density) and ultrafast Fe-ion implanted InGaAs layers for the applications of THz photomixer and photoconductive switch. The measured Hall mobility, sheet resistance, carrier density, and carrier lifetime of the optimized 1.2-μm-thick Fe-implanted InGaAs layer are $3.4x10^{2}$ cm^{2}/Vs, 0.24 MΩ, $6.5x10^{14}$ cm^{-3}, and 0.13ps, respectively. The fabrication of photomixers and PCSs with the Fe-implanted InGaAs layer is under way for efficient and broad-band THz generation.

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