CONF-8608147--2

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

LA-UR--86-4285

DE87 003744

TITLE GaAs Photoconductors to Characterize Picosecond Response
in GaAs Integrated Devices and Circuits

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SUBMITTED TO International Conference on High-Speed Electronics,
Stockholm, Sweden, August 7-9, 1986

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GaAs Photoconductors to Characterize Picosecond Response in GaAs Integrated Devices and Circuits

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1. Introduction

Optoelectronic techniques that use femtosecond lasers and promise the precise measurement of transient response in high speed electronic devices and circuits have been under study for several years. We have investigated on-wafer electrical-impulse generation and sampling using femtosecond-laser-excited GaAs photoconductors. This approach is applicable to any transmission line structure, it is directly integrable, non-invasive, jitter-free, and it is applicable to both microwave and digital circuits.

We have developed the capability to: a) generate electrical impulses in on-wafer GaAs transmission lines with 3-dB bandwidths in excess of 60 GHz, and b) sample the electrical impulse response of an on-wafer test structure without jitter and with a 3-dB measurement bandwidth of 103 GHz at a noise level of -67 dBm. We have studied dispersion in GaAs on-wafer coplanar-waveguide transmission lines.

2. Sample Preparation and Experiment

We prepared on-wafer photoconductor pulse generators and sampling gates in coplanar waveguide transmission lines on 625- μm -thick Cr-doped semi-insulating GaAs wafers. Center conductor widths were 67 μm and the spacing to the ground planes was 33 μm . This gave a characteristic impedance of approximately 50 ohms and a cut-off frequency of approximately 100 GHz. The photoconductor pulse generators consisted of 25 μm gaps in the center conductor. Photoconductor sampling gates were placed at 33, 400, and 1200 μm distances from the pulsers. The test structures were formed with evaporated AuGe alloy, patterned with lift-off photolithography, and annealed at 425°C for 2 minutes.

In order to produce photoconductors on GaAs with picosecond response we used ion-beam irradiation to introduce point defects into the semi-insulating substrate. This structural damage produces deep-level trapping sites that reduce carrier-relaxation time in the crystals. The samples were damaged with a dose of $5 \times 10^{14} \text{ cm}^{-2}$, 6 MeV He ions. This dose produces a uniform point-defect density of $2 \times 10^{19} \text{ cm}^{-3}$ in the top 3 microns of the GaAs substrate. Increasing the ion-beam-damage dose above this level caused the material to become conductive.

Optoelectronic correlation measurements were performed on these test structures using a colliding-pulse modelocked dye laser producing 0.2 ps optical pulses at a wavelength of 620 nm, and a repetition rate of 125 MHz.

3. Experimental Results and Analysis

Figure 1 shows a measured optoelectronic correlation from an on-wafer GaAs photoconductor pulse-generator/sampler pair. A fit to the measured correlation using the photoconductor model of D. H. Auston [1] allows us to separate the correlation into the sampling aperture function and the

actual electrical pulse shape. In the fit we allowed the carrier relaxation in the pulser and sampler to vary independently. The best fit to the experimental correlation is shown in Fig. 1, along with the derived sampler aperture function and the electrical pulse shape.

Fig. 1.
Measured optoelectronic correlation between on-wafer GaAs photoconductor pulse generator and sampling gate. The raw data were fit with the model due to D. H. Auston to derive the sampling aperture function and electrical pulse shape. These are also shown

Data from our test structure permitted us to investigate pulse propagation in coplanar-waveguide transmission lines. Figure 2 shows measured correlations taken at distances of 33, 400, and 1200 micron distances from the photoconductor pulse generator. The data indicate that coplanar waveguide has very low dispersion. The data show no degradation in the 3.3 ps risetime of the correlation over the full 1.2 mm propagation length.

4. Summary and Conclusion

In summary we have developed on-wafer GaAs photoconductors that should permit measurements of transient response in GaAs devices and circuits with overall measurement bandwidths greater than 50 GHz and time resolution of 2.2 ps. Because of the absence of jitter in these electrical measurements it should be possible to characterize integrated GaAs devices and circuits at frequencies up to hundreds of GHz. Also we have shown that coplanar waveguide is a very low dispersion, scalable, all-planar transmission line that is very attractive for these time-domain measurements.

Fig. 2.
Measured optoelectronic correlations taken with photoconductor sampling gates at distances of (a) 33, (b) 400, and (c) 1200 microns from the photoconductor pulse generator

REFERENCE

- [1] D. H. Auston, "Impulse response of photoconductors in transmission lines," IEEE J Quantum Electron., Vol. QE-19, pp. 639-648, 1983.