Grafted GaAs Detectors on Lithium Niobate and Glass Optical Waveguides

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Abstract—**We report the first integration of a GaAs MSM (metal-semiconductor-metal) detector with $LiNbO_3$ and glass optical waveguides. A 250 nm thick GaAs detector layer was fabricated using a recently reported liftoff technique [1] and subsequently grafted onto the waveguide chip. Proof of the optical interaction between the waveguide and its grafted detector was provided by the total absorption of 633 nm guided light within a distance of ~1 mm from the leading edge of the GaAs layer and by the presence of a photocurrent at the detector terminals. We project that the grafting technique reported here will prove useful in the design of new and cost effective optoelectronic devices.**

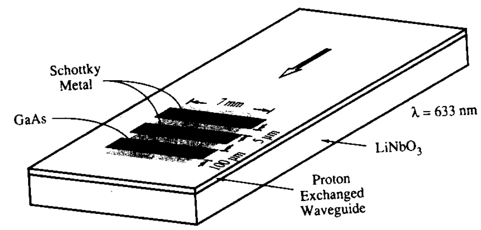

Fig. 1. Grafted GaAs MSM detector on planar proton exchanged (PE) $LiNbO_3$ waveguide.

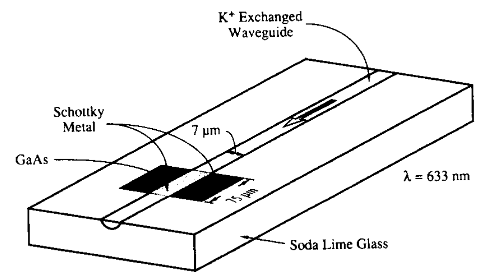

Fig. 2. Grafted GaAs MSM detector on K^+ exchanged glass waveguide.

Introduction

THE design of integrated optical components for fiber communication systems has centered, in the past decade, on three major material groups: glass, $LiNbO_3$, and III–V semiconductors. The salient features of each material group are well known: low-loss waveguides in glass, polarization control and high electrooptic coefficients in $LiNbO_3$, and bandgap engineering in the III–V compounds to realize sources, detectors, and high-speed electronic devices.

Considerable effort has recently been devoted to the realization of optoelectronic integrated circuits (OEIC's); for this purpose, the III–V compound materials have been the natural choice because sources and detectors cannot be made in glass or $LiNbO_3$. Although most of the optical functions demonstrated in glass and $LiNbO_3$ have been replicated in III–V semiconductors, their performance has, in general, been compromised either by material limitations or the compatibility of epilayers in a multitask function. Ideally, monolithic OEIC's integrating state-of-the-art devices from each material group are desirable; however, the disparity between materials has made this proposition less realistic.

In this work, we report on the first integration of a III–V semiconductor detector with $LiNbO_3$ and glass waveguides using a recently reported liftoff technique. The feasibility of optical interaction between the waveguide and its optically grafted detector has been verified. This result opens up possibilities for the design of novel, efficient, and cost effective optoelectronics devices.

Fabrication

The undoped GaAs detector layer was grown by MBE to a thickness of 250 nm on top of a 50 nm thick AlAs liftoff layer which had been previously deposited, also by MBE, on a GaAs substrate. Chips of approximate dimensions of 3 mm × 7 mm were cleaved off the wafer and immersed in buffered HF. Because of the preferential etching of AlAs by the acid, the GaAs epilayer is lifted off from the substrate and subsequently deposited on the surface of the waveguide chip where, once dried, is bonded by van der Waals forces.

The optical waveguides were fabricated before the epilayer transfer. Planar $LiNbO_3$ waveguides were obtained by proton exchange of z-cut crystals in pure benzoic acid at a temperature of 230°C for an exchange time of 2 h 45 min. Stripe glass waveguides were fabricated using the sodium–potassium exchange process, through an Al mask, of soda lime glass in a KNO_3 melt held at 375°C for an exchange time of 2 h.

Following the grafting of the epilayer film on the surface of the waveguide, Schottky metal was evaporated and subsequently patterned to form the MSM detectors. For planar waveguides, an array of detectors comprising 100 μm wide metal strips separated by 5 μm gaps was fabricated, each metal electrode running perpendicular to the direction of light propagation and extending along the length of the GaAs epilayer (see Fig. 1). For stripe waveguides, the GaAs was etched before Schottky metal deposition leaving detectors with a length of 75 μm and with a width of 7 μm to match the width of the waveguide (see Fig. 2).

Manuscript received July 13, 1989.
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IEEE Log Number 8931450.

1041-1135/89/1100-0379$01.00

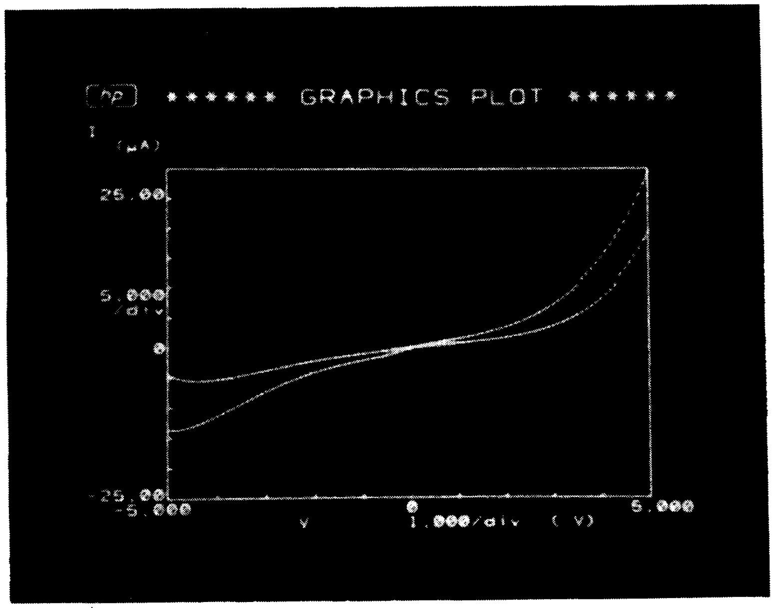

Fig. 3. Photoresponse of MSM detector on PE-$LiNbO_3$ waveguide.

It must be pointed out that no attempt has been made to optimize the optical and electrical parameters of these devices as the main purpose of this work has been to demonstrate the feasibility of optically grafting two different materials and establish interaction between them. Detailed analysis on these devices will be reported in the future.

Results

Linearly polarized light from a 633 nm HeNe laser was launched into the $LiNbO_3$ waveguide using rutile prism. The waveguide was found to support two TM modes. The guided modes were observed to be absorbed by the GaAs epilayer within a distance ~1 mm from the leading edge of the film. Photocurrent measurement at the first two detectors was performed with a 5 V bias and ~0.5 mW incident laser power; a reading of 6 μA was obtained for the first detector, ~150 μm behind the leading edge of the GaAs film, while the photocurrent at the second detector, 100 μm behind the first, was 4 μA. These figures correspond to a waveguide-detector absorption coefficient of 40 cm^{-1}. Fig. 3 shows $I-V$ curves for the TM_0 mode.

Endfire technique, by means of a fiber, was used to launch unpolarized 633 nm light into the stripe waveguide. In this case, only partial absorption of the guided light was observed (detector length: 75 μm) and a photocurrent of 120 nA was measured at a biasing voltage of 5 V (see Fig. 4). The absorption coefficient is estimated to be 0.14 cm^{-1}.

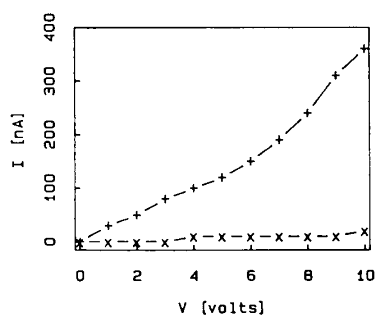

Fig. 4. Photoresponse of MSM detector on K^+ exchanged stripe waveguide.

Conclusions

MSM GaAs detectors have been successfully integrated with $LiNbO_3$ and glass waveguides using a liftoff technique. Optical coupling between the waveguide and its optically grafted detector has been verified by the absorption of guided light in the detector layer and the presence of a photocurrent at the detector terminals. This grafting technique is expected to prove very useful in the design of new, efficient, and cost effective optoelectronic devices.

References

[1] E. Yablonovitch, T. Gmitter, J. P. Harbison, and R. Bhat, *Appl. Phys. Lett.*, vol. 51, p. 2222, 1987.