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Abstract: For the InP Membranes On Silicon (IMOS) platform [1], we developed an electro-optic modulator based on a slot-waveguide with a high nonlinear polymer. A variety of fabrication techniques are used, including electron beam lithography (EBL), optical lithography (OL), dry etching and metallization. The fabrication of such modulator requires a complex fabrication process. In this work we present and discuss the most important fabrication steps.

It has become clear that in order to have a competitive photonic integration platform, high performance devices have to be included. A Mach-Zehnder interferometer structure with a phase modulator based on a slot waveguide with a highly nonlinear electro-optic polymer is a good candidate [2]. The high confinement of the optical electric field inside the low refractive index area in the slot waveguide, allows a high overlap with an electro optical polymer, letting to an effective phase modulation. We have predicted that this device working at $V_\pi = 1.2\,V$ and having a length of $750\,\mu m$ can have a $V_\pi \times L = 0.7Vmm$ and a bandwidth higher than 40GHz.

To fabricate this device we need five EBL steps and one OL step. The first two lithographic steps (E-beam) are the definition of the alignment marks and the grating couplers. A ZEP/C_{60} resist in combination with a SiN_x mask is used for this purpose. The etching of the semiconductor is performed with inductively coupled plasma (ICP) dry etching using a methane-hydrogen chemistry (CH_4:H_2). ZEP/C_{60} resist was used because it gives better control of the dimensions and higher resolution of the structures than normal ZEP [3].

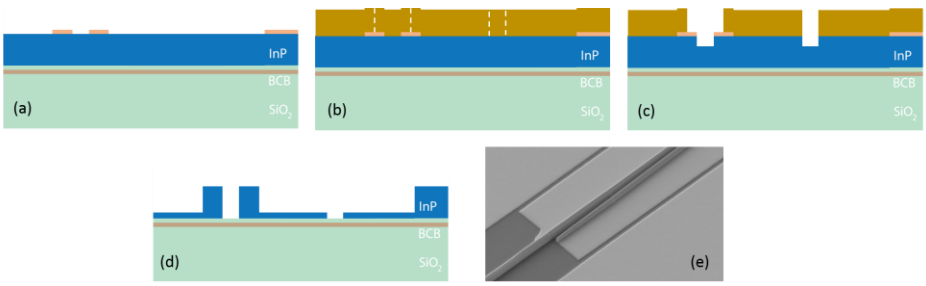

Fig. 1. (a) Hard mask definition (SiNx). (b) Definition of the opening areas. (c) Etch of the opening areas. (d) Schematic of the final structure. (e) SEM picture of fabricated slot waveguide and the spot-size converter to normal stripe waveguide.

The third and fourth EBL steps define two different height levels with a high resolution overlay exposure (a few nanometres tolerance). One level of footing which electrically connects the slot waveguide with the metal contacts (n-doped InP), and the second level which define the electric isolation section. A self-alignment technique is used to overcome the narrow tolerance. Fig. 1 illustrate this process. In the first step the slot waveguide is defined, as in the previous lithographic steps, with ZEP/C_{60} resist in combination with a SiN_x

mask. When the hard mask is defined. We remove the resist with an oxygen plasma (Fig. 1-a). The next step consists of depositing a new layer of ZEP/C_{60} resist and exposing the areas where an electrical isolation is needed. Because the real definition of the waveguide is given by the hard mask already present, this exposure has a good tolerance to misalignment (Fig. 1-b). When we have developed the resist, we etch the sample with an ICP process with a depth for around 100nm, which will be enough to assure the electrical isolation (Fig. 1-c). Finally, we remove the ZEP/C_{60} resist with an oxygen plasma process and we continue the etching with ICP until we reach the desired footing thickness (~50nm). We remove the hard mask with a reactive ion etching (RIE) process thereby obtaining our two level structures (Fig. 1-d).

The next step consists of the fabrication of the contacts. We need to have the contacts outside the MZ structure, to optimize the microwave properties and obtain good RF performance. This can be done with a two-level contacts scheme, as Fig 2(a) illustrates. To do so we start spinning a layer of polyimide of at least $1\mu m$ thick to avoid absorption when the metal cross the waveguide underneath. After the polyimide layer is deposited, we spin 2.5 μm of negative photoresist (MaN 440). We define the areas where the metal will contact the semiconductor with optical lithography. When these areas are developed, we reflow the resist at 140°C to create a slope at the pattern edges. Using a polymer RIE process we transfer the slope from the photoresist to the polyimide. This is possible because they have the same etch rate. We remove the rest of the photoresist using acetone. Having created the slope, we define the metal contacts with an EBL step using PMMA photoresist and evaporate the metals (Ni(30nm):Ge(50nm):Au(250nm)). Finally we do a lift-off. Fig 2(b) illustrates a fabricated MZ device. The last step which has not yet be implemented is the deposit and poling of the electro optical polymer.

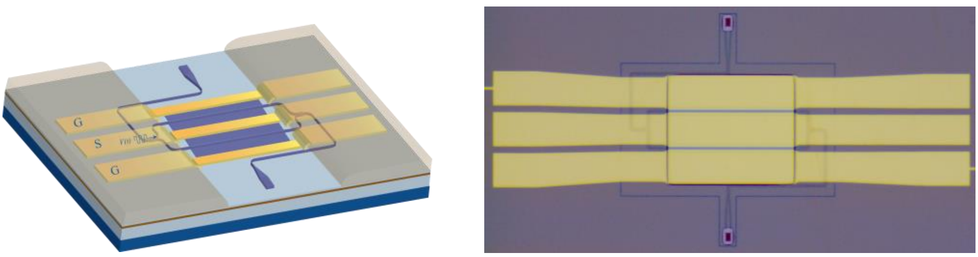

Fig. 2. (a) Illustration of the MZ device where the two levels metal contacts are clearly seen. (b) Picture of the fabricated MZ modulator

In conclusion we have shown a general overview of the processing technology to fabricate an electro-optic modulator based on slot waveguides in a Mach- Zehnder configuration. The most critical steps and their results have been presented and demonstrated. The fabrication is almost finished and it is ongoing. Acknowledgments: This work was supported by the ERC Project NOLIMITS and NANOLAB TU/Eindhoven

References

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