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TECHNOLOGY PROCESS FOR A LARGE VARIETY OF POLYMERS

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Abstract: Progress in chemical engineering provides new chromophores with higher $\mu\beta$ as well as more and more stable crosslinked polymers. This leads to new potentialities and possibilities for high-performance electrooptic devices. However their use in integrated optics is limited by aggressive technological processes. In microelectronics, photolithography uses photosensitive resists to transfer pattern on a substrate. Resist nature is similar to polymer's one and in most case polymer may be damaged either by resist spinning or resist removal. Nowadays solvents like alcohol or acetone are quite unavoidable in semi-conductor process but incompatible with polymers.
A fabrication process for polymer based electro-active integrated optics has been developed. Each of this steps fulfills the following conditions: no acetone, no alcohol, shorter contact with solvents, as few chemical contacts as possible and temperature compatibility. We success in determining a process which could be suitable for a large variety of polymers and with the previous propositions. The fabrication and characterization of a microstrip line on polymer which could be used as a traveling electrooptic modulator electrode has been demonstrated.

1 Introduction

In semi-conductor processing, polymers are classically divided in two groups: photosensitive resists and passivation polymers. As bastards of both groups, functionalized polymers face a dilemma:

- to resist to usual technology and to aging, whereas glass/liquid phase transition of polymer is typically in the range 100-200°C, and acetone is a good solvent of them;
- to be soft enough for patterning. For instance, highly crosslinked or thermosetting polymers are resistant to chemical and mechanical aggressions, but hard to process and lead to rough surface.

A drawback of chemical engineering is that every polymer might have their own technological process. Several processing approaches have been reported, among these we find technologies from plasturgy like molding [1,2,3] but they are not easily adaptable for micro-electronics. Another approach consists in spinning functionnalized polymer at the last process step [4] in order to limit strains. This technology is yet limited and does not exploit the whole potential of polymers. We chose to keep semi-conductor type technology and match it to polymer requirements. We validate the two main elementary process steps for a large variety of polymers :

- Definition of electrodes on polymer
- Patterning of polymer

Using this technology, we demonstrate a micro-strip line on polymer up to 40 GHz suitable for a traveling-wave modulator design.

2.Basic technological steps

2a).Definition of electrodes

Lift-off metallization technique can not be applied to polymers since it requires to dip the sample into solvents for several minutes and generally polymers do not resist to this treatment. So we adopt the other technique, i.e. metal etching. Technological process is represented on figure 1.

Step1 : Sputtering of 400 Å gold on polymer | Step2 : Photolithography | Step3 : Gold electroplating | Step4 : Resist and sputtered gold film removal

Figure 1: Definition of electrodes

Concerning step 4, the first gold layer can be etched by different chemical ways. We tested $HCl/HNO_3/H_2O$ (« eau régale » in french) which pH is under zero, and $I_2/KI/H_2O$ solution which initial pH is 6 and decreases with gold etched quantity. Since gold layer is thin, we have chosen $I_2/KI/H_2O$ for fast and polymer-inert etch.
To avoid acetone and alcohol, resist is removed by full-sheet insulation and development.
This process presents many advantages:

- A thin gold layer protects polymer from resist solvents and developers [5,6].
- Electroplating solution pH about 7 and temperature about 45°C are not aggressive for polymer. The gold growth is fast: several micrometers are easily deposited, this is important to reduce microwave losses.
- Thin gold layer permits well-defined patterns. Wet etching undercut is of the order of the layer thickness (i.e. 400 Å thin layer ≅ 400 Å undercut).
- Combining isotropic sputtering and electrolysis, we can grow gold on vertical walls (see figure 2). This can lead to new structures of electrodes on polymers and especially for interconnection with planar circuits.

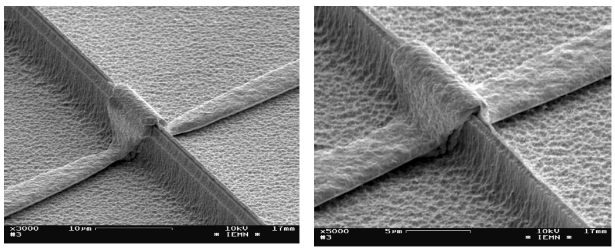
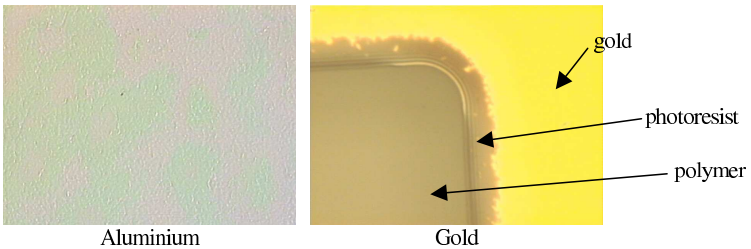


Figure 2 : Gold electroplating on vertical polymer wall

2b).Patterning of polymer

Because of our requirements (i.e. no contact with resist solvents) and etching depths, we chose inorganic masks. Silica protective coatings have been tested but silica, deposed by 200°C (high temperature degrades polymer)-Plasma Enhanced Chemical Vapor Deposition, is strained and forbids any further steps. Metallic masks could be good

candidates : deposited at room temperature, malleable, they form a solvent-proof coating. We have tested aluminium and gold because their removal is relatively inert with polymers : $NaOH/H_2O$ for aluminium and $I_2/KI/H_2O$ for gold. Since aluminium is naturally oxidised, it makes chemical links with polymers and its removal damages polymer surface (see figure 3 left). On the other hand, gold is not easily oxidised and does not react with polymer. Its removal keeps polymer surface clean (see figure 3 right).



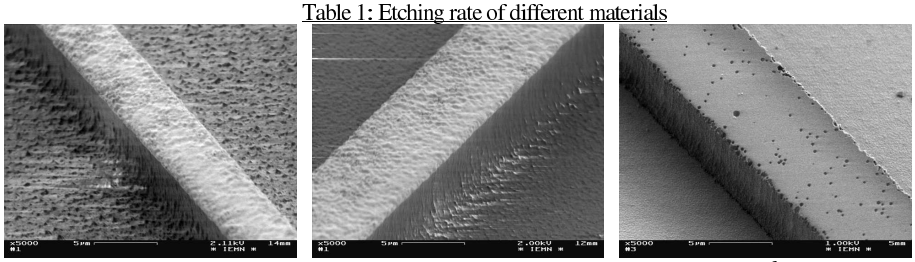
Aluminium Gold

Figure 3: Polymer surface after removal

We chose gold and use the same process as described in previous paragraph to pattern the mask. Gold is relatively insensible to oxygen plasma and a thin (about 400 Å) layer is sufficient to etch several micrometers of polymer. But even at low power, oxygen plasma voltages are several hundred volts (table 1) and R.I.E. damages the optical properties (transparence) of polymer [7] (see figure 4). Moreover, a silica layer is formed during organosilicon polymer [8] oxygen plasma and etching is stopped. An hexafloruride sulfur addition in the plasma etches silica, decreases etching voltage and improves etching rate (table 1). Gold is however sensitive to this O_2/SF_6 plasma (its etching rate is given in table 1); a gold/polymer thickness ratio about 30 leads to a remaining thin gold layer after the plasma etch which is easily and quickly removed .

Materials	Gaz and Flow	Power	Pressure	Voltage	Etching rate
Ultradel 9020	0_2 20 sccm	100 W	0.35 T	300 V	2000 Å/min
Ultradel 9020	0_2 40 sccm SF_6 5 sccm	100 W	0.2 T	200 V	2500 Å/min
PMMA-DR1	0_2 40 sccm SF_6 5 sccm	100 W	0.35 T	80 V	7000 Å/min
PMGI SF11	0_2 40 sccm SF_6 5 sccm	100 W	0.2 T	200 V	2200 Å/min
Gold	0_2 20 sccm SF_6 5 sccm	100 W	0.35 T	80 V	70 Å/min

Table 1: Etching rate of different materials



with 200 V.R.I.E. with 80 V R.I.E. at the end of a process

Figure 4: Polymer strips in Ultradel © 9020 (Amoco)

3.A micro-strip line on polymer

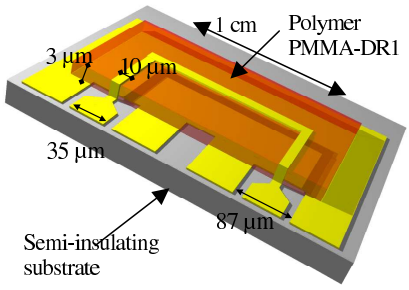


Figure 5 : The micro-strip line and its coplanar transition

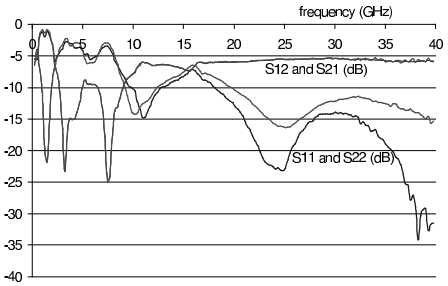


Figure 6 : Measured scatter parameters

With the developed process, we produce a micro-strip line suitable for an electro-optic traveling wave modulator. The micro-strip/coplanar transition allows repetitive probe measurement since there is no more sensitivity to probe pressure on the polymer. The results for a one centimeter long line show constant insertion losses (S_{12} and S_{21}) from 10 Ghz up to 40 Ghz at a value around -5 dB. Reflection coefficients (S_{11} and S_{22}) are lower than –10 dB on the same range. The behavior under 10 GHz is still being studied.

4 Conclusion

We develop an acetone-free and alcohol-free fabrication process for polymer based integrated optics. Respecting macroscopic polymer requirements, like temperature (always under 110°C), acidity or basicity (4<pH<7) and solvent contact limitations, the process could be extended to a large variety of polymers. We demonstrate a micro-strip line on PMMA-DR1 and its electrical characterization has been made up to 40 GHz owing to an integrated coplanar-microstrip transition.

Acknowledgements

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