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Abstract: The InP Membrane on Silicon (IMOS) generic technology promises high index contrast photonic integrated circuits. To make this a reality fabrication of an electrically pumped twin-guide laser is pursued. In this paper, one of the bottle-necks for the processing is discussed, the planarization step and subsequent etch-back. Benzocyclobutene (BCB) is used to planarize SOA structures before contacting. Complete curing of BCB at 280^{o}C creates uniformity issues during etch-back. To mitigate this, a partial cure at 180^{o}C before the etch-back and a complete cure afterwards is performed. Experiments show repeatability and reproducibility. Good uniformity after etch-back is found.

Introduction

InP Membrane on Silicon (IMOS) is a novel technology to realize high index contrast photonic integrated circuits. Passive components such as single mode waveguides, 1x2 MMI couplers, ring resonators and polarization converters have already been fabricated and characterized [1]. The next step in the development of this technology is to make active components such as electrically pumped lasers. Feasibility studies of such lasers on the IMOS platform have been reported in [2]. Furthermore, different configurations for such a laser integrated with other components have been designed [3].

As part of the process flow, one of the fabrication steps involves planarization of the SOA structures for p-metal definition. The schematic for this is shown in Fig.1. Divinylsiloxane-bis-benzo-cyclobutene (DVS-BCB, in short BCB) is the obvious candidate of choice for this purpose, based on its physical properties, such as the high degree of planarization, low moisture absorption, low curing temperature, excellent chemical resistance, low dielectric constant, rapid curing, low viscosity and

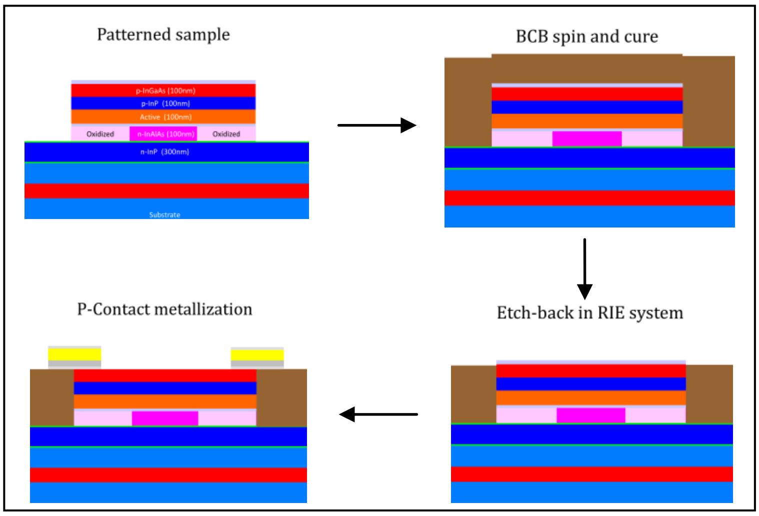


Fig.1: Schematic of the planarization and metallization process.

dry-etch compatibility [4].
The procedure involves spinning BCB on top of the patterned sample, curing, and etching back the cured BCB in a reactive-ion etching (RIE) system to expose the semiconductor surface for contacting. However, complete curing at 280^{o}C followed by etch-back in the RIE system creates non-uniformities in the etch-depth at different positions on the sample. Possible cause could be solidification of BCB after complete curing at 280^{o}C (see Fig.2) leading to larger thermal non-uniformities affecting the reaction rates at different positions. With the step height on the patterned sample being only 400 nm, a non-uniformity of 300 nm is not tolerable. This could result in the p-contact metal reaching the n-doped side of the diode, giving a short circuit. To alleviate this problem and to have better uniformity over the entire sample, a new recipe is developed. This involves a partial cure at 180^{o}C, followed by etch back in a RIE system. Because of the partial preservation of fluidity, a reflow and a better thermal conductivity is obtained, creating a better uniformity. Finally, a complete cure at 280^{o}C is performed. The detailed procedure is described in the next section.

Planarization technique

As described in the previous section, a new recipe is developed to mitigate uniformity issues during etch-back. A thin layer (70-80 nm) of PECVD SiO_x is deposited on the patterned sample to improve the adhesion of BCB to the surface. BCB is spin-coated at 3000 rpm and the sample is placed inside a baking oven for curing. Partial curing at 180^{o}C is performed for one hour. For these conditions, as is evident from Fig.2, the extent of cross-linking in the polymer is around 50%.
After the spin coating and the partial cure, the step-height in the patterned substrate is reduced from 400 nm to ~ 40 nm clearly showing the planarization property of BCB. The total thickness of the BCB layer itself is ~ 1.3 µm. This has to be reduced to 400 nm or a little less, to expose the semiconductor surface for further processing. For this, an

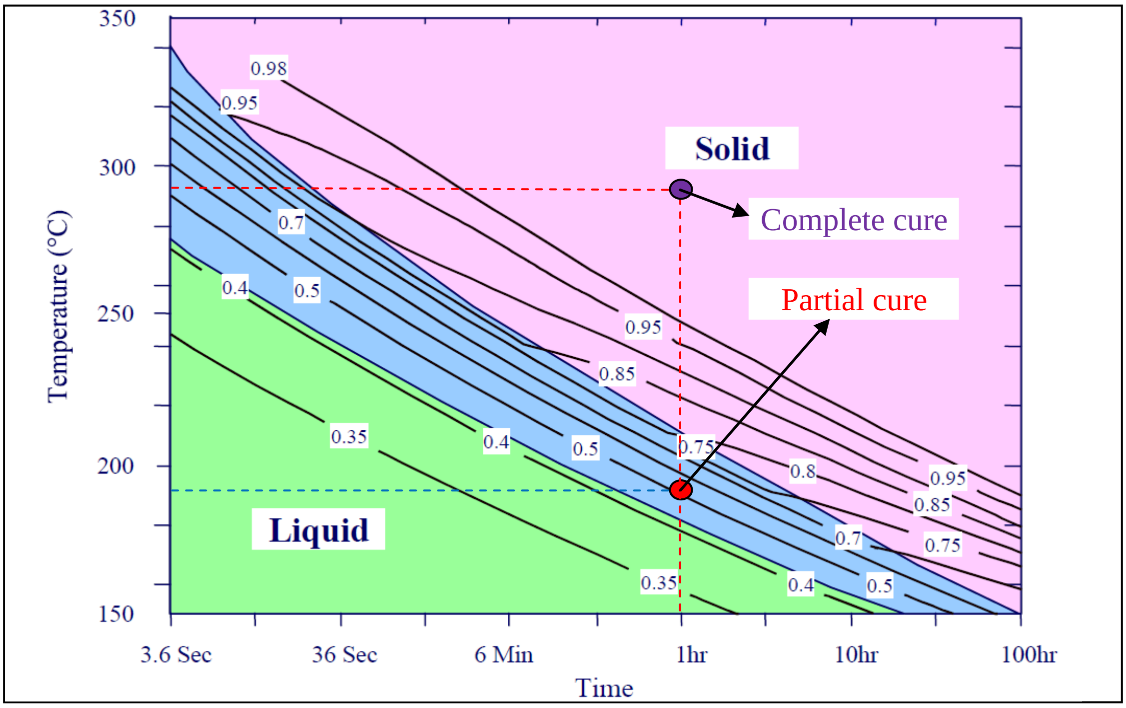
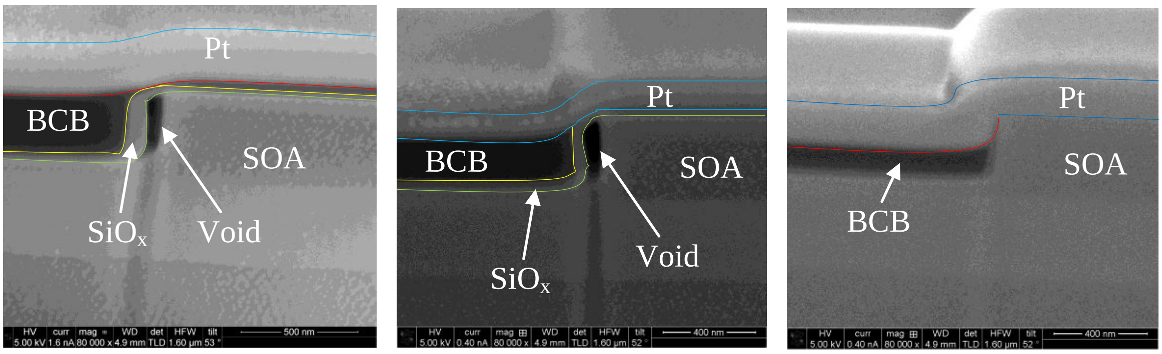


Fig.2: Extent of BCB cure (cross-linking fraction) as a function of temperature and time

etch-back is performed in a RIE system for polymers with a combination of CHF_3 – O_2 gases. The RF power, the chamber pressure and the flow rates of both these gases are optimized for BCB etching. The reaction is dependent on the temperature and the chemical reaction itself is exothermic. These factors, combined with the low thermal conductivity of BCB, could result in localized points with higher etch rates. To avoid non-uniformities from such effects, the etch-back is done in short cycles (1 minute), allowing a cooling down phase in-between. After every step, height variations are measured at nine different positions on the sample.

After sufficient etch-back, SiO_x layer on the semiconductor surface is exposed. The sample is subjected to another curing step at 280^{o}C for one hour. In this step, BCB is almost completely cured and solidifies into a harder, uniform layer (Fig.2). As a final step, the SiOx is etched in a RIE system. This exposes the semiconductor surface for further processing: p-contact definition and metallization. A uniformity of within 50 nm between the nine different measurement positions is obtained. The test is repeated several times to check for reproducibility.

During the test runs, FIB cuts are performed at all the intermediate steps to check the BCB and SiO_x layers (Fig.3). Platinum is evaporated locally before the cut to avoid deformation of the top surface during the cut. While planarity and uniformity are apparent from these images, sometimes as seen in Fig. 3 (a) and (b), voids are observed at the edges of the SOA structures. An explanation could be that during the curing steps there is shrinkage in the BCB, and the adhesive force of the SiO_x on the semiconductor surface is not large enough to resist this.



(a) *(b)* *(c)*

Fig.3: FIB images of the etch-back process after (a) Partial BCB etch, (b) Complete BCB etch, and (c) Complete SiO_x etch.

Conclusions

BCB is used to planarize SOA structures before contacting. To mitigate uniformity issues with complete curing at 280^{o}C, a new recipe involving partial cure at 180^{o}C, followed by etch-back and complete cure, is developed. After every process step, step-height measurements at nine different positions all over the sample are performed. A uniformity of within 50 nm between different positions is obtained by this technique. The process is found to be reproducible.

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