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Patterned InterVia for Heterogeneous Integration of III-V devices onto silicon photonics by using micro-Transfer Printing

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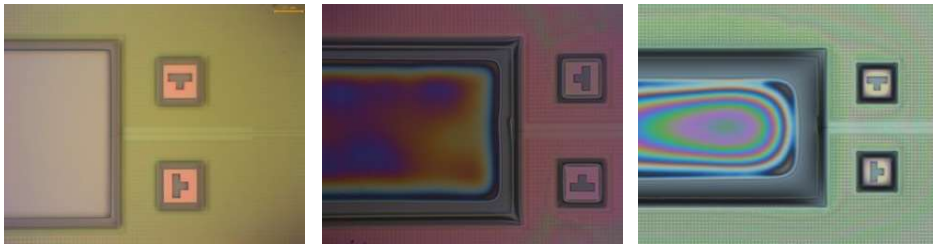
The integration of optical components through micro-transfer printing involves the bonding of coupons to a target surface, which relies on the properties of the mating surfaces [1,2]. The preparation of smooth and clean surfaces is crucial during the source and target preparation. When the Van der Waals forces between the two surfaces is strong enough, adhesive-free integration may be possible. However, in many cases, a thin polymer adhesive layer, such as InterVia [3] is required for reliable and repeatable integration between III-V and target surfaces. This polymer not only provides excellent adhesion, but also works as a stress release buffer layer, especially when thermally cycling the integrated devices. The thickness of the adhesive layer is determined by the thermal and mechanical properties of the polymer in agreement with the thermal budget of the integrated system and the flatness and roughness of the mating surfaces of device and substrate. The adhesive layer should also accommodate stress coming from different expansion coefficient of the bonded material and of the integrated substrate.

8023 series InterVia is a negative tone polymer that can be developed in a TMAH based solution. When used as an adhesive of thickness <500nm InterVia has to be diluted in PGMEA, layers of thickness below 100 nm require large dilution ratios. In this work, the thickness of the adhesive layer investigated ranges from 50 nm to 200 nm. There are various techniques available to deposit these films onto the targets, such as spin-coating and spray-coating [4]. While it is possible to achieve a flat surface with a uniform film on targets that have a non-structured surface, it can be difficult to do so on targets that have a topography on them. Moreover, in specific applications, it may be necessary to remove the adhesive material from undesired locations.

In this work, we report selective removal of adhesive material piled-up at the sidewall of 7 µm deep recesses etched into an SOI wafer, the actual recesses are 120 µm wide and 2.5 mm long. Next, < 5 µm thick edge-emitting GaAs quantum dot (QD) lasers with 60 µm x 2.4 mm footprint were successfully integrated into the recesses using micro-transfer printing, similar to previous work [5].



Recess before coating | Spray-coated InterVia | Spin-coated InterVia

Figure 1. 120 µm wide and 2.5 mm long recess etched into a silicon photonics substrate before and after adhesive coating (spray / spin coat). Material piling at the edge of recess is visible under optical microscopy.

Figure 1 shows spray/spin coated materials including InterVia pooling towards sidewall of the deep recess. The meniscus from the adhesive (several microns long in lateral and few microns in vertical direction) increases the longitudinal spacing between the emitting facet of the QD laser and the receiving Si waveguide positioned close to the sidewall of the recess. The additional adhesive material needs to be removed for efficient light coupling, while keeping the adhesion strength of the layer to ensure high yield integration of the devices and minimum misalignment between III-V and SOI waveguide.

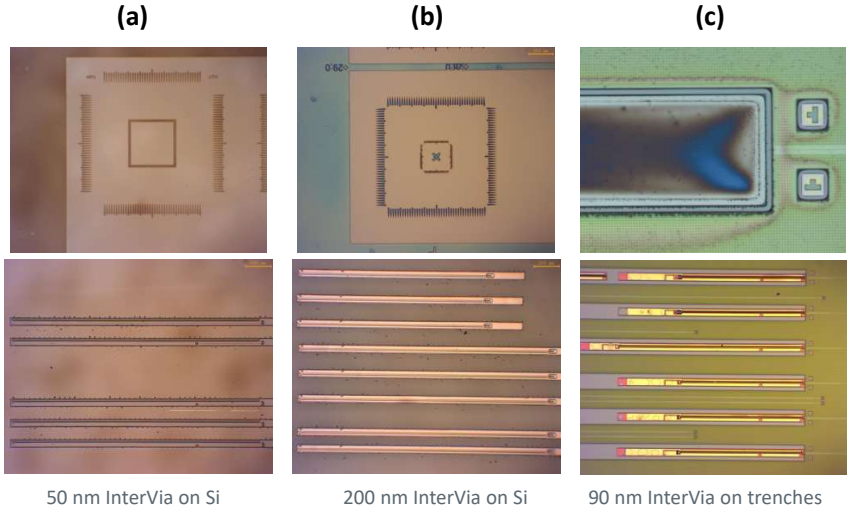


Figure 2. (a) 200 nm and (b) 50 nm spray-coated InterVia *on flat Si was patterned via photolithography and test coupons were transfer-printed with >95% yield. (c) Patterned* InterVia *on SOI with 7 µm deep recesses hosting micro transfer printed QDs lasers.*

One particular challenge related to using thin layers of InterVia is related to the lithography process which strongly depends on the amount of photoactive component in the layer, which in turn is influenced by the dilution ratio. Figure-2 (a)-(b) show an adhesive layer of patterned InterVia with thicknesses between 50 and 200 nm on Si wafers with transfer-printed GaAs laser coupons, while Figure-2 (c) shows a 90 nm thin layer of InterVia spray-coated on a SOI wafer with 7 µm deep recesses, with GaAs laser coupons up to 2.4 mm long transfer-printed inside them.

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