Micro-transfer-printing for heterogeneous integration

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***Abstract*—Micro-transfer-printing is a key enabling technology for the heterogeneous integration of different materials and devices. The technique is particularly applicable to photonics where a typical system requires diverse arrays of components.**

I. Introduction And Background

There is a need to build compact smart systems-on-a-chip to reduce size and costs while increasing functionality and performance. This is especially relevant for photonics where each component may require a different material resulting in high assembly costs. A solution is to intimately integrate the components using micro-transfer-printing[1] (μTP) where the essential layers can be picked up from source wafers in an array format and transferred in parallel and repeatedly to target substrates. The low temperature, high throughput process allows the transfer thin and delicate materials from the individual source wafers with ±1.5μm positional tolerances on the target wafers. We are now upscaling the technology to establish an open access pilot line[2] which requires detailed analysis and understanding to allow optimisation of the individual process steps.

II. Results

The μTP process requires the creation of arrays of tethered and suspended coupons (isolated mesas) on the source wafer which may have been pre-processed and pre-tested in a specialist laboratory. The tethers be composed of the semiconductor, a deposited dielectric or polymer. The release process can use wet or plasma steps and depends on the material comprising the device coupons and the chosen tether system. Techniques have been developed to release III-V materials (GaAs, InP, GaN), dielectrics, Ge, Si by selective etching.

The key element for the pick and place transfer process is an elastomeric stamp composed of e.g. polydimethylsiloxane (PDMS), and structured with pillars arranged to select designed sets of devices. The dynamic properties of the PDMS were measured as were the rate-dependent adhesion forces between PDMS and a SiN surface. A maximum stress of 0.45 MPa was achieved at velocities >30mm/s for five different sample structures (Fig. 2) with low standard deviation and good reproducibility between the different structures. The material data was used in Finite Element Analysis to assess the fracturing of different materials, numbers and geometries.

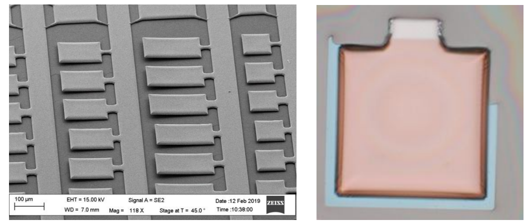

Fig. 1. Left SEM image of arrays of released GaN coupons on <111> Si and Right transferred coupon bonded to intervia coated target substrate.

The coupons are transferred to different surfaces for direct van der Waals bonding and with thin (50nm – 2mm) adhesive layers of BCB or intervia. Effective direct bonding requires that the mating surfaces have roughness < 2nm which can be achieved with chemo-mechanically polished processed wafers and with epitaxially grown device materials. Using the μTP technology high-performance microdisplays comprising of pixels of red, green and blue microLEDs together drive circuits have been demonstrated[4].

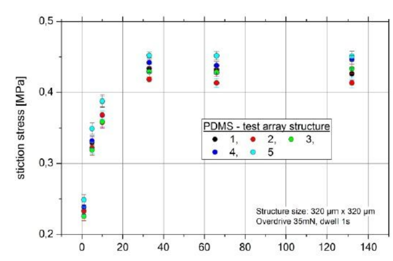

Fig. 2. Adhesion force as a function of velocity. 100x single measurements for each structure and each velocity.

Acknowledgment

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