A high yield micro-assembly for wafer scale, hybrid opto-electronic systems manufacturing

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Industry Challenge

The development of advanced opto-electronic systems has required the integration of multiple different photonic materials at micron scales[1]. Especially, next generation and high-resolution micro-displays require the hetereogenous integration of thousands of small semiconductor pixels (10-30 μm^2) onto non-native substrates and electronic back-planes[2]. In order to fabricate large arrays of optoelectronic devices at the scale of the manufacturing levels, mass transfer methods are required with high throughput, high placement accuracy and high yield at wafer levels, as well as a rapid assessment of the transferred devices[3].

Proposed Research

To address this challenge, we have developed a rapid, high yield and accurate automated device roll-transfer process at scale[4] and an automated metrology process for high speed, sub-micron resolution assessment[5]. In this work, we present the full roll-transfer printing of a quarter VGA (QVGA) pixel array consisting of 320x240 devices, with individual pixel dimensions of 30x30 μm^2, on centre-to-centre spacing of 50 μm [549 dpi] and the analysis of the printed device.

1. Roller-transfer printing:

- A commercially available elastomeric rubber Si roller.
- A high vertical load for height and pressure control.
- An automated linear translation stage which induces the revolving motion of the roller when they are in contact.
- Bearings for minimizing friction on the sides of the roller.
- Rely on the competitive adhesion between the elastomer and the material used for deposition.

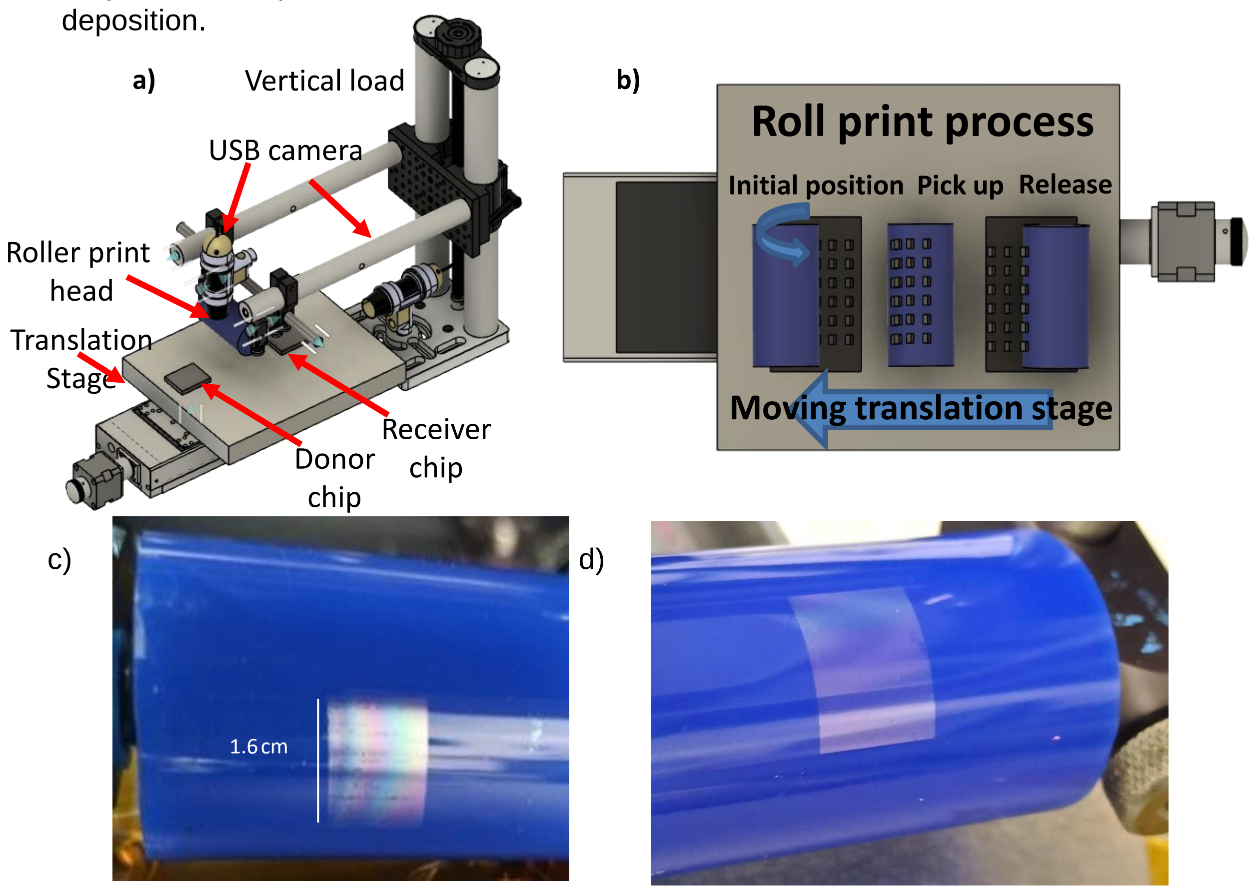

Figure. 1 : a) Schematic 3D representation of the roll printing process employed in the study. The roller is passed subsequently over the donor chip then the receiver chip placed on the same translation stage, b) perspective view showing donor and receiver samples, c) is a typical mini-LED and d QVGA) array fully picked up by the roller in mid-printing process.

The roller is positioned at the edge of the donor chip, translated by using single motion stage such as the roller passed over the entire area with a constant height, downward pressure and velocity for pick-up the devices from their native chip. The translation motion continues until the edge of the receiver where the devices were then released to the target chip in a single continuous process.

2. Automated metrology system:

- Dynamic microscopy system for capturing high magnification, field of view images covering the entire chip with high resolution.
- Computational image processing based on cross-correlation technique for translation and rotation accuracy, and yield assessment.

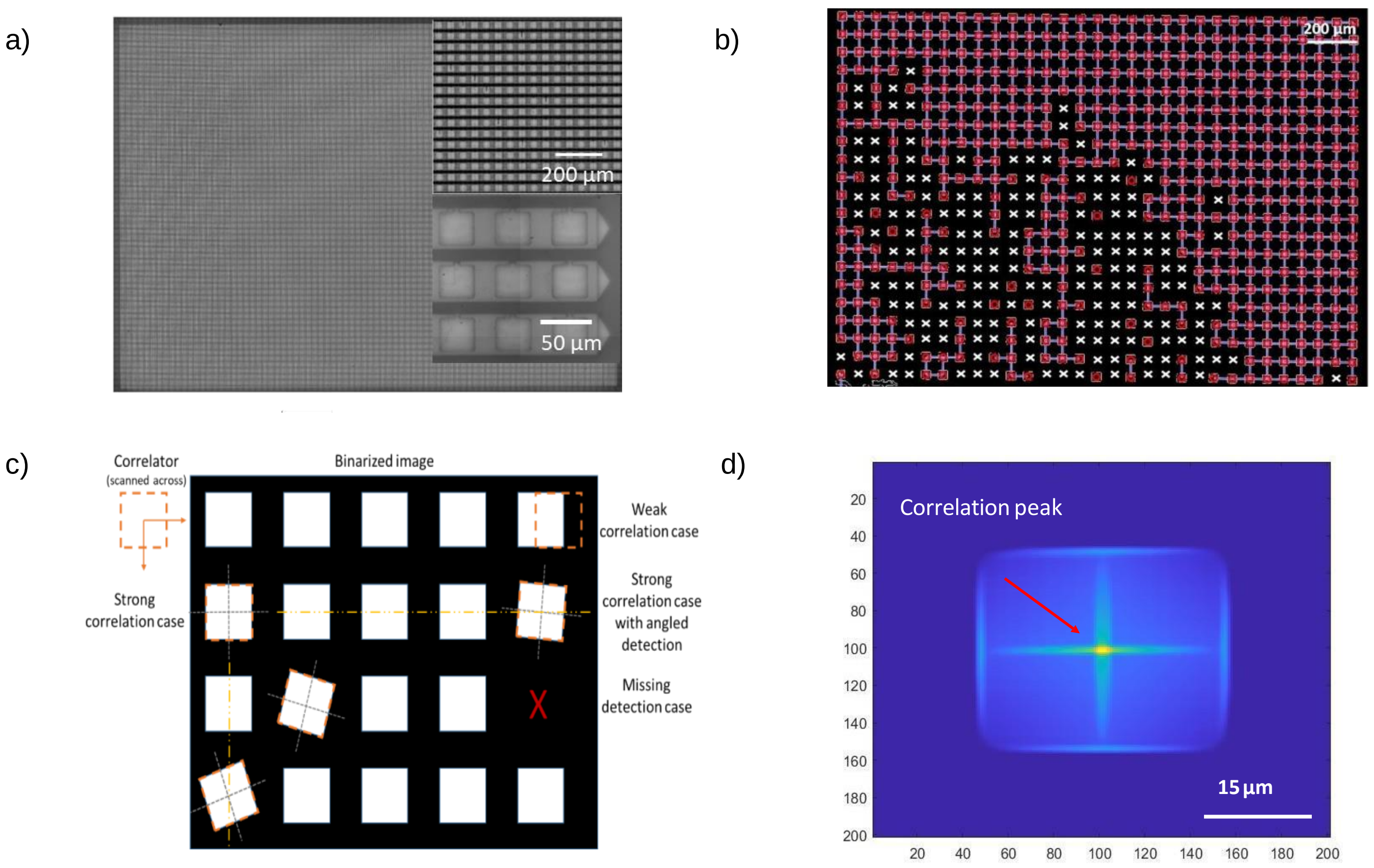

Figure 2: : a) Example of stitched microscopy micrographs with under different resolutions and FOV QVGA micro-LED device (320x240 elements) with a close up snapshot of the stitched elements, b) Example of the analysis highlighting the center detection, pitch values and missing devices of the QVGA, c) Schematic representation of the cross correlation and d) Close up of a reconstructed device after the cross correlation for the translation assessment.

Over 75.000 devices with less than 1 μm accuracy in a single shot.

Results

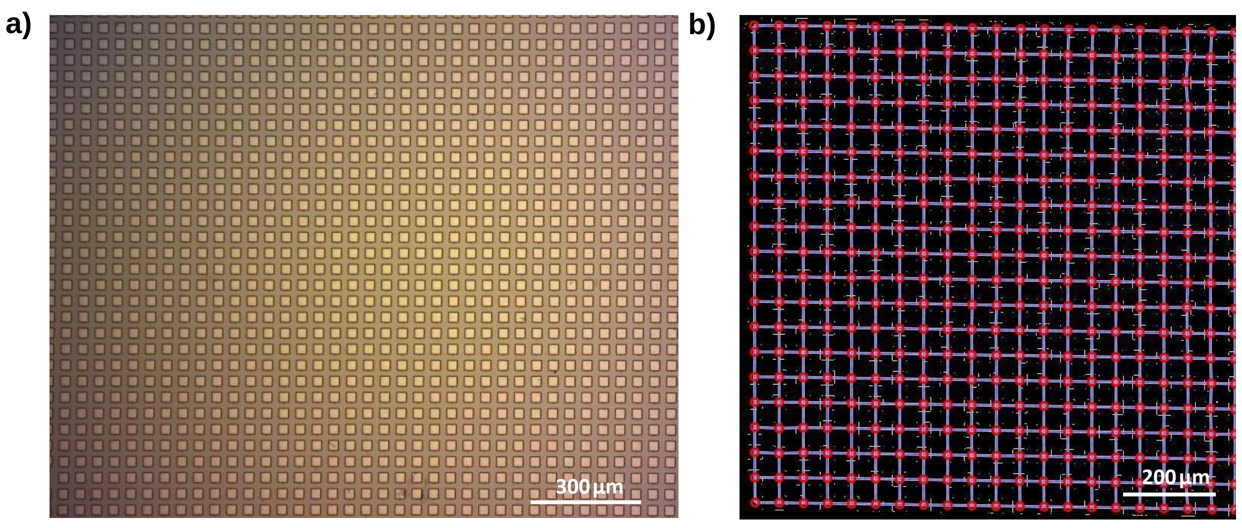

Figure 3: Roll-transfer printed QVGA a) High resolution microscopy image (94 nm/pixel and accuracy ± 830nm) and b) Analyzed section including center detection and pitch values of the roll-printed QVGA.

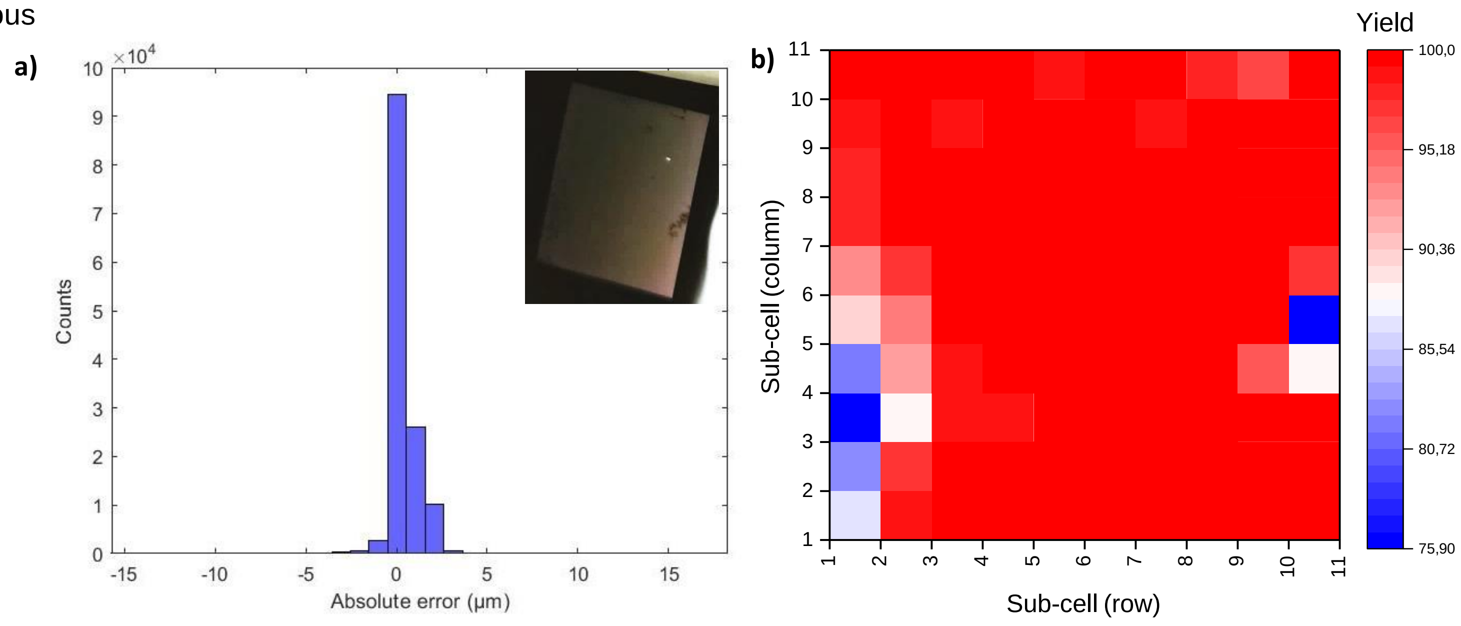

Figure 4: Analyzed full roll-printed QVGA a) Histogram of the error in x and y direction of the roll-printed devices including a microscope image of the entire roll-printed QVGA on the receiver (micrograph of the receiver on top right), b) Heat map of the yield across the whole printed QVGA chip[6].

Conclusions

99.9% mass transfer local yield

We presented an automated roll-transfer printing method which allows the printing of thousands of devices in a single continuous process. In order to evaluate our method in terms of accuracy and yield, we developed an automated sub-micron inspection method that we used both for the analysis of a non-printing chip as well as the analysis of a roll printed devices. For the analysis of the roll-printed QVGA, by using a pixel resolution limit of 720 nm/pixel, we found for the printing of more than 70.000 devices an error of 430nm and a standard deviation of 980 nm. By mapping the printed chip a local yield of more than 99.9% was confirmed. The technology fully utilizes the well-established infrastructure and semiconductor processes developed by the Si-based IC industry and can be translated into established industrial foundry manufacturing processes.

References:

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