Optoelectronic Devices on-Fiber Enabled by Micro-Assembly Process Using Polydimethylsiloxane Probes

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We present a novel micro-assembly process using Polydimethylsiloxane (PDMS) probes. This process permits us to assemble different membrane optoelectronic devices into a system. In particular, we show examples of assembling devices directly on facets of standard optical fiber to functionalize the fiber. Applications range from to single-photon detection to chemical sensing.

As presented in *Figure 1*, the micro-assembly process includes three major steps: (1) picking up the membrane from the substrate (top panel); (2) flipping the membrane (middle panel); (3) roll-printing the membrane on a receiving substrate (bottom panel). Depending on applications, step (2) can be skipped. The tool for these manipulations is a specially-made PDMS micro-probe with a size of several tens micrometer.

Compared with previous work of transfer-printing devices, [1,2,3] this process has several advantages, including: (1) accurate alignment, as presented in *Figure 2* (position-misalignment<1 μm, angular misalignment<1º); (2) establishing robust and repeatable electrical contact that tolerates dramatic temperature changes; (3) keeping the devices completely intact with a yield near 100%.

Using this process, we assemble membrane optoelectronic devices into various systems. As one example, we show assembling devices directly on facets of standard optical fiber to functionalize the fiber. These devices include nanowire photon counters (as presented in *Figure 3*) and photonic-crystal micro-cavity lasers. [4] Among them, we have tested the photon counter on-fiber: The photon counter is well-aligned with the core of the optical fiber (*Figure 3*) and it detects individual infrared photons at the temperature of 4 Kelvin, thanks to the above-mentioned advantages of this assembly process. This process allows lens-free coupling from optical fiber to these micro-scale optoelectronic devices. The resulting compact, light-weight, pig-tailed devices can be used in applications such as single-photon detection and chemical sensing.

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[2] G. Shambat, *et. al*., Appl. Phys. Lett. 100, 213702 (2012).
[3] B. Wang, , *et. al*., Opt. Lett. 37, 833-835 (2012).
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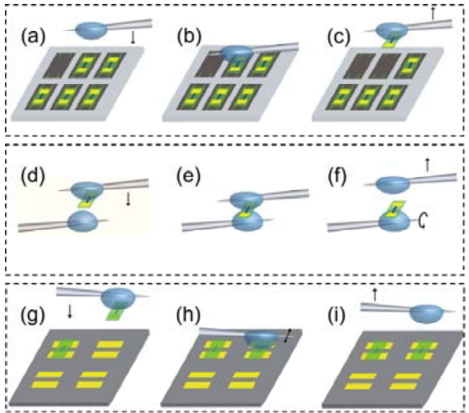

Figure 1. Schematics of micro-assembly process. The process includes three steps: (1) picking up the membrane from a substrate (top panel); (2) flipping the membrane if needed (middle panel); (3) roll-printing the membrane on a receiving substrate (bottom panel). (a) – (i) show steps in detail.

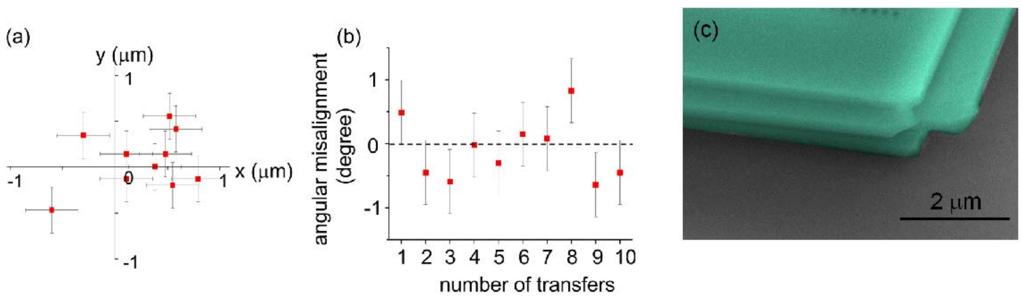

Figure 2. Alignment accuracy of the assembly process. (a) The position-misalignment of this process can be controlled within 1 μm and with 0.5±0.3 μm on average. (b) The angular misalignment of this process can be controlled within 1 degree and with 0.4±0.3 degree on average. (c) A false-colored scanning-electron micrograph of a stack of membranes shows both position and angular alignment accuracy.

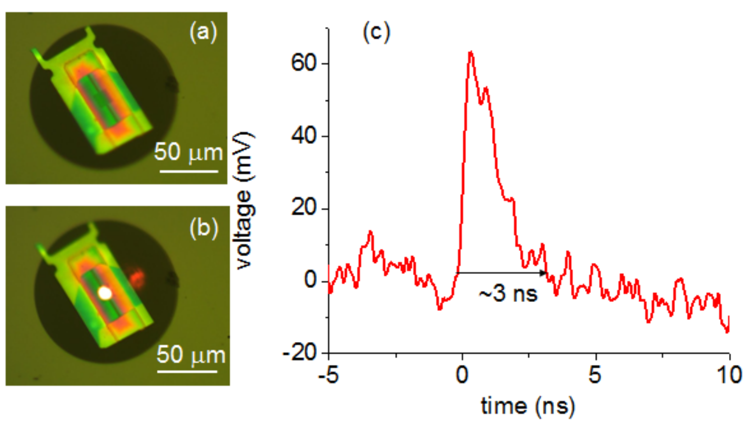

Figure 3. Photon counters on-fiber enabled by the assembly process. (a) and (b) show the optical spot through optical fiber is aligned with the active area of the photon counter; (c) the electrical output pulse from the photon counter on-fiber. The working temperature is 4 Kelvin.