# Fabrication and Transfer Assembly of Microscale, Solid-State Light Emitting Diodes and Solar Cells for Transparent and Flexible Electronics Applications

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Efficiency metrics for some solid-state electronic materials systems have progressed to the point where theoretical limits are being approached. Gallium nitride-based light-emitting diodes (LED)[1-2] and silicon solar cells[3], for example, have achieved such extraordinarily high performance metrics that only incremental improvements upon them are expected in the next decade of intense research. This pseudo-plateau in performance development means concentrated effort can now be placed on strategic implementation of these materials into platforms that fill a growing demand for high-performance consumer products. Such products have traditionally relied upon large-scale materials, but possibilities now exist for manipulating microscale, wafer-based devices in ways that promote improvements in areas of electrical current spreading[4], light absorption and extraction[4-5], and thermal management[6].

To this end, my research has focused on routes to fabricating and assembling solid-state LEDs and solar cells of indium gallium nitride (InGaN) and single-crystalline silicon, respectively, in configurations which optimize characteristics of their performance. Specifically, I have worked, in collaboration with others, to achieve a processing strategy that creates dense arrays of InGaN LEDs on a silicon wafer of (111) orientation and assemble them onto transparent and flexible substrates (Figure 1a-b).

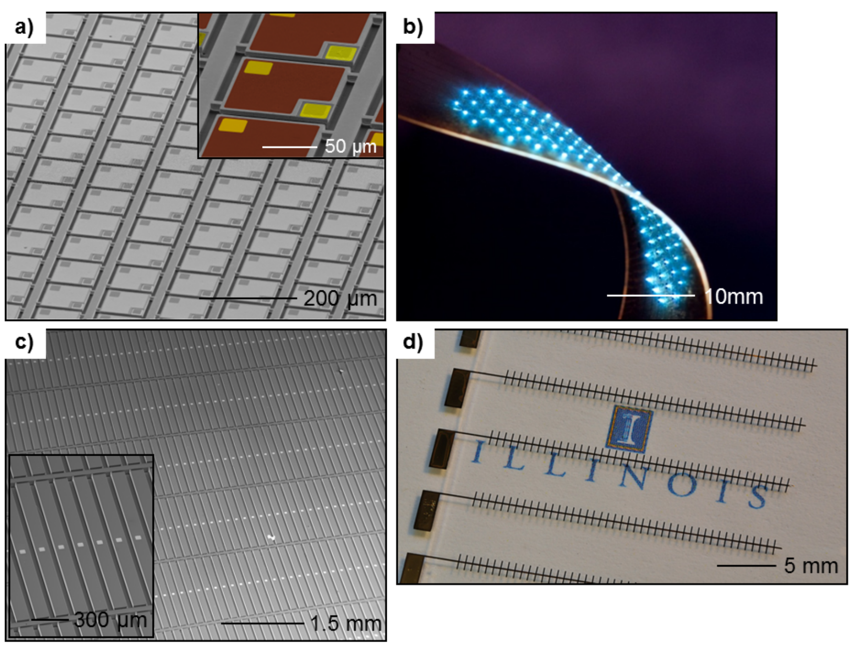


**Figure 1**: a) Scanning electron micrograph (SEM) of microscale InGaN LEDs before and b) after assembly onto a transparent and flexible substrate. c) SEM image of microscale Si solar cells before and d) after assembly onto a transparent substrate.

This work produced novel form factors for solid-state lighting where small LEDs were spatially distributed and integrated with color-converting phosphors in ways that controllably tuned their chromaticity. We also demonstrated that incredible passive heat dissipation with these microscale elements stemming naturally from their small size and integration with metal films serving dually as an electrically interconnecting medium. The cell design and etching strategies used were then transferred to a single-crystalline silicon system where small, ribbon-like solar cells were fabricated and deterministically assembled onto transparent glass substrates (Figure 1c-d). This work improved upon previous studies creating similar devices by increasing critical solar cell performance metrics. The developed solar cell structure utilizes a highly robust manufacturing layer of thermally-grown silicon dioxide which naturally doubles as an anti-reflection and passivation layer. Other improvements to previous performance metrics comes from optimized cell assembly onto structures that recycle and redistribute incident irradiation.


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