Title: Directed Assembly: Integration of Heterogeneous Systems Across Length Scales and Material Boundaries

Award Number: 601454

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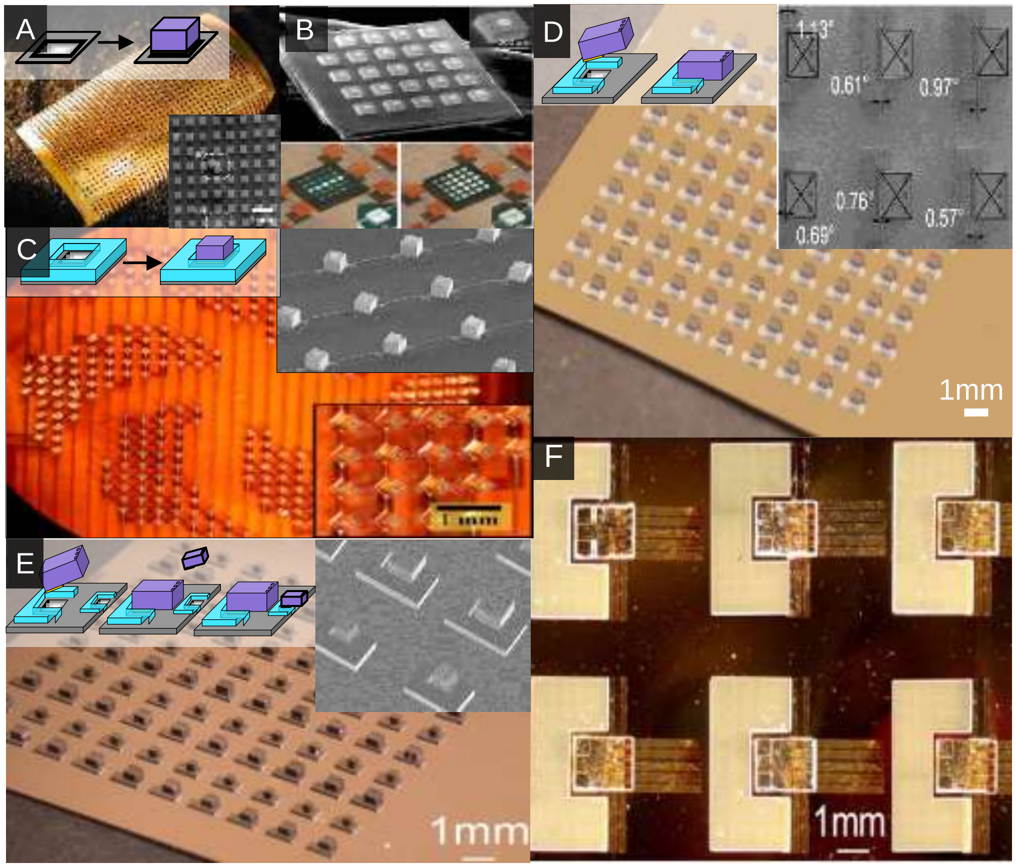


**Fig. 1** Summary of self-assembly results with varying docking site types using AlGaAs-LEDs, Si, Glass, and SU-8 blocks. A) Simple solder-directed assembly of silicon parts, B) simple solder-directed assembly of LEDs, C) thermally activated receptors, D) unique-angle orientation assembly, E) sequential batch assembly F) flip-chip assembly of parts with multiple I/O connections.

The construction of man-made artifacts such as cell phones and computers relies on robotic assembly lines that place, package, and interconnect a variety of devices that have macroscopic (> 1 mm) dimensions. The key to the realization of these systems is our ability to integrate/assemble components in 2D/3D as well as link/interconnect the components to transport materials, energy, and information. The majority of these systems that are on the market today are heterogeneous in nature. Heterogeneous systems can be characterized as systems that contain at least two separate parts that prohibit monolithic integration. Such systems are typically fabricated using robotic pick and place. The size of the existing systems could be reduced by orders of magnitudes if microscopic building blocks could be assembled and interconnected effectively. Professor Heiko Jacobs and his research group at the University of Minnesota have advanced knowledge in an emerging area that can be referred to as directed assembly, self-assembly-by-design, or programmable self-assembly. The focal points are heterogeneous systems and assemblies that contain components made of different materials with different physical dimensions that cannot be assembled effectively with robotic assembly lines, wafer-to-wafer transfer techniques, or existing self-assembly methods.

The objectives and selected accomplishments of this activity are as follows: 1) Develop a fluidic agitation concept to suspend disparate microscopic parts (chiplets) for self-assembly resulting in the images shown in Fig. 1 (*Materials Research Society Symposium Proceedings* 2007, *Proceedings of the National Academy of Science*, 2010). The selected samples demonstrate self-assembly across both scale and material types in substrates and components (Fig. 1a,b) as well as sequential programmable LED assembly (Fig. 1c) enabled by the 2) Development of a new method for activating receptors that enable programmable self-assembly and transfer of chiplets onto desired locations on a surface relying on integrated heaters (*Journal of Microelectromechanical Systems* 2006). A third objective, 3) Enabling self-assembly defect reduction by combining geometrical shape recognition with surface tension directed self-assembly enabling multiple I/O connections per die (*Advanced Materials*, 2006), is shown in Fig 1d,e,f. Finally, 4) Demonstrate an application of the gained knowledge by fabricating a sensor system that contains disparate units for sensing and communication can been seen in Fig. 2 (*Advanced Functional Materials,* 2005, *Journal of Microelectromechanical Systems*, 2006).

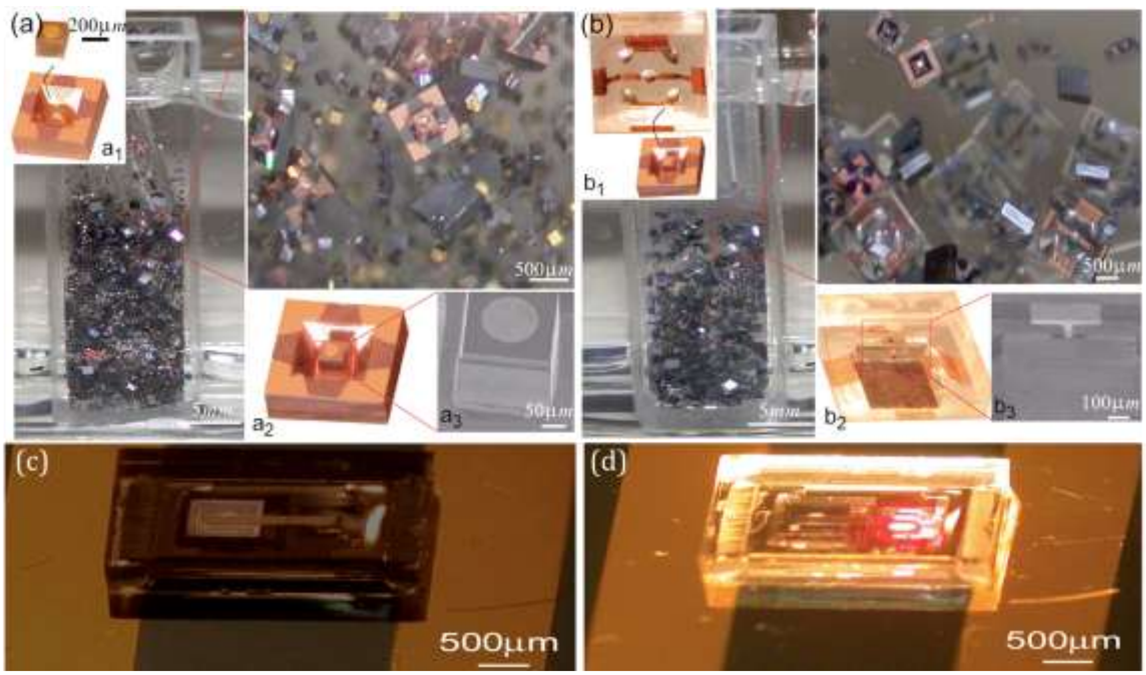


**Fig. 2** Experimental realization of LED chips that were assembled and packaged as well as the testing of a four-component sensor module interrogated remotely after being assembled and packaged by directed 3-D self-assembly (c) in the OFF state and (d) in the ON state.

The ability to assemble disparate microscopic components (integrated circuits, optical components, sensors, actuators, fluidic devices) in two- or three dimensions impacts the creation of improved and entirely new systems that cannot be achieved with current micromachining and microassembly techniques. The technology shown here has applications including sensor systems to gather optical, IR, UV, acoustic, chemical, and/or radiological data that would improve many areas of our daily lives including healthcare, the environment, energy, food safety, manufacturing, and national security.

Publications Acknowledging Funding:

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