DNA Origami as Molecular Circuit Boards: Attachment, Patterning, and Stability

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DNA origami self assemble into high yields of complex nanostructure designs, which can be further functionalized with non-DNA structures such as quantum dots, nanoparticles, and nanotubes.[1] The origami bridge size scales of 1-100 nm, which suggests they could be used as molecular circuit boards to integrate nanoelectronic, nanomagnetic, or nanophotonic devices into functional systems. Since many nanodevices require input or output structures made using CMOS technology, it is desirable to develop ways to interface DNA origami with semiconductor substrates. Ideal methods should allow deterministic patterning and compatibility with other CMOS processing steps.

Attachment of DNA origami is dependent on ionic interactions between the nanostructure and the surface. We found that this interaction can be tuned by the formation of a cationic-self assembled monolayer (SAM) of 3-aminopropyl triethoxysilane (APTES). Not only do APTES SAMs promote nanostructure adhesion, a technique called "molecular liftoff" can be used to create lithographically patterned areas for guided deposition of DNA origami. Poly(methylmethacrylate) (PMMA) is patterned and developed using e-beam lithography; APTES is then deposited onto the pattern before PMMA removal.[2] This process creates patches of APTES in spatially defined areas to which DNA origami preferentially adhere, even after removal of the deposition buffer.

Many CMOS processes, such as silicon dioxide or metal deposition and baking and stripping of photoresist, would expose DNA origami to temperature and solvent environments which are quite foreign to the room temperature, aqueous environment in which duplex DNA is normally handled. We found that when DNA origami are dried on a surface, they are stable to solvent exposure and heating which would irreversibly damage them in solution.[3] However, there are process dependent limitations on the incorporation of DNA nanostructures into CMOS device fabrication and applications. We found that the ability of origami structures to bind non-DNA components is degraded by heat and by non-aqueous solvents, probably due to non-equilibrium disassembly of the origami when they are reaquated, and irreversible chemical changes begin to occur at 150°C. There is clearly a need to map out the structural, functional, and chemical tolerances of DNA origami for use in nanoelectronics.

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[1] O. I. Wilner et al. *Chem. Rev.* **112**, 2528-2556 (2012).
[2] K. Sarveswaran et al. *Langmuir* **22**, 11279-11283 (2006).
[3] M. Pillers et al. *J. Vac. Sci. Technol. B* **32(4)** 040602 (2014).