Functionalization of Self-Assembled DNA Origami

Darius Z Brown Literature Seminar October 29, 2009

The DNA molecule has many key features that make it a promising candidate for nanotechnological design and construction. Due to its well studied Watson-Crick base pairing, microscopic size, and unique structural features such as being flexible in single stranded or stiff when double stranded, DNA can be well utilized in the 'bottom up' fabrication of functionalized nanostructures. One major goal in the field of nanotechnology is to be able to program molecules to self assemble with controlled positioning and at very high precision. DNA building blocks offer great programmability because of the single strand binding between complementary base sequences. Thus, by controlling what sequences are on your DNA molecule, one can control the interactions amongst them.

Throughout the last 25 years scientist have been trying to use DNA molecules for the self-assembly of 2-dimension and 3-dimension nanostructures. This has been achieved through many advances in the field of DNA nanotechnology, most notably being the addition and control of 'sticky-ends' to the synthesized DNA object.[5,6] The 'sticky-ends' of DNA molecules can be programmed, so that two molecules with complementary ends will self-assemble in solution, and form a structure. Another breakthrough that led to even more complex and organized nanostructures was the development of 'scaffolded DNA origami'.[3] In DNA origami, a long, single-stranded DNA molecule is folded into a desired shape by shorter 'staple strands'.[3] This is achieved when the long scaffold strand is mixed with 100-fold excess of staple strands, salt and buffers, and is gradually annealed from nearly boiling temperatures of water to room temperature. DNA origami has been demonstrated as being a very facile way to obtain 2D and 3D nanostructures,[4,7-9] and programmability of strands during designing procedures can lead to the functionalization of these complexes.

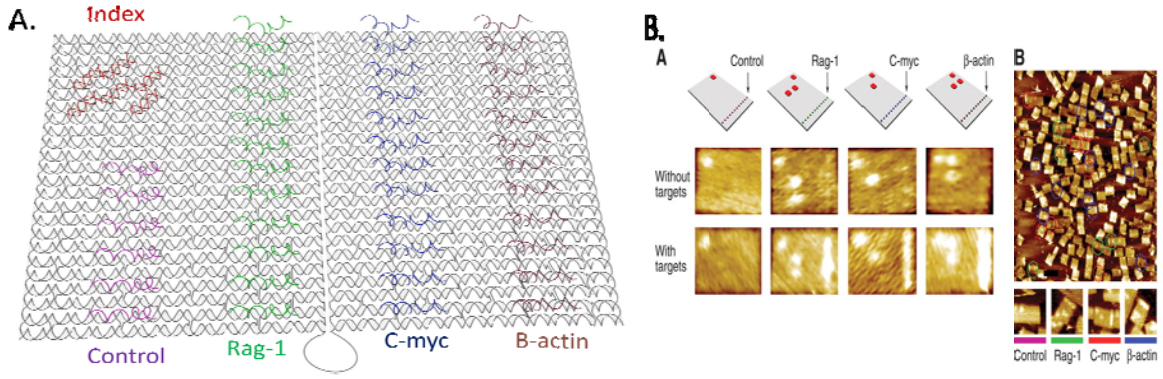

Figure 1: A. DNA Origami tile with index hairpins (red), and 4 lines of extended staple strands (one for control, three to act as probes for correspond mRNAs) B. Topographic illustration of bar-coded tile designs and corresponding AFM image of simultaneous detection

One way to achieve the functionalization of DNA origami, is through strand manipulation and modification, performed during and after the designing process of the arbitrarily shaped DNA object.[12, 13] With addition of items such as hairpins, thiols and biotin to the staple strands of the DNA origami, addressable precision patterning on DNA surfaces, immobilization of DNA nanostructures and detection of target species is all achievable.[12,13] This approach of staple strand alteration during designing procedures of DNA origami can be taken one step further, through the employment of rectangular tiles.[1,2,10,11,14,15] Very high yields (nearly 100%) of monomeric, rectangular nano-sized tiles can be obtained through DNA origami, and coupled with strand modification, these tiles can be functionalized and engaged in nanotechnological applications. As shown in Figure 1a, hairpins added to a DNA origami substrate can serve as an index, and extended staple strands can serve as a probe, for the hybridization of mRNAs in solution.[1] With different index geometries arranged on different tiles, tiles can be 'bar-coded' for distinguishable simultaneous multiplex detection of mRNAs in solution. (Figure 1b) DNA origami tiles can also be employed through addition of adapter strands on a side of a tile that induces the nucleation of a DNA ribbon, consisting of the origami tile, or in other words, the seed, and a group of smaller tiles that are about 100th of the size of the origami tile.[10,15] (Figure 2) By added hairpin structures to the smaller tiles, and by controlling the 'stick-ends' of the adapter strands, and of the small tiles, it is possible to achieve complex binary coded ribbons of DNA, which all initiated through the information-encoded DNA origami tile.

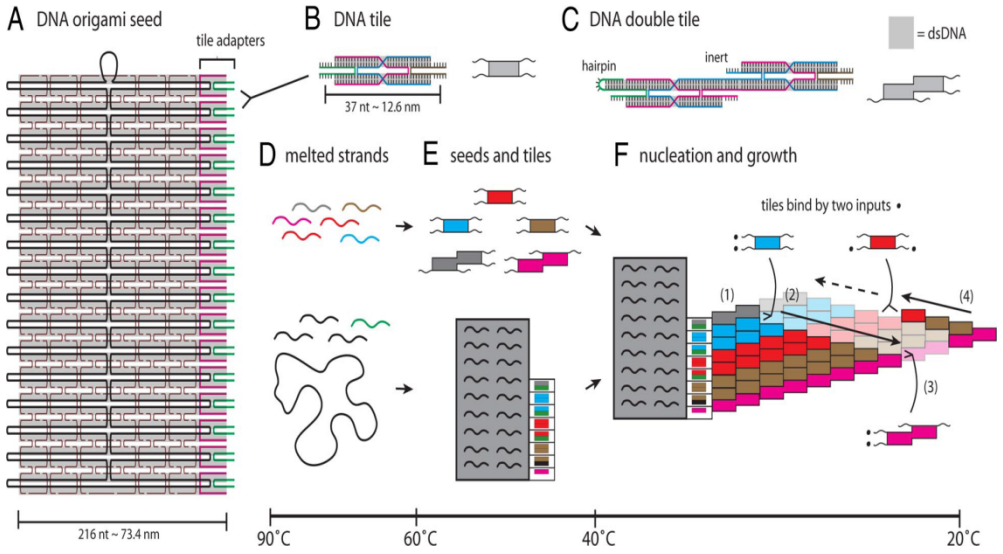

Figure 2: Molecular design and self-assembly scheme of DNA origami tile used as an information-encoded seed for nucleation of DNA ribbon

Functionalized DNA origami has many technological applications. These nanomaterials have the ability to carry cargo such as biomolecules and nanoelectronical devices,[11] perform simultaneous multiplex diagnosis, direct high precision positioning of information-encoded species, and optimize spatial and structural features of molecules[16], providing the platform for DNA to be a part of and thrive in the field nanotechnology for years to come.

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