

## Top Down Meets Bottom Up: Controlled Placement of DNA Nanostructures

Ryan J. Kershner\*<sup>†</sup>, Ruoban Han<sup>†</sup>, Luisa N. Bozano<sup>‡</sup>, Christine M. Micheel<sup>‡</sup>, Albert Hung<sup>‡</sup>, Ann R. Fornof<sup>‡</sup>, Jennifer N. Cha<sup>‡</sup>, Charles T. Rettner<sup>‡</sup>, Marco Bersani<sup>‡</sup>, Jane E. Frommer<sup>‡</sup>, Paul W.K. Rothmund<sup>+</sup>, Greg N. Wallraff<sup>‡</sup>

<sup>†</sup> University of Wisconsin-Madison, Mechanical Engineering, Madison, WI

<sup>‡</sup> IBM Almaden Research Center, San Jose, CA

<sup>+</sup> California Institute of Technology, Computer Science and Bioengineering, Pasadena, CA

Custom tailored self-assembled DNA structures provides a promising route for the fabrication of nanoscale features over large areas. This aptly named DNA origami extends the realm of single nanometer-scale features to dimensions large enough to interface with traditional top-down semiconductor processing methods. Here we demonstrate the placement of individual DNA origami nanostructures, with specific control over both location and orientation. This technique provides a bridge between top-down and bottom-up fabrication methods, with potential applications in nanoelectronics, sensors, and nanoscale surface engineering. Standard e-beam lithography was used to define patterns on a semiconductor compatible thin film. The surface chemistry in- and outside of the patterned region was tuned to control the selective adsorption of origami, with densities controlled by the pattern resolution. Patterned features having the same approximate shape and characteristic dimension as the origami were found to direct the orientation of single and multiple structures.

The ability to tune this adsorption has broad implications for potential applications in nanoelectronics, sensors and nanoscale surface engineering. We report a detailed study of origami adsorption as a function of ionic species, ionic strength, and preparation of the surfaces. An electrokinetic analysis technique (streaming current) was used to measure the zeta potential of substrates of interest (mica, silicon dioxide, DLC and oxygenated DLC) under various conditions, including ion species ( $Mg^{2+}$ ,  $Na^+$  and  $Ni^{2+}$ ) and ionic strength (1mM, 12.5mM and 100mM). The results reveal a strong dependence of zeta potential on both ion valence and ionic strength. Charge inversion was observed in bivalent ion solutions at a pH value near 9. On all surfaces exhibiting DNA origami adsorption (mica, silicon dioxide and oxygenated DLC) the lowest zeta potential (-40mV) corresponded to a pH value near 7. Based on these data, the adsorption of DNA origami to silicon dioxide was predicted, which was confirmed by atomic force microscopy under identical solution conditions. Results concerning the role of pH in tuning adsorption of DNA origami will also be presented.