Stevens Institute of Technology

Nanotechnology Graduate Program

High Throughput Direct-Write Near-Field Nanopatterning

Wednesday February 16, 2011, Babbio 122, 11am

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Near-field intensity enhancement enables laser modification of materials with feature sizes below the classical diffraction limit. Incorporating such effects into direct write techniques allows for the creation of arbitrary patterns with nanoscale resolution, but is typically limited by its serial nature, making it unsuitable for manufacturing operations. In this presentation, we review direct-write strategies with an eye toward increasing the throughput to enable more rapid processing. In particular, we examine the applicability of optical trapping to position near-field focusing elements near the substrates of interest. In this experiment, a CW laser is used to optically trap and position an array of liquid-dispersed microspheres near a substrate using 2-d Bessel beams. A second, pulsed laser is directed through the bead array and modifies the surface below. Both ablative and non-ablative transformations are possible and direct manipulation of the bead or substrate enables the accurate control of the feature placement. The constant optical scattering force in the propagation direction created by the Bessel beam on the microsphere is balanced by the net repulsive interaction near the surface thereby creating an equilibrium spacing between the two, regardless of large scale surface features. This effect enables nanoscale direct-write over rough or curved surfaces and the parallelization of the process using arrays of beads, each with identical spacing above the surface. In addition, the harmonic nature of the interaction potential and the liquid environment allows the microsphere to be displaced from its equilibrium position only to quickly return with large damping. This effect has important implications for ablative and chemically enhanced processes.

Professor Craig B. Arnold is an associate professor at Princeton University in the department of Mechanical and Aerospace Engineering and the associate director for Acadmic Affairs in the Princeton Institute for Science and Technology of Materials. His research primarily focuses on laser processing and transport in materials with particular emphasis on shaping laser-material interactions for applications in energy storage, photonics, nanoscale patterning, and laser based direct write technologies. He earned his PhD. in condensed-matter physics from Harvard University in 2000, and was an NRC post-doctoral fellow prior to joining the faculty at Princeton in 2003. Previous awards include the ONR young investigator award (2005) and the NSF Career award (2006).

Co-sponsored by the Department of Mechanical Engineering

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