486f Materials and Processes and High Resolution Patterning Using Thermal Cantilever Array Lithography

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The long term goal of our work is to develop revolutionary nanofabrication technology based on the use of arrays of heated atomic force microscope (AFM) cantilevers for nanoscale thermal manufacturing. In the processes being investigated, patterning of various materials is performed using thermal cantilever arrays in which heated cantilever tips having nanometer-scale sharpness “write” structures onto a surface. This writing can be performed using various operational modes ranging from “thermal dip pen” (tDPN) deposition of materials from the cantilever tip to the direct thermal decomposition and removal of material from a surface. Since this fabrication method requires no mask or template as is required in conventional high-volume lithographic methods (e.g. optical lithography), it is potentially a very low cost alternative to other existing nanopatterning technologies. Also, since the cantilever array can be easily scaled to large numbers of cantilever tips (i.e. more than 4,000 active cantilevers have already been made in a 64 X 64 array), the throughput of such a multi-tip system can be large using highly parallel writing strategies. This parallel writing capability overcomes the major limitation to the other primary existing maskless nanofabrication technology, namely the single beam serial writing nature of electron beam lithography. Finally, the thermal cantilevers fabricated thus far can already access a wide temperature range from ambient to ~700 °C. This large temperature range enables the use of a variety of thermally activated processes for the direct patterning, deposition, or removal of materials. The versatility of the thermal cantilever technology will enable a variety of applications including: (1) direct fabrication and repair of nanoscale structures and circuit elements, (2) combined writing, inspection, and repair of nanostructured surfaces such as next-generation photomasks and imprint lithography templates, and (3) the direct patterning of surfaces to direct nanoscale self-assembly of complex structures. In order to design such thermal cantilever array systems and processes, significant research on the fundamental issues which control the performance of these systems and the materials used with them is required. Preliminary work in our labs at Georgia Tech has already shown the feasibility of directly depositing conductive metal patterns from a thermal cantilever tip using the “thermal dip pen” writing mode. In this mode, the tip is coated with a relatively low melting metal or alloy and then scanned over the surface to be patterned. By selectively heating the cantilever above the melting temperature of the metal as the tip is scanned over certain regions of the surface, metal can be made to flow from the tip and solidify on the cold substrate. We have also shown the basic feasibility of using the local thermal decomposition of polymers to form polymer micro- and nanostructures. This paper will focus on our work directed at designing and optimizing "thermally sacrificial polymers" which can be used as the analog of conventional photoresists for such a thermal cantilever array lithography system. Such sacrificial polymers are designed so that they cleanly decompose to gaseous byproducts when heated to a well defined temperature. Thus local heating of a thin film of such a polymer allows for the clean removal of the heated area to produce polymer physical relief structures. The impact of the polymer structure and physical properties on the thermal imaging process will be discussed and illustrated using results from our polymer synthetic and image testing work. Additional imaging modes for polymers will also be presented and compared to the sacrifical polymer imaging approach.