Development of jet rollable nanoimprint process to fabricate bio-polymer nanostructures

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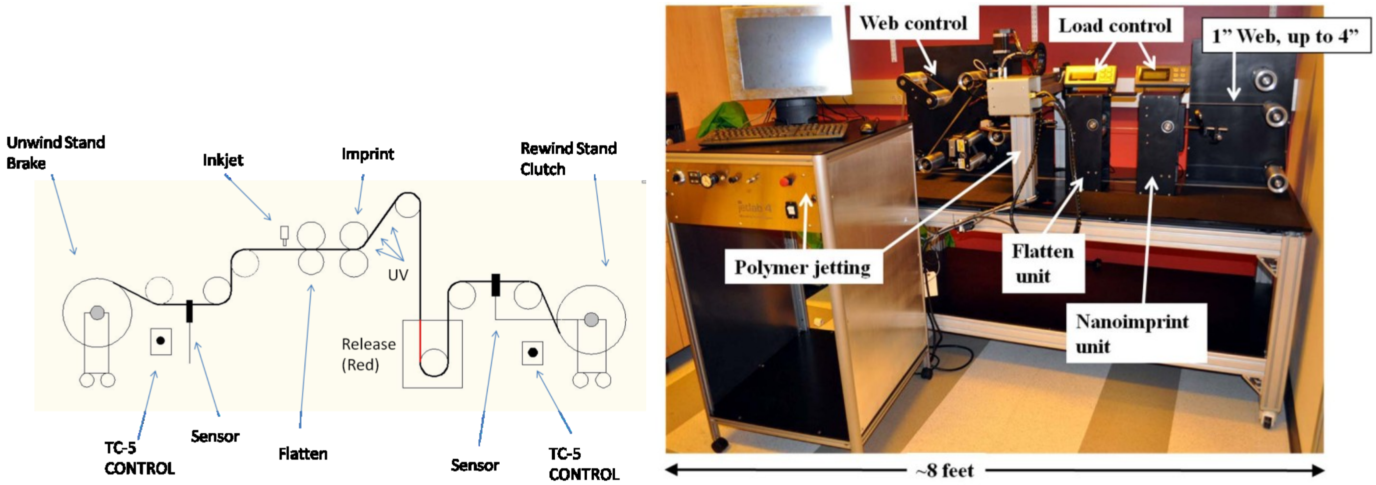
Both bottom-up chemistry and top-down engineering methods are capable of making polymeric nanostructures. For example most polymeric nanoparticles for biomedical applications are produced using solution chemistry, such as emulsion polymerization, dispersion polymerization, and interfacial polymerization/denaturation and desolvation. These techniques are mainly driven by the free energy of the chemical reaction or self-assembly processes, which are inefficient for the incorporation of multi-functional agents. It is difficult to control particle size, shape, and uniformity with these methods. On the other hand, in the field of microelectronics, polymers as photo-resist can be precisely patterned to have arbitrary shapes using state-of-the-art photo, e-beam, and x-ray lithographic technologies. But, they are limited either by high cost, poor accessibility, slow speed, or radiation damage to functional polymers. In the past decade, many low-cost nano-patterning techniques have been invented to pattern polymer structures, such as nanoimprint lithography (NIL), among others. These methods are capable of making nanostructures of the desired shape and size. However, they are still not straightforward to produce large quantities of bio-functional nanostructures with a low cost comparable to solution chemistry.

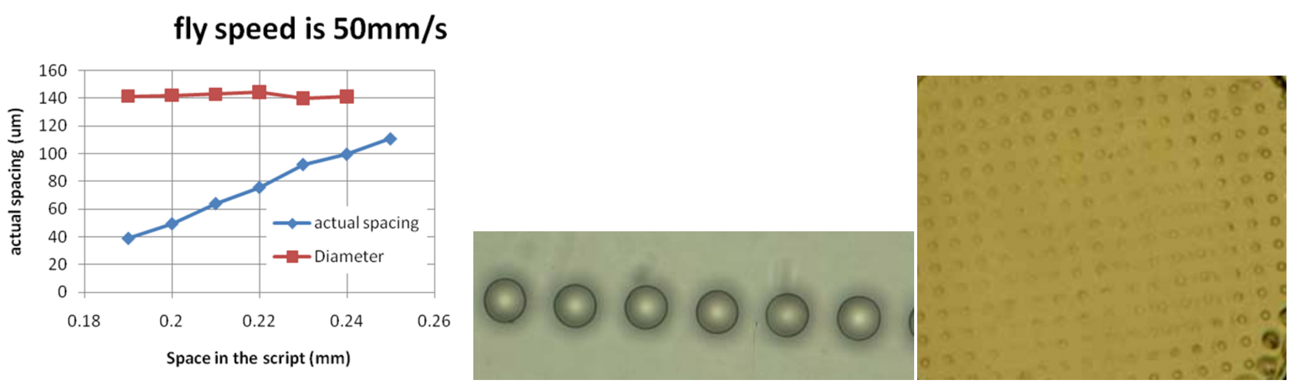
Recent emergence of roll-to-roll nanoimprint (R2R-NIL) shows great promise to lower the cost and increase throughput [1]. For fabrication of nanostructures for biomedical applications that do not require overlay, R2R-NIL can become a feasible nano-manufacturing technology. One technical challenge of currently reported R2R-NIL systems might be the uniform deposition of functional polymer without material waste during the process. In this work, we have designed a jet rollable nanoimprint process and system using precision micro-inkjet technique to deposit micro-droplet array of biopolymer onto the rolling web to form uniform films followed by rollable nanoimprint process to create microscale and nanoscale structures in functional polymer such as PEG. Such a printing process is about 1000 times faster than planar imprint processes used in our lab to create similar structures and also reduces material cost significantly by avoiding material waste using the jetting process to deposit material on the web. In contrast, spincoating used in planar imprint processes causes large wastes of expensive bio-polymers and agents. The imprint molds were made in PFPE film using conventional NIL [1] and then wrapped onto the imprint roller for printing. Figure 1a shows the designed close-loop jet rollable imprint system; Figure 1b shows an image of the constructed printer. Figure 2a and 2b shows the biopolymer droplet arrays on the moving web deposited using precise inkjet printing, and Figure 2c shows some preliminary micro-discs (1μm in diameter, 200 nm in thickness) printed using the tool. In the paper, we plan to show more results of nanostructures printed in biopolymers and extensive characterization of the printing process in terms of speed, fidelity, controllability, process window, etc.

[1] Se Hyun Ahn and L. Jay Guo, "Large-Area Roll-to-Roll and Roll-to-Plate Nanoimprint Lithography: A Step toward High-Throughput Application of Continuous Nanoimprinting," ACS Nano, 2009, 3 (8), pp 2304–2310.



(a) (b)

Fig 1: (a) Schematic of jet rollable nanoimprint process; (b) finished instrument with polymer inkjet module, flatten module, nanoimprint module, and web control module.



(a) (b) (c)

Fig 2: (a) Uniform jetting of 140 µm polymer droplets on web with linearly controllable spacing to control resulting film thickness; (b) optical image of jetting of polymer droplets; (c) nanoimprinted 1µm wide, 200 nm high SU8 disc particles on web.