Continuous nanopatterning of very large areas using nanocoining and roll-to-roll nanoforming

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Nanoscale patterns can dramatically affect the way materials interact with light and their environment, thus enhancing technologies ranging from displays and augmented reality headsets to self-cleaning and anti-drag surfaces. However, the traditional nanofabrication techniques used to create nanopatterns are prohibitively slow and expensive to nanopattern the large areas needed for industrial-scale manufacturing of functional patterns large enough to cover things like solar panels and television screens. Here, we will present truly large-area nanopatterning of hundreds of square feet of polymer film using a combination of nanocoining and roll-to-roll patterning. We will also present recent work to create seamless cylindrical photomasks and use these in R2R processes to nanopattern large-area plasmonic metamaterials with tunable IR absorption spectra.

Smart Material Solutions, Inc. first uses its nanocoining process to seamlessly nanopattern the outside of a cylindrical mold. This process, illustrated in Figure 1, uses a diamond-turning lathe and a nanopatterned diamond die that is mounted on an ultrasonic actuator to create a spiral of indented nanofeatures around the outside of a rotating metal drum. Precise control of the drum rotation speed, crossfeed, and the actuator frequency enables side-by-side, registered tiling of the indented features. MicroContinuum, Inc. then mounts the resulting nanopatterned cylindrical mold on their roll-to-roll nanoforming pilot line to rapidly create hundreds of feet of patterned polymer film.

The process described above has been used to create a variety of functional nanopatterned films, such as 500 linear feet of a moth-eye film with 300 nm features (Figure 2). The team has also created hundreds of feet of polycarbonate film patterned with 400 nm features and a hierarchical pattern that consists of 500 nm features on top of 4 micron microlenses (Figure 3). The team will discuss the effectiveness of these features for dust-mitigating films for NASA and light-trapping, self-cleaning coatings that can increase the efficiency of thin-film solar panels.

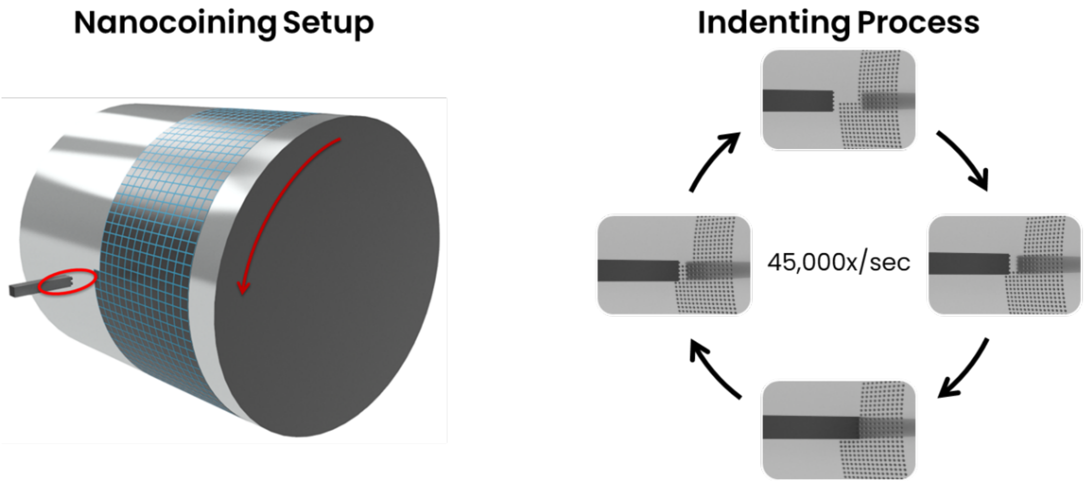

Figure 1. Illustration of the nanocoining setup (left) and a closeup of the indenting process (right).

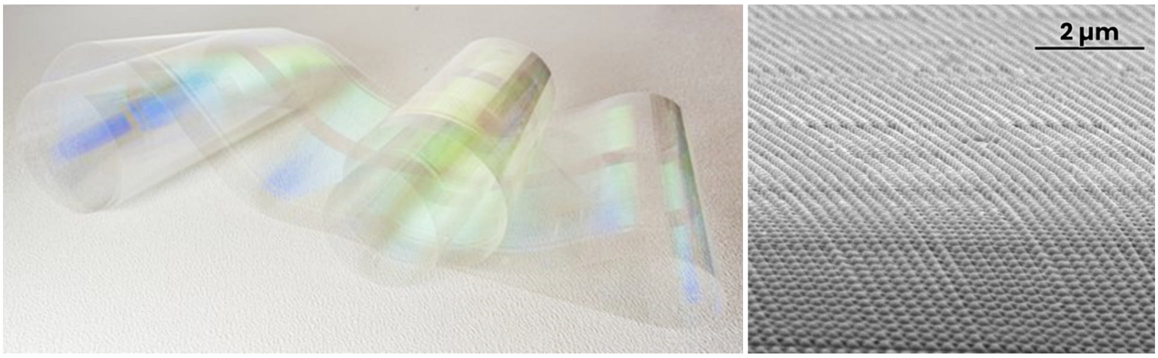

Figure 2. Photo (left) and SEM image (right) of a piece of 500 feet of polycarbonate patterned with 300nm features.

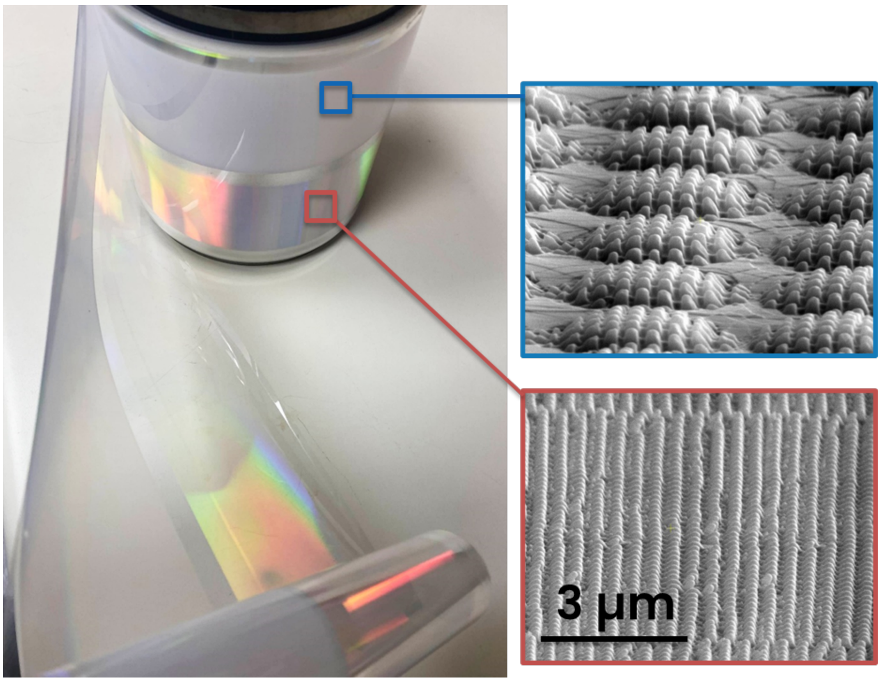

Figure 3. Photo (left) and SEM images (right) of 90 feet of polymer film patterned with hierarchical features (top) and 400 nm features (bottom).