Towards Quasi-real-time, Tip-based Process Control in Roll-to-Roll Nanomanufacturing

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A Roll-to-roll (R2R) approach as applied to nanomanufacturing aims to bring devices with performance akin to counterparts produced with traditional silicon wafer-based substrates while possessing unique mechanical properties, and most importantly, significantly lowered cost. From optical devices, hydrophobic, anti-fouling, and other coatings to integrated circuits, the promise of lower cost nanofeatured products has driven intense research efforts towards enabling R2R fabrication techniques which can successfully make the jump from academic experimentation to high volume manufacturing (HVM). The barriers in front of profitable R2R HVM centers on yield and throughput. While R2R manufacturing holds a major throughput advantage, it may only become a successful strategy if cost feasible yields may be achieved. The National Institute of Standards and Technology has identified high-throughput alignment, real-time metrology, and closed loop process control as the most critical areas in need of innovation. While small-scale fabrication has been demonstrated, there exists a significant hurdle to economically feasible, widespread adoption of these manufacturing techniques — the metrology problem. Many approaches towards yield enhancement have been studied and demonstrated to be effective at distinct, and often disparate, measures of performance and efficacy. These generally vary by the physical phenomena which they leverage. Despite these approaches originating from years of development for similar tools in the wafer semiconductor fabrication industry, commiserate application to R2R nanomanufacturing remains a challenge. This work presents the development from a proof-of-concept tool to a higher volume prototype to perform tip-based measurements on flexible, nanopatterend substrates in a R2R manner[1]. The goals of this design evolution revolve around improving precision to facilitate quasicontinuous scanning of R2R substrates, or the implementation of atomic force microscope sampling without the need to halt the web.

[1] Connolly, L. G., Yao, T.-F., Chang, A. & Cullinan, M. A tip-based metrology framework for real-time process feedback of roll-to-roll fabricated nanopatterned structures. Precision Engineering 57, 137–148 (2019).

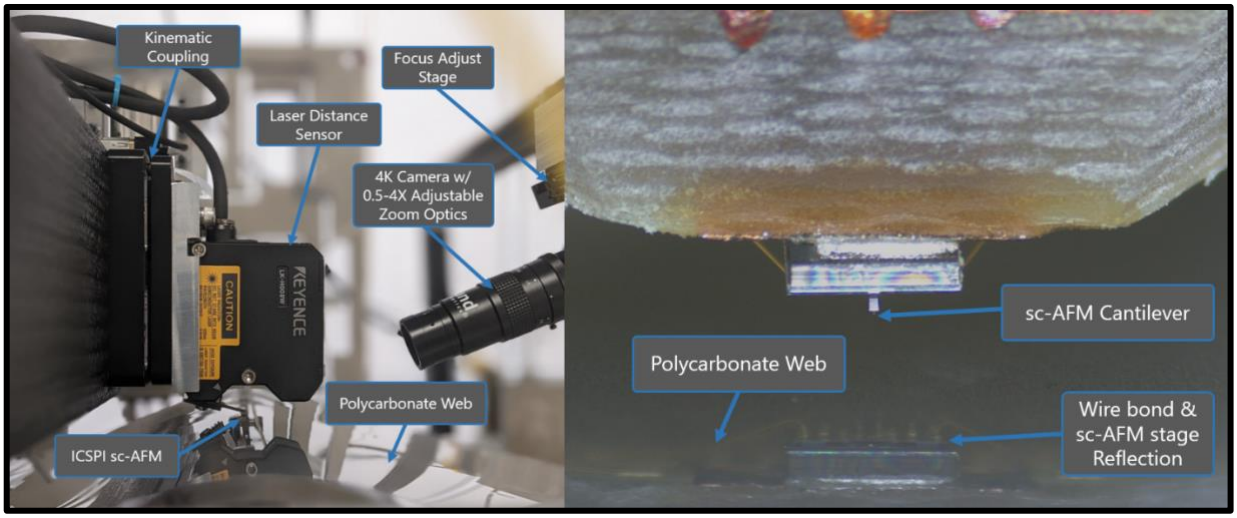

FIGURE 1: Side-view of the upgraded tool's measurement sensor module (left) and micrograph from the on-tool optical monitoring system (right) with major sub-systems labelled.

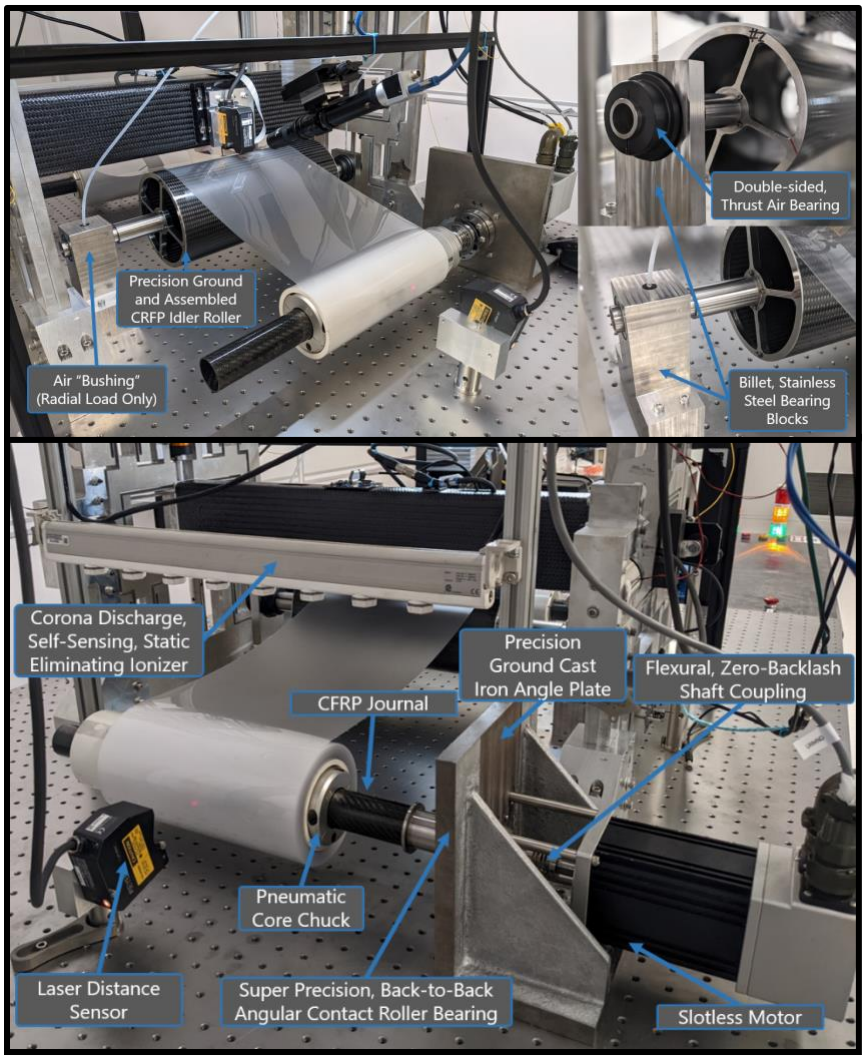

FIGURE 2: Upgraded carbon fiber metrology roller and stainless steel air bearing housings (Top) , wind stand architecture with improved actuator, motion bearings, and sensing (bottom), and control and power electronic systems with major components highlighted.