# Atomically Precise Manufacturing: Control and Automation on the Atomic Scale

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**Abstract –** Improvement in manufacturing precision has been the driving force behind technological advancements throughout history. Atomically precise manufacturing (APM) requires the ultimate in engineering precision. While most manufacturing techniques treat matter as infinitely divisible, APM uses the quantized nature of matter to enable fabrication of devices with atomic precision. Hydrogen Depassivation Lithography (HDL) is an approach to atomically precise manufacturing, whereby a scanning tunneling microscope (STM) tip is used to inject electrons into surface chemical bonds, causing them to break. By scanning the tip across a hydrogen passivated surface, lines of hydrogen atoms are removed creating patterns of exposed silicon dangling bonds. Compared with the background hydrogen-terminated silicon atoms, these dangling bonds are more reactive to many species of material that prefer to adsorb into the patterned area. This method has been used recently to create nanoscale electronic devices including wires, transistors, qubits and quantum dots.

This approach to APM depends on reliable and repeatable operation of a scanning tunneling microscope. However, STM is a characterization tool and its use for nano-fabrication results in challenges, the foremost being frequent occurrence of tip-sample crash in such APM systems. A common cause of tip sample-crash is the poor performance of STM feedback control system. We show that there is a direct link between the Local Barrier Height (LBH), a quantum mechanical property of the tip and sample, and stability robustness of the feedback control loop. We demonstrate how the LBH can be estimated reliably and used to adaptively tune controller parameters so that closed loop stability is preserved. We report experimental results, conducted on two STM scanners, that establish the efficiency of the proposed PI tuning method in avoiding the tip/sample crash in STMs.

**Bio -** Reza Moheimani currently holds the James Von Ehr Distinguished Chair in Science and Technology in Department of Systems Engineering at the University of Texas at Dallas. His current research interests include ultrahigh-precision mechatronic systems, with particular emphasis on dynamics and control at the nanometer scale, including applications of control and estimation in nanopositioning systems for high-speed scanning probe microscopy and nanomanufacturing, modeling and control of microcantilever-based devices, control of microactuators in microelectromechanical systems, and design, modeling and control of micromachined nanopositioners for on-chip scanning probe microscopy.

Dr. Moheimani is a Fellow of IEEE, IFAC and the Institute of Physics, U.K. His research has been recognized with a number of awards, including IFAC Nathaniel B. Nichols Medal (2014), IFAC Mechatronic Systems Award (2013), IEEE Control Systems Technology Award (2009), IEEE Transactions on Control Systems Technology Outstanding Paper Award (2007 & 2018) and several best paper awards in various conferences. He is Editor-in-Chief of Mechatronics and has served on the editorial boards of a number of other journals, including IEEE Transactions on Mechatronics, IEEE Transactions on Control Systems Technology, and Control Engineering Practice.