# Fiducial Registration and Field Stitching for Multi-Scale Scanning Tunneling Microscope Lithography

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Scanning tunneling microscopy (STM) and hydrogen depassivation lithography (HDL) provide a powerful tool and technique for atomic scale manufacturing. However, crossing length scales from nanometers to microns while leveraging the atomic precision of HDL and mitigating the scaling limitations of present STM hardware requires the development of HDL field stitching technologies. In this work, we present our progress on the development of automated fiducial finding and field stitching approaches for the development of our STM lithography system.

On size scales below approximately 200 nm, atomically precise lithography can be achieved by creep-corrected STM without referencing fiducial markers. However, over larger areas, which must be accessed to fabricate wiring, bond pads, and alignment marks, hysteresis and slow thermal drift cannot be neglected. To mitigate these effects we implement an automated, stored-image fiducial generation and relocation system. Based on the pattern design, HDL is used to place fiducial marks across the scan field such that creep-corrected atomic precision can be maintained (Fig. 1).

After writing each fiducial mark, a small STM image is collected to record the detailed atomic structure of the mark (Fig. 2). Subsequently, this data is referenced during a device write operation by an automated centering procedure by which the fiducial mark is compared with stored image data. By this approach we incorporate surface imperfections (e.g. dangling bonds and atomic step edges) into the centering procedure, often allowing a fiducial to be identified over other, nominally identical, patterns in the same field. The impact of using these procedures while writing large area device patterns is discussed.

Finally, we explore overhead minimization (Fig. 3) to reduce the time required for fiducial relocation which maintaining relocation confidence. Efficient field stitching requires rapid fiducial relocation, and for a given fiducial geometry we observe a limit to the scan line density for which the fiducial mark can be reliably identified.

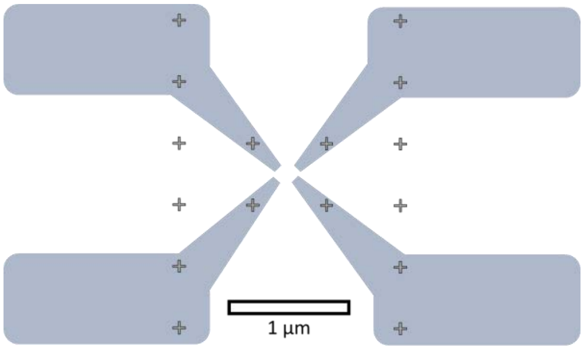

*Figure 1: Field Stitching*: Schematic representation of a field stitched contact microstructure overwriting an array of fiducial markers and interfacing with a nanoscale structure near the origin.

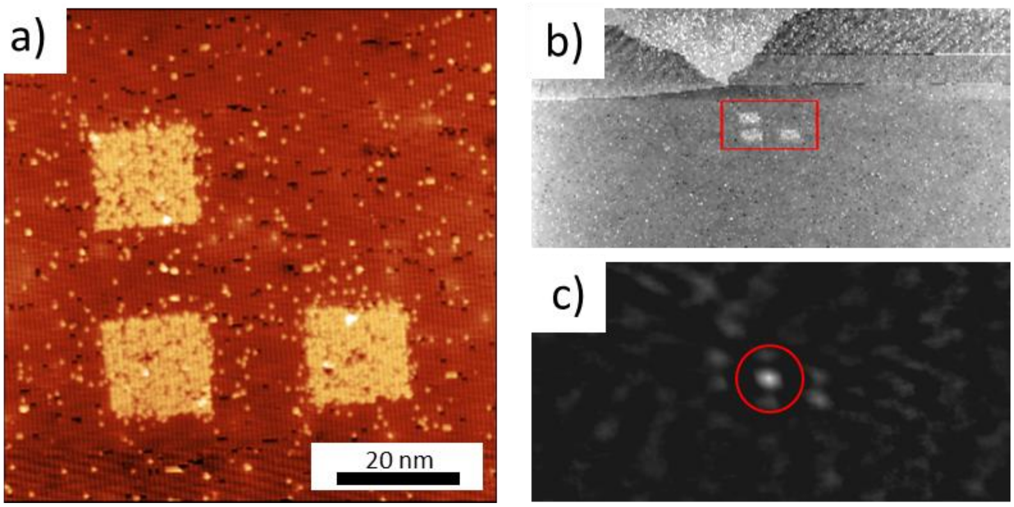

*Figure 2: Fiducial Relocation*: Results of fiducial relocation. a) High-resolution STM topograph of fiducial mark. b) STM topograph with the automatically-identified fiducial mark identified with a red box. c) 2D plot of correlation versus position. The brightest spot within the image corresponds to the fiducial mark.

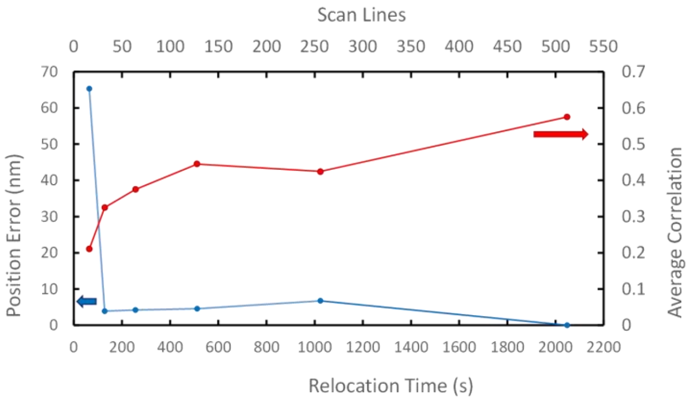

*Figure 3: Overhead Minimization*: We adjust the number of scan lines collected during fiducial relocation (and thus, the time required for relocation). For a specific fiducial mark, we identify the minimum time required for reliable fiducial mark identification.