IMM Report:
A Three-Axis Jig for Assembling Molecular Blocks
by Ted Kaehler
Institute for Molecular Manufacturing
Ted@imm.org
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Abstract
Scanning probe microscopes can construct vertical columns by stacking up molecular building blocks. The probe is unable to attach blocks to the side of a column, severely limiting what it can synthesize. The proposal here is a jig that rotates a macromolecule, so blocks can be added along the X or Y axes using a probe tip that only moves in the Z axis. The jig can be 'pushed over' on the microscope stage to present a different side to the tip. The length of each arm of the jig is several times the width of the probe. The jig could be etched from silicon.

Background
Molecular Assembly has long been a goal. Equipment to automatically make atomically precise objects will need some parts that are atomically precise. Lacking a better way, the parts for early machines will be made 'by hand' using a scanning probe microscope. This has been done, but capabilities are limited. Building blocks are made by bulk chemical processes. They are added to a workpiece at precise places. Specifically, it is easy for a probe to add a block by lowering it straight down onto the workpiece. It is often impossible to add a block to the side of the workpiece. Here we present a jig to aid adding blocks from other directions.

The Jig
The jig is a cube with three arms protruding from it at right angles. It resembles the three axes of a 3D coordinate system with a cube near the origin (Figure 1). The workpiece is attached to the far corner of the cube. The coordinates on the microscope stage are (Sx, Sy, Sz). The coordinates of the workpiece, and the jig, are (Wx, Wy, Wz). The key goal is for the probe be able to reach the workpiece unobstructed from three directions, positive Wx, positive Wy, and positive Wz. This is accomplished by 'pushing over' the jig

on the stage.

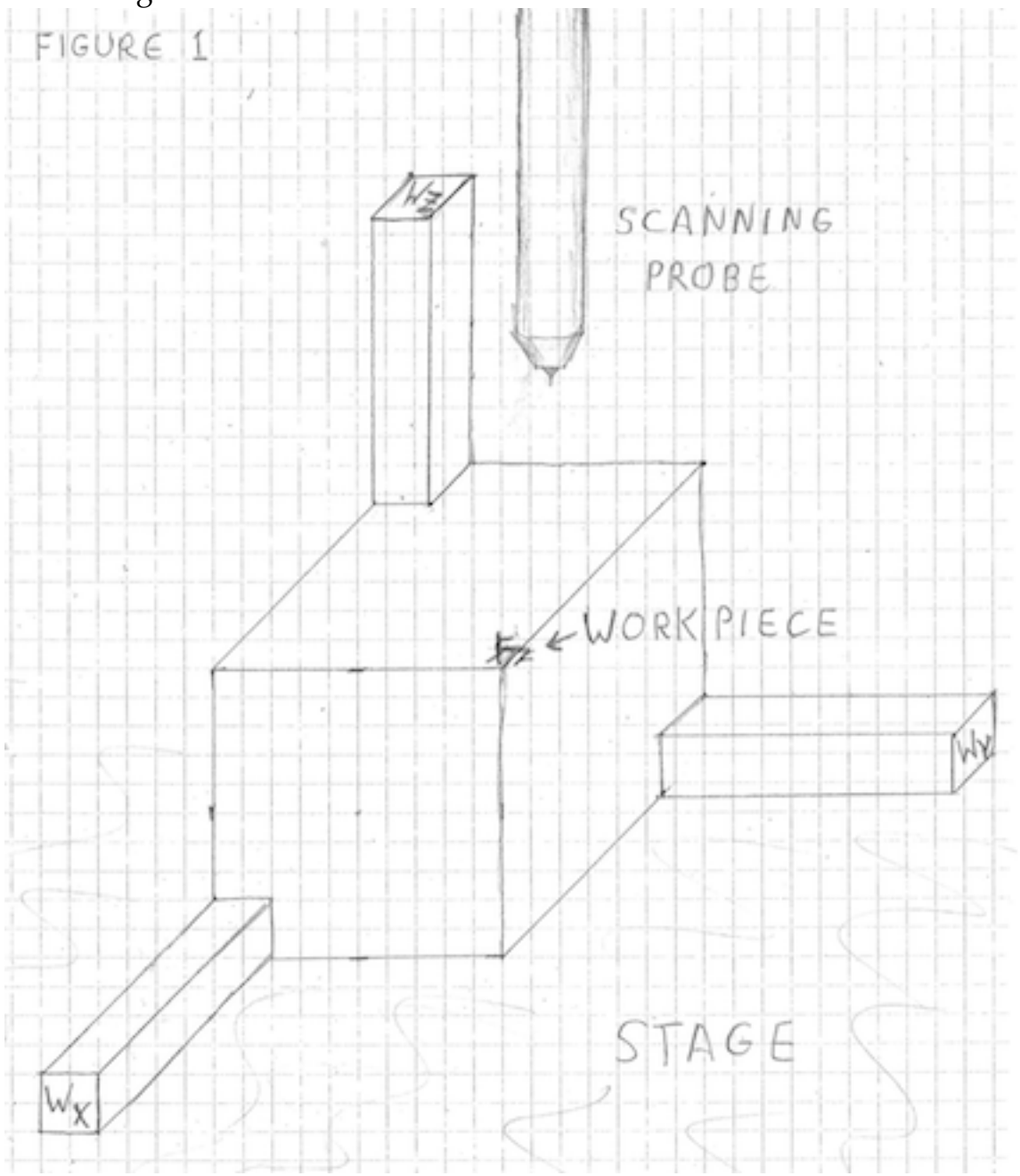


Figure 1 shows the jig on the stage in a position where the workpiece coordinates (Wx, Wy, Wz) are aligned with the stage coordinates (Sx, Sy, Sz). The scanning probe points straight down in Sz, and can deposit building blocks to build a column in Wz.

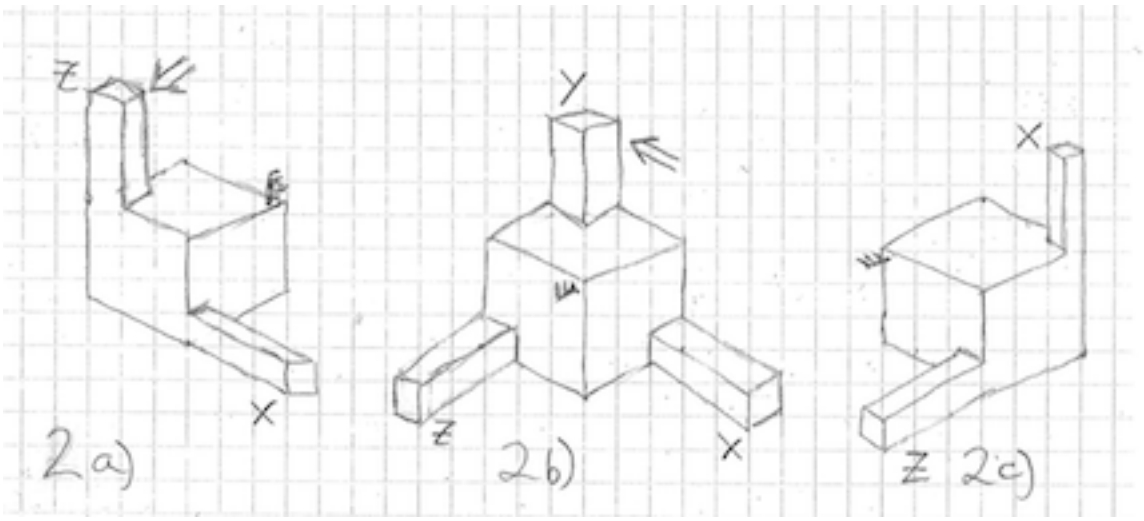


Figure 2a shows the same positioning as Figure 1, but viewed from the back. Blocks can be added from the Wz direction. When a probe (which might not be the main probe) presses on the Z arm of the jig from the Y direction (double arrow), the jig tips over.

Figure 2b shows the jig in the new position. Blocks can be added from the Wy direction. When a probe presses on the Y arm of the jig from the X direction, it tips over again.

Figure 2c shows the jig in the new position. Blocks can be added from the Wx direction. The tipping operations can be reversed and performed in different orders.

The jig must be attracted to the stage surface, but not too much. Pushing on an arm should not break it off. The jig should remain steady while the probe images the workpiece and adds a block to it. Pushing on an arm of the jig should push it over, not slide it along the stage. The pushing should not detatch the jig from the stage.

One way to control attraction of the jig for the stage is via electrostatics. The jig could be an insulator. It could be bombarded with electrons when it is made, to implant a charge inside it. One layer of stage could be a conductive sheet, and the microscope can control its potential. A positive voltage will strengthen the attraction of the jig to the stage. When it is time to flip the jig, this voltage could be reduced. Some sequence of attraction adjustment during

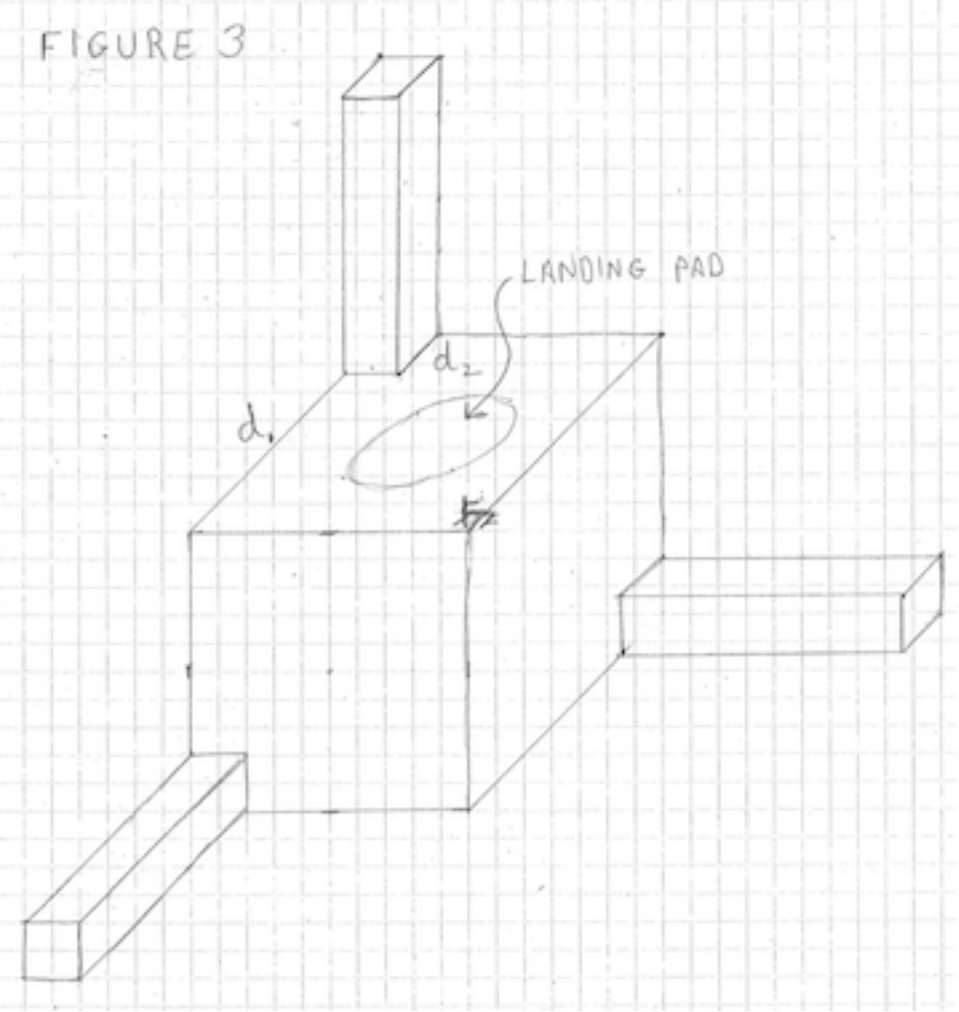
the flip can ensure good control as the jig changes orientation.

Limits on the Jig

Blocks can only be added from three of the six primary directions. Blocks can descend from the positive Sz direction and be attached to the workpiece. This restricts what can be built. A spiral or shape that curves back on itself cannot be built. However, if a previously assembled piece can be used as a block, more complex structures can be built.

The assemblage of blocks being built must be stiff enough to be imaged by the tip.

The length of the cube is (d1 + d2). See Figure 3. d1 must be large enough that the probe can operate comfortably in an area of d1 by d1. The upper flat surface of the cube can serve as a landing pad for the probe when it approaches the jig. Once the probe finds the surface, it can move to the workpiece and image it. d2 is the thickness of each arm. It must be large enough that the arm will not break when the jig is pushed over.



Building blocks are always added to the workpiece from the Sz direction. After the jig is rotated, a new column of blocks can be added to the workpiece in a new direction. The block that serves as the base for a new column must have an attachment point on its side. Several different types of blocks will be needed to build a complex object.

Conclusion

A jig on the stage of a scanning probe microscope allows building blocks to be added to a workpiece from three of the six directions. The probe only needs to deposit blocks from the Z direction. The jig can be 'pushed over' on the microscope stage to present three different sides to the probe.

References

(Coming soon)