

Short Handout for the Flying Cube Method

In this method, a silicon hard mask is used, which is positioned above the subsequent cross-section position using a lift-out needle without contact (from ~100 nm up to a few microns distance above the surface) and held there. This avoids edge rounding of the uppermost layers on the sample and provides the advantage of curtaining-reduced cross-sections by using a hard mask for their preparation.

Workflow:

Steps

1. **Select a suitable Si-Cube**
2. **Tilt the frame to Ionbeam-orientation**
3. **Enlarge Needle-Cube contact area**
4. **Connection between Cube and needle**

Details

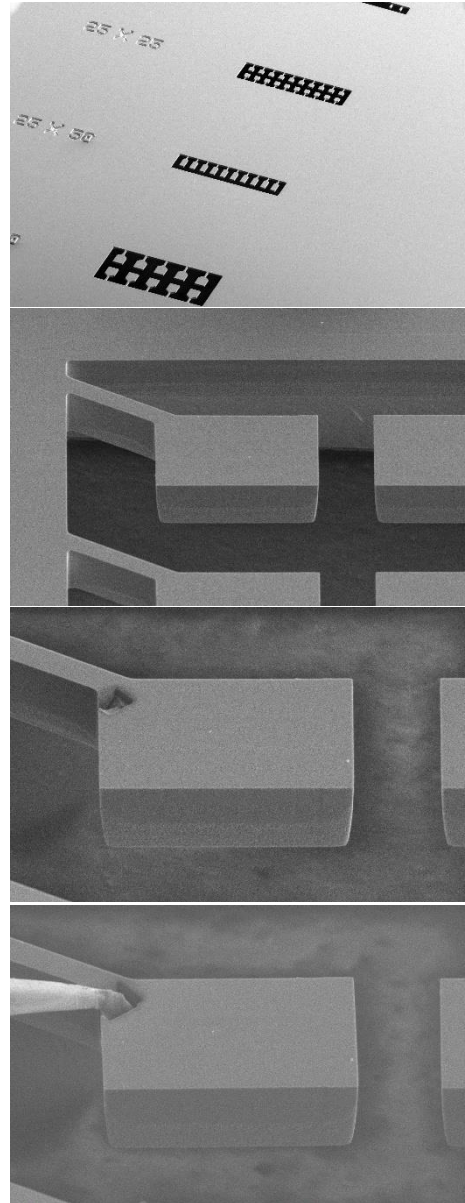
Select the suitable Si-Cube out of the cube-reservoir-frame
Xe-Plasma-FIB (Cube height appr. 20µmm "Flying Cube **Type I**",
Ga-FIB (Cube height appr. 4-6µmm "Flying Cube **Type II**")
 mounted on a standard SEM pin stub.

Tilt the Frame to the Working-Tiltangle of the Ionbeam (i.e. 52deg, Thermo Fisher FIBs)

Various developed strategies enable contamination-free attachment to the needle without gas deposition. E.g., a lift-out needle tip shaped staircase wedge, which is sputtered into the surface of the Si cube, enables the contact surface to be enlarged from a point to a line when the needle is subsequently inserted

The stable connection between the needle and Si cube can be created by an U-shaped sputter pattern around the tip, in which the redeposition of the sputtered material is forced with increased dwell time to fill the remaining gap.

Images



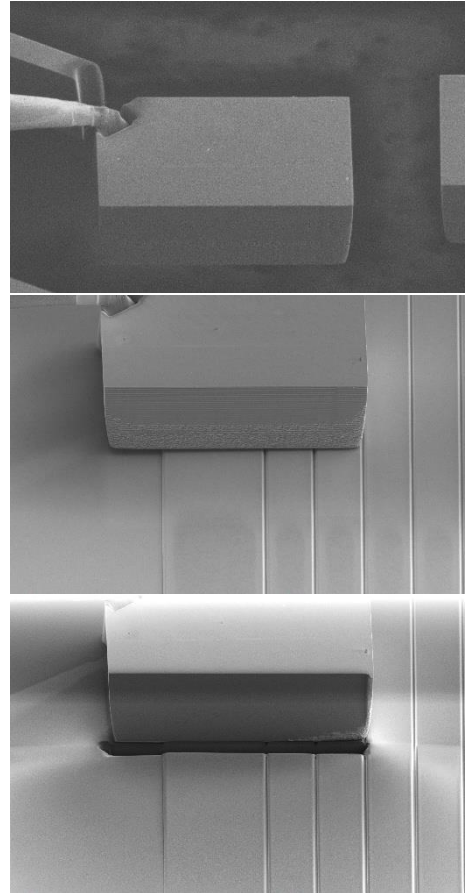
- 4.1. Larger Cube, more stability**

For additional connection stability for larger Si cubes dimensions and, therefore, higher weight ($> 200\ \mu\text{m}$ width for use in Xe plasma-FIBs) an additional C-deposition on top of the contact area would also be possible.
- 5. Cut out and make the cube fly**

The Si cubes are connected to the frame by bridges, which need to be cut after attaching the Si cube to the lift-out needle.
- 6. Positioning of the flying cube**

Once the Si cube has been cut free, the Flying Cube can be positioned over the sample.
- 7. Parking and reuse of the cube**

After cross-section preparation, the flying cube is moved to the parking position again using the lift-out system and can be reused several times (at least 30-40 times, depending on the dimension of the Si-cube and the depth of the cross-section), due to the minimal removal of the cutting edge, without having to be fixed to the needle again in a time-consuming process ($\sim 15\ \text{min}$).



The use of commercially available Si cubes of different thicknesses and dimensions makes it possible to use them in a wide variety of FIB systems with all kinds of lift-out systems.

The great time saving related to this method is not only due to the elimination of long gas-induced deposition, but also to the fact that many times higher ion currents (6.5 nA rough cut, 2.8 nA fine cleaning, FEI Helios G1; 0.5-1 μA rough cut, 60 nA fine cleaning, FEI Helios G4 PFIB CXe) for the cross-section preparation can be used, as the hard mask can reduce the effects of the beam tails of the Gaussian beam shape on the prepared cross-section.