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Fabrication of Ultrasensitive Transition Edge Sensor Bolometric Detectors for HIRMES

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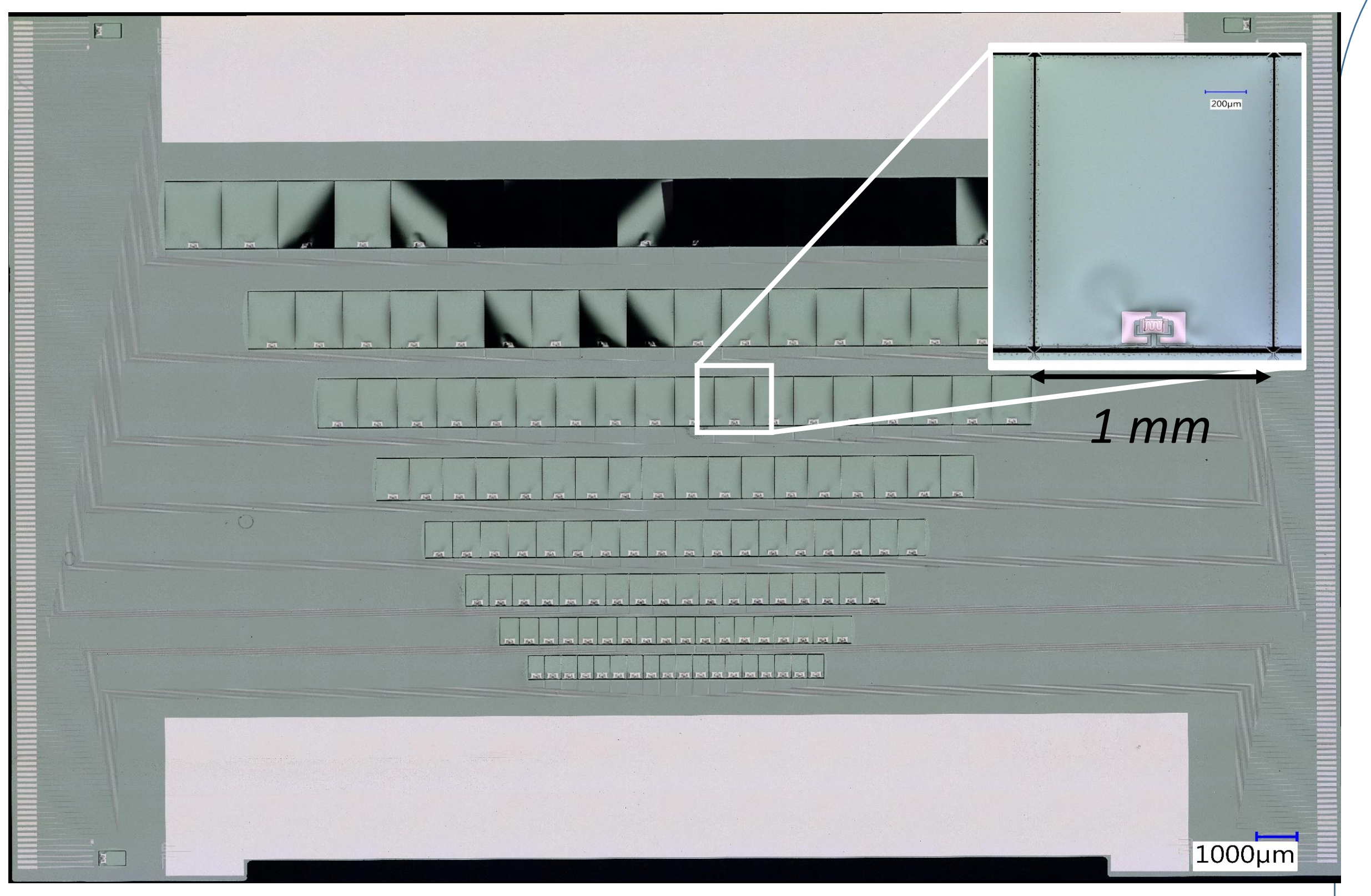
The high resolution mid-infrared spectrometer (HIRMES) is a high resolving power (R~100,000) instrument operating in the 25-122 μm spectral range and will fly on board the Stratospheric Observatory for Far-Infrared Astronomy (SOFIA) in 2019. Central to HIRMES are its two transition edge sensor (TES) bolometric cameras, an 8x16 detector high resolution array and a 64x16 detector low resolution array. Both types of detectors consist of Mo/Au TES fabricated on leg-isolated Si membranes. Whereas the high resolution detectors, with a noise equivalent power (NEP)~2 $aW/\sqrt{Hz}$, are fabricated on 0.45 μm Si substrates, the low resolution detectors, with NEP~10 $aW/\sqrt{Hz}$, are fabricated on 1.40 μm Si. Here we discuss the similarities and differences in the fabrication methodologies used to realize the two types of detectors.

High Resolution Detector Array:
Si Device Layer = 0.45 μm – Mechanical Yield>70%

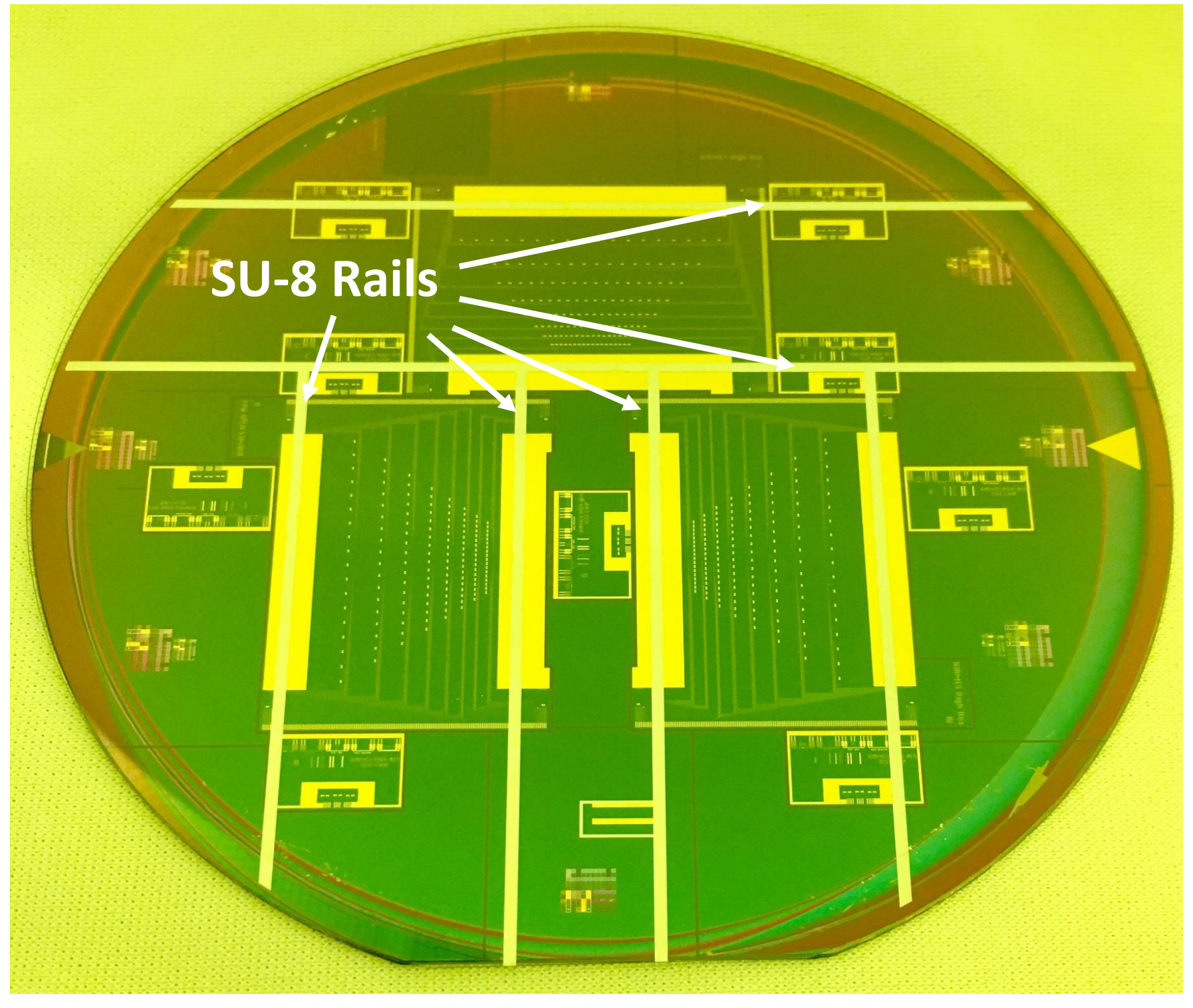
Use of the generic fabrication process results in low pixel yield due to breaking of the silicon thermal isolation legs.

We believe that capillary pressure is partially responsible for leg breakage.



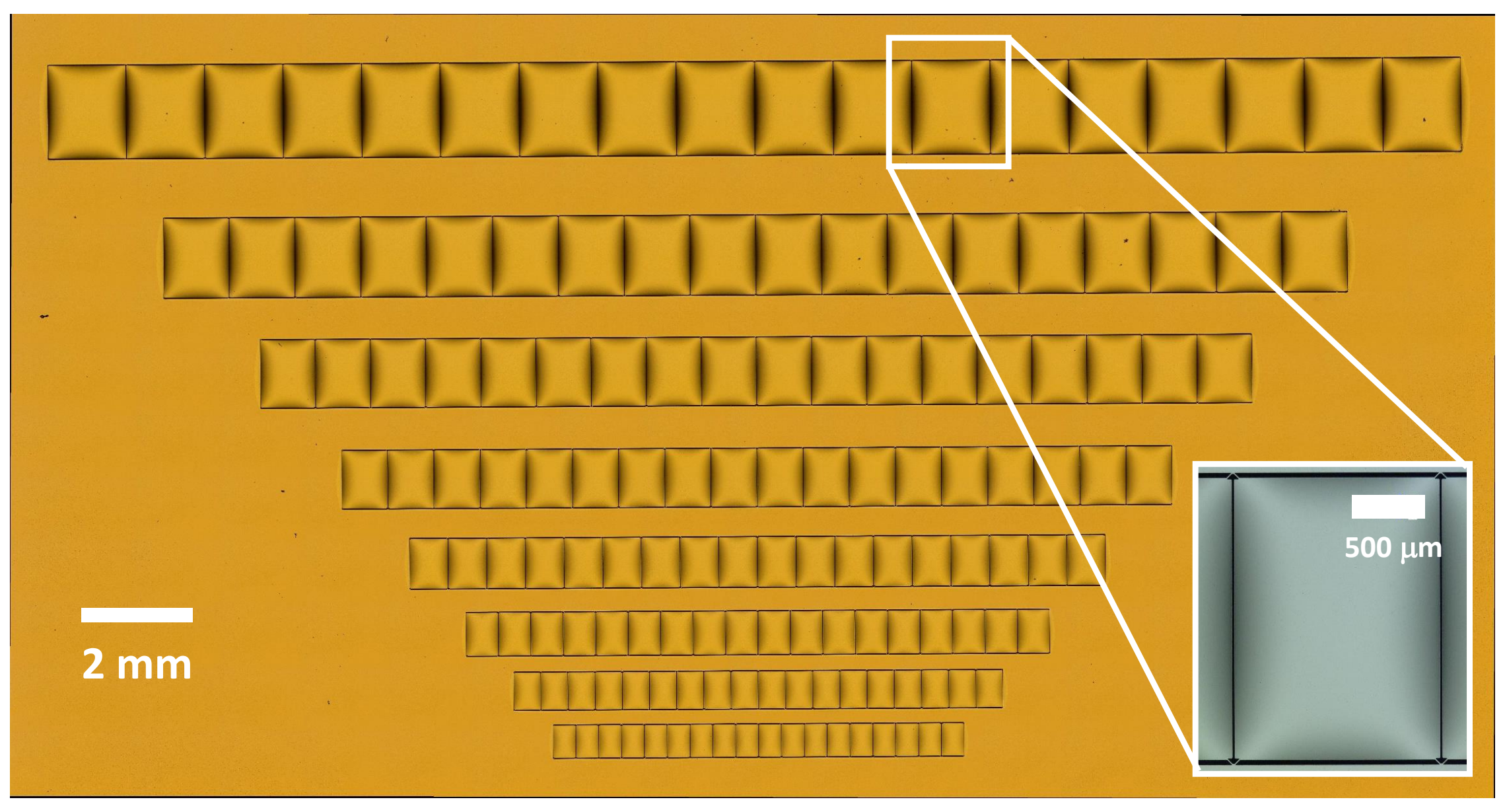
The capillary pressure is proportional to γ/r, where γ is the surface tension and r is the distance between the (sapphire backing wafer and Si) surfaces was reduced by:

- Increasing r by fabricating SU-8 "rails" on the sapphire wafer.
- Decreasing γ (to zero) by drying the parts in a critical point dryer once the wax is dissolved.

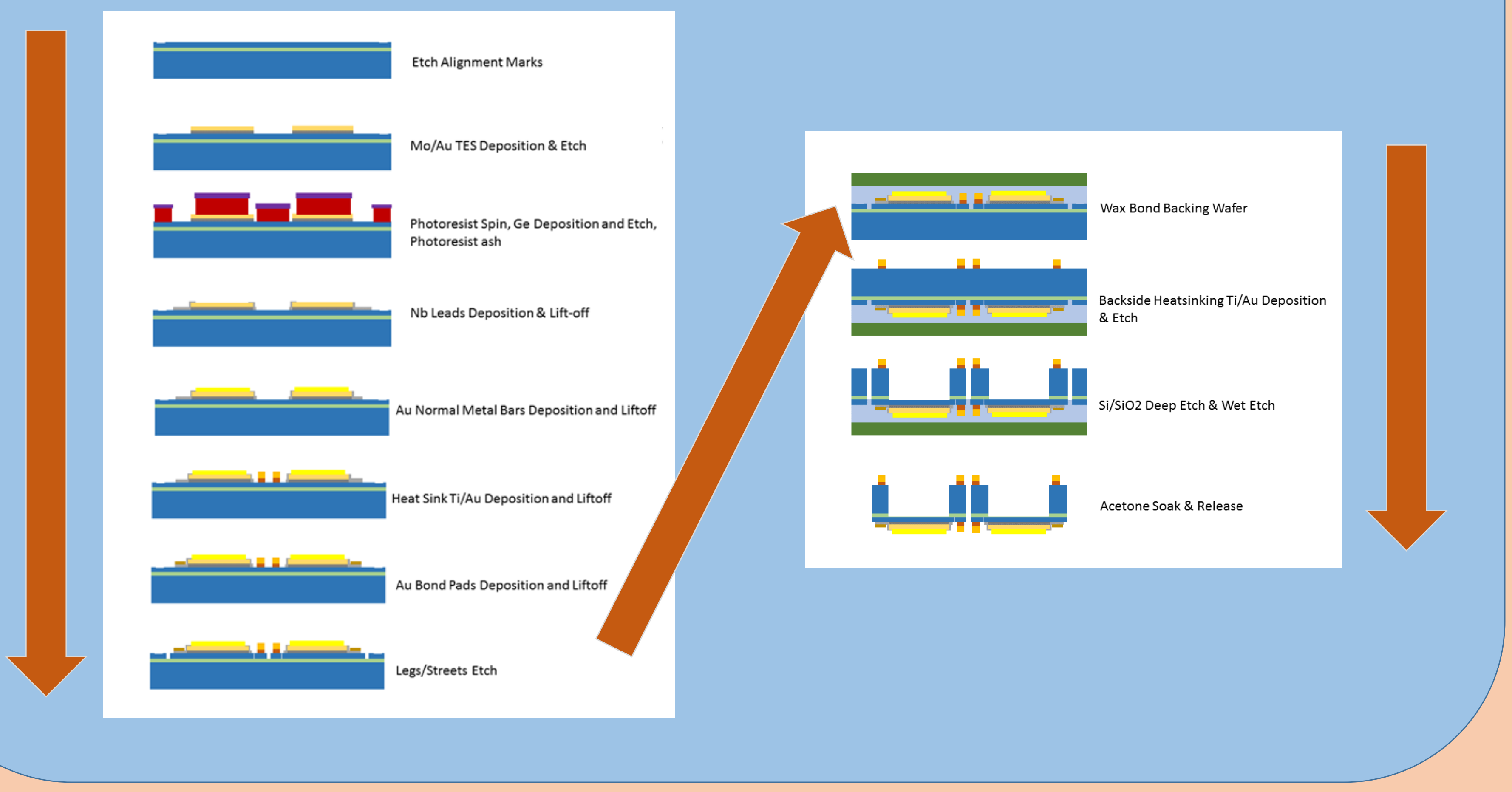


The SU-8 "rail" process was vetted on a mechanical model. The mechanical yield was 100% in the absence of bubbles in the wax or other defects.

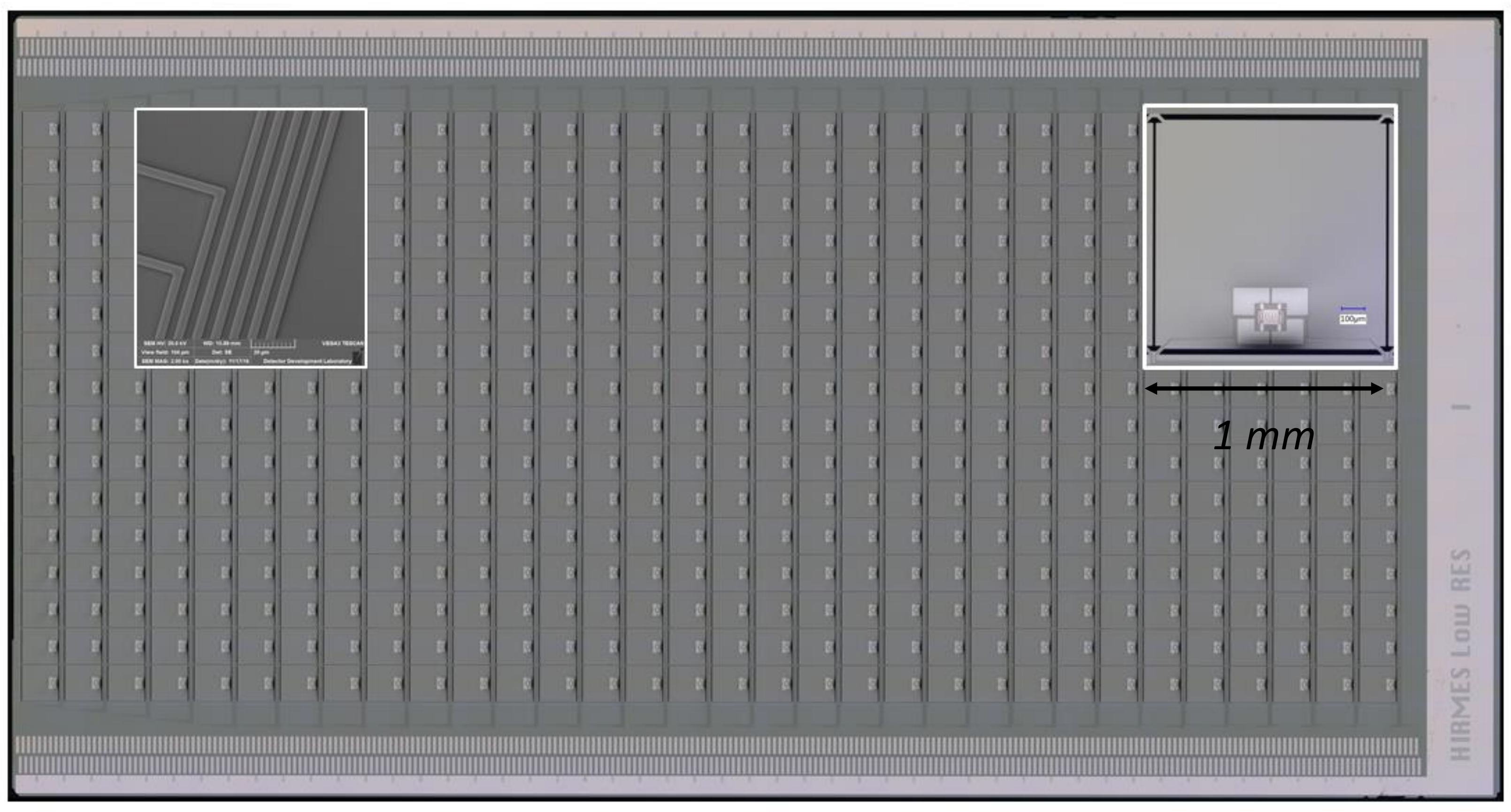
Without rails, the membranes became adhered to the sapphire substrate and broke.



Generic Fabrication Process for TES Bolometric Detectors: Starting with a Silicon-on-Insulator Wafer



Low Resolution Detector Array:
Si Device Layer = 1.4 μm – Mechanical Yield>99%

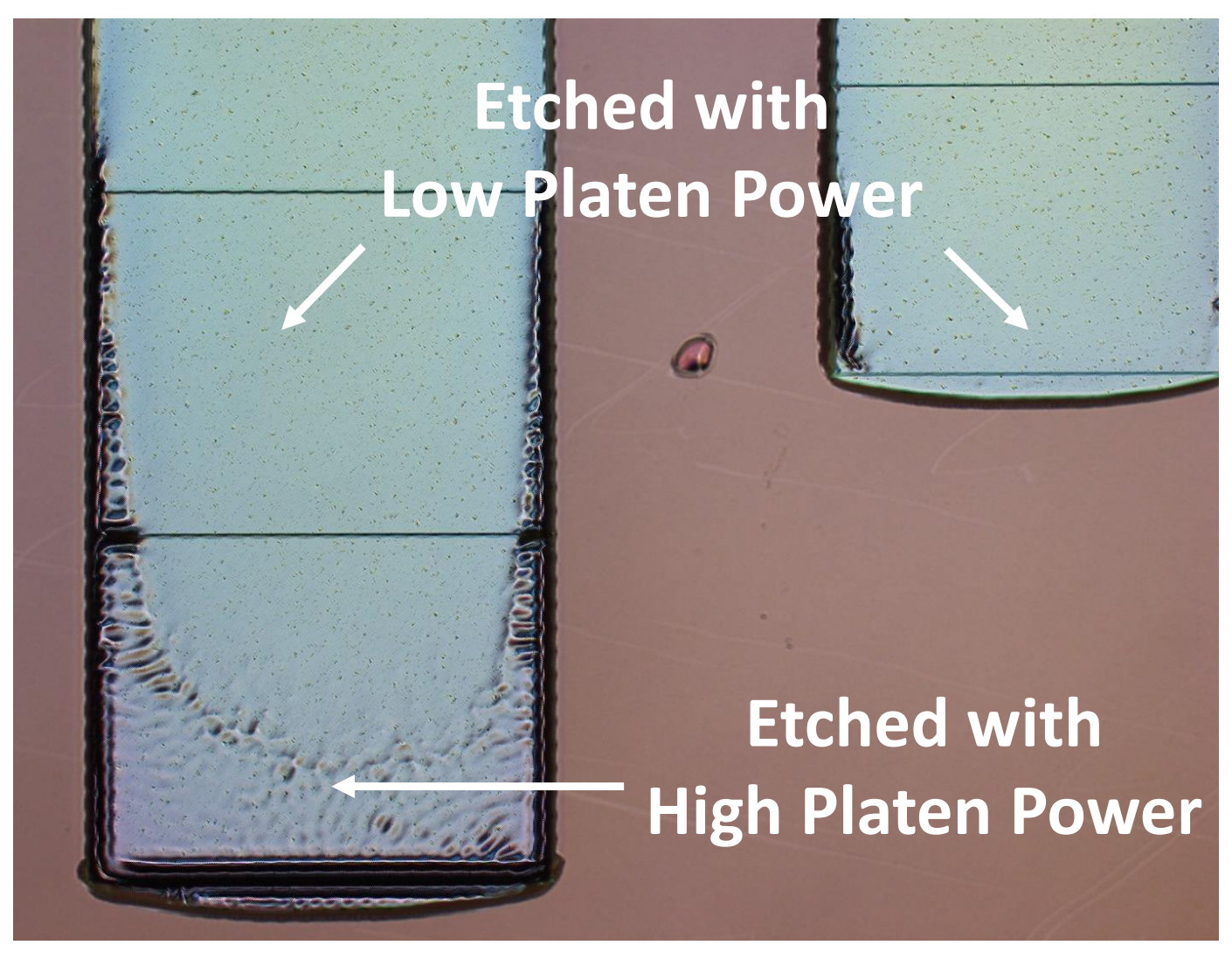


Micrograph of a 32x16 TES bolometric detector array. *Right*, the pixel area is 1 mm^2 and the Si membrane thickness is 1.40 μm. There are four thermal isolation legs which are 15 μm wide and 30 μm long. *Left,* a scanning electron micrograph of several of the lifted off 4 μm wide Nb leads.

Conclusions & Future Challenges

- As membranes get thinner (for low NEP bolometric applications) risk of mechanical failure increases.
- A process for achieving high mechanical yield on large filling fraction leg-isolated ultrathin Si membranes was demonstrated.

Further developments to increase the yield by adjusting deep reactive etching parameters, in order to prevent wax reflow, are on-going.



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