SAND2005-7703P

SCRIBE-AND-BREAK FOR POST RELEASE MEMS DIE SEPARATION

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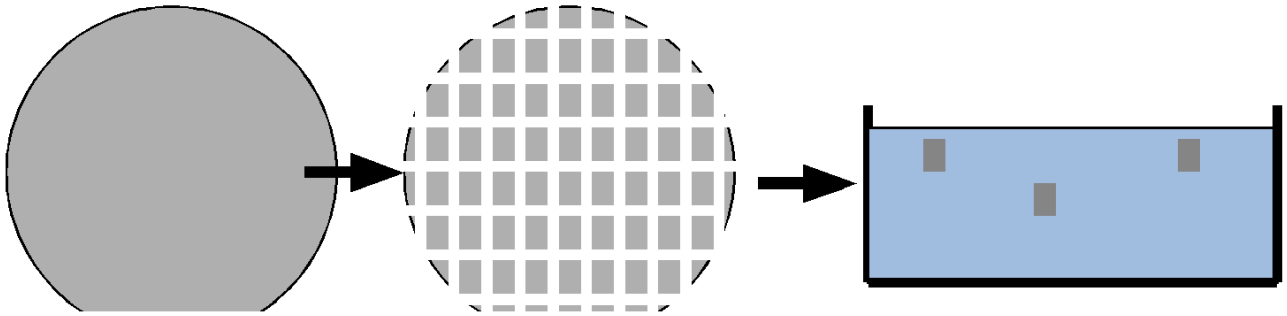
WHY POST RELEASE DIE SINGULATION FOR SURFACE MICROMACHINES?

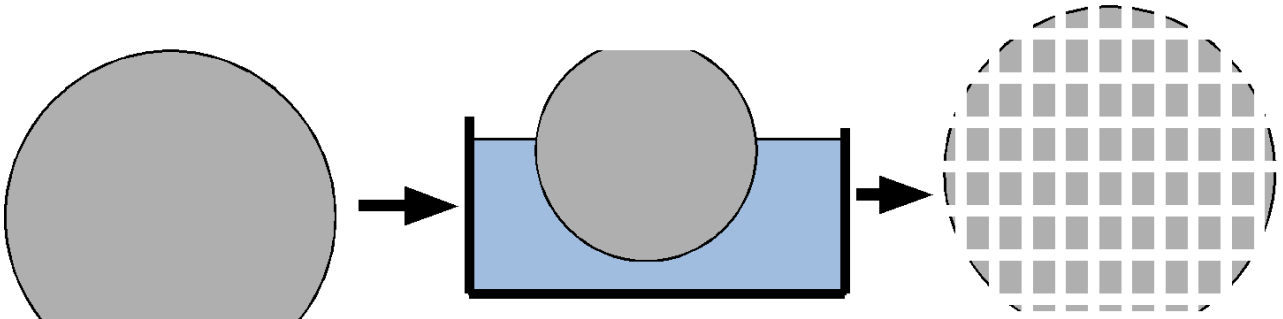


Completed Wafer

Dice

Release and Dry Dice

Current Process



Completed Wafer

Release and Dry Whole Wafer

Scribe-and -Break

Scribe and Break Full Wafer Process

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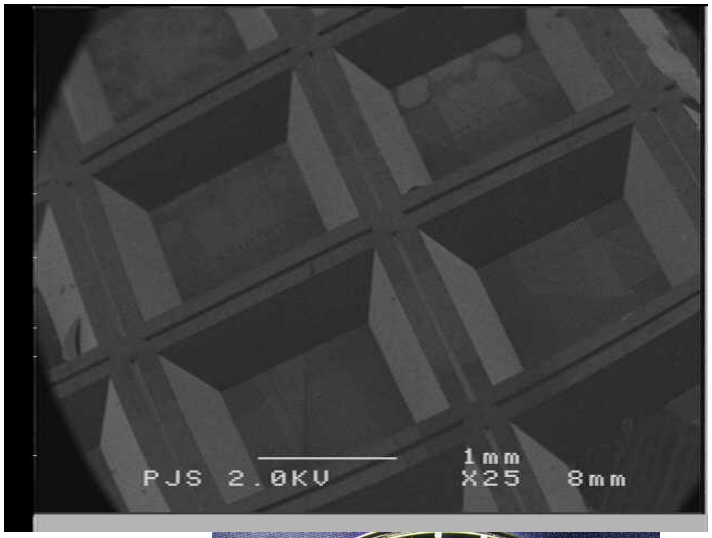
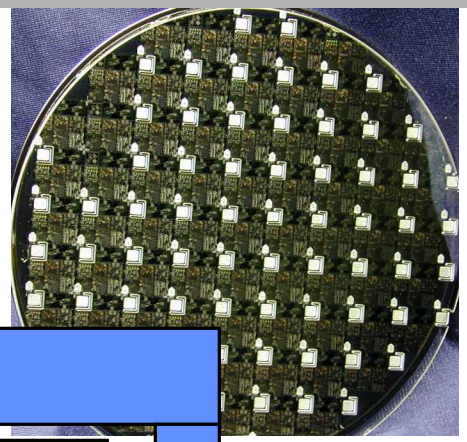
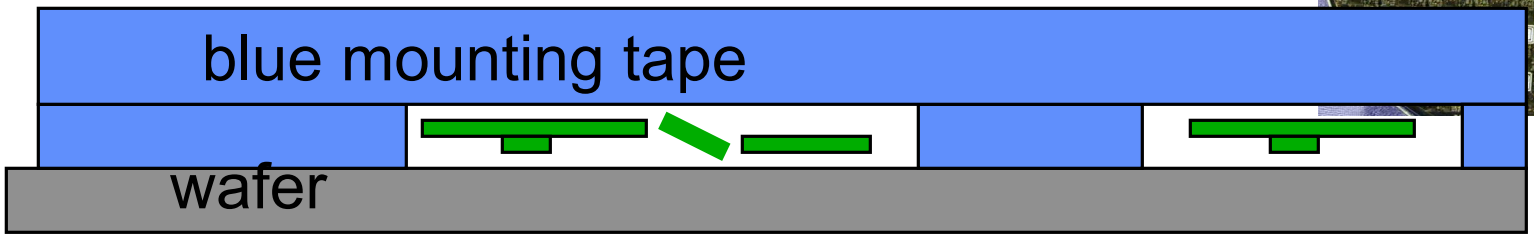
APPROACHES

- Dice and then Release
  - Sandia
  - No process changes
- Permanent Cap
  - Motorola
  - Provides first level package but it changes the device and the process
- Temporary Cap
  - Analog Devices
  - Need to allocate real estate for the cap
  - Changes the Process
- Break after Release
  - Texas Instruments







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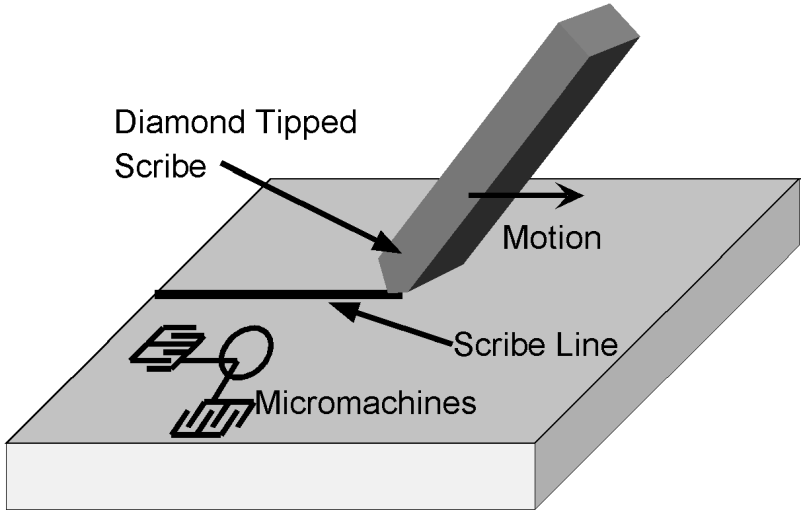
CRITERA AND CHOICES

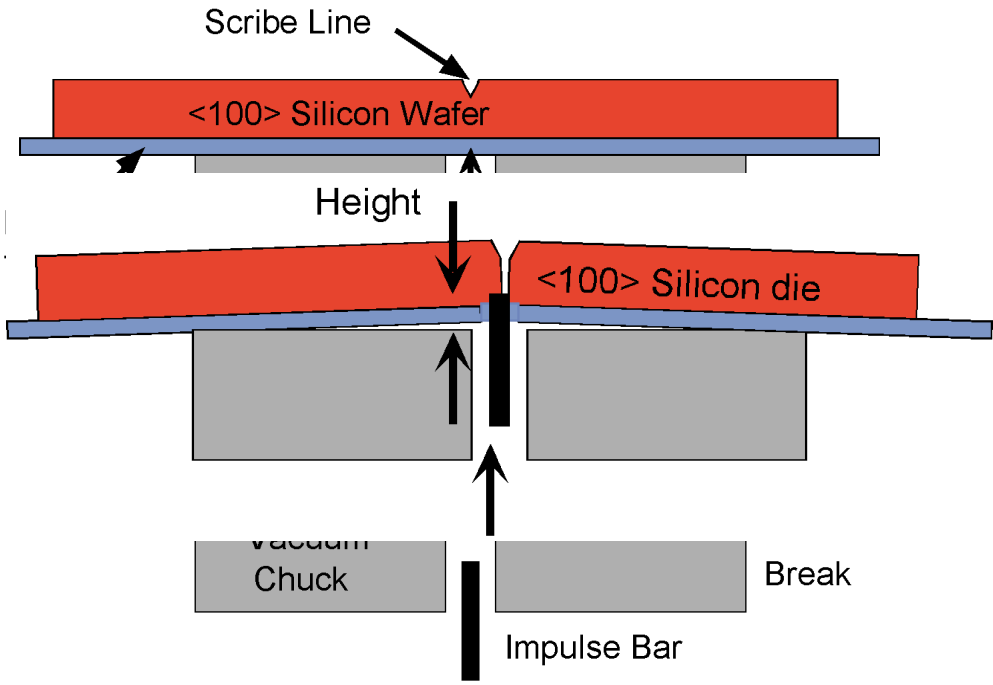
- **Process must be**
  - **Dry**
  - **Particle free**
  - **Robust**
- **Alternatives**
  - **Analog Devices**
  - **Texas Instruments (partial saw and break)**
  - **Laser Cutting**
  - **Laser Scribing**
  - **Diamond Scribing**

ADVANTAGES TO SCRIBE AND BREAK

- No process changes
- 100% of die size devoted to MEMS
- Transparent to designers
- Fast
- Low cost
- Disadvantage
  - Not well understood

SCRIBE AND BREAK





1. Released MEMS wafer is scored with a diamond scribe

2. Wafer is broken into die along scribe line

Post release die singulation enables full wafer release of MEMS devices

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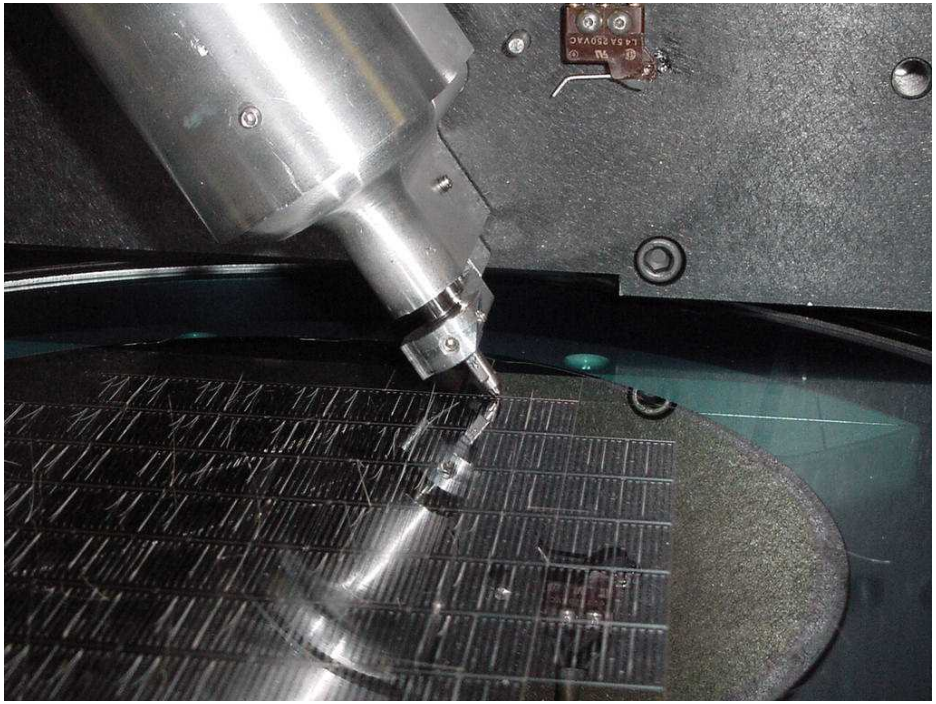
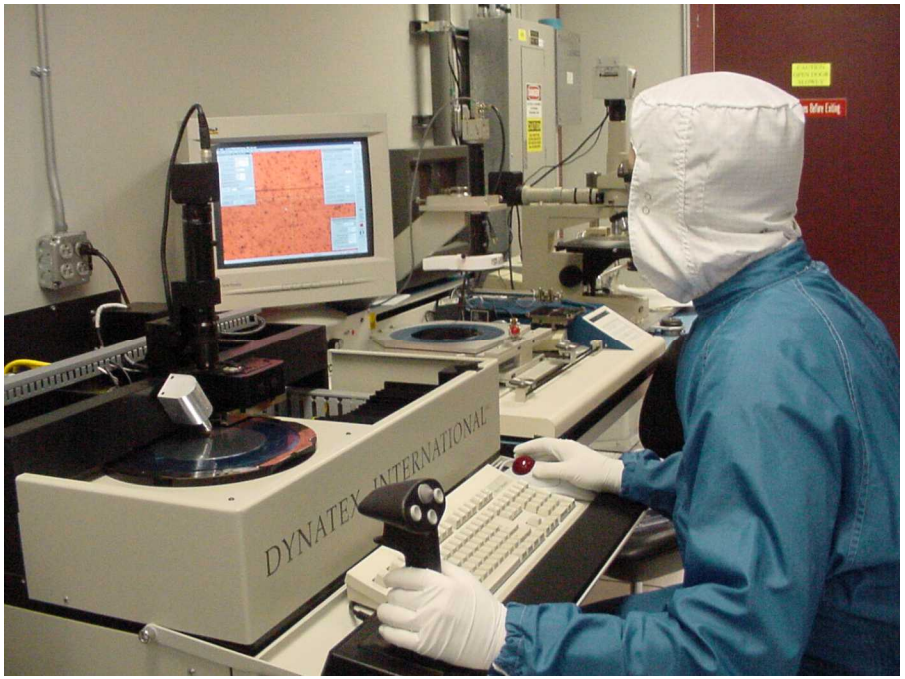
SCRIBE AND BREAK MACHINE





- GST Scriber/Breaker
- Manufactured by Dynatex International, Santa Rosa, California
- Handles substrates up to 150 mm in diameter

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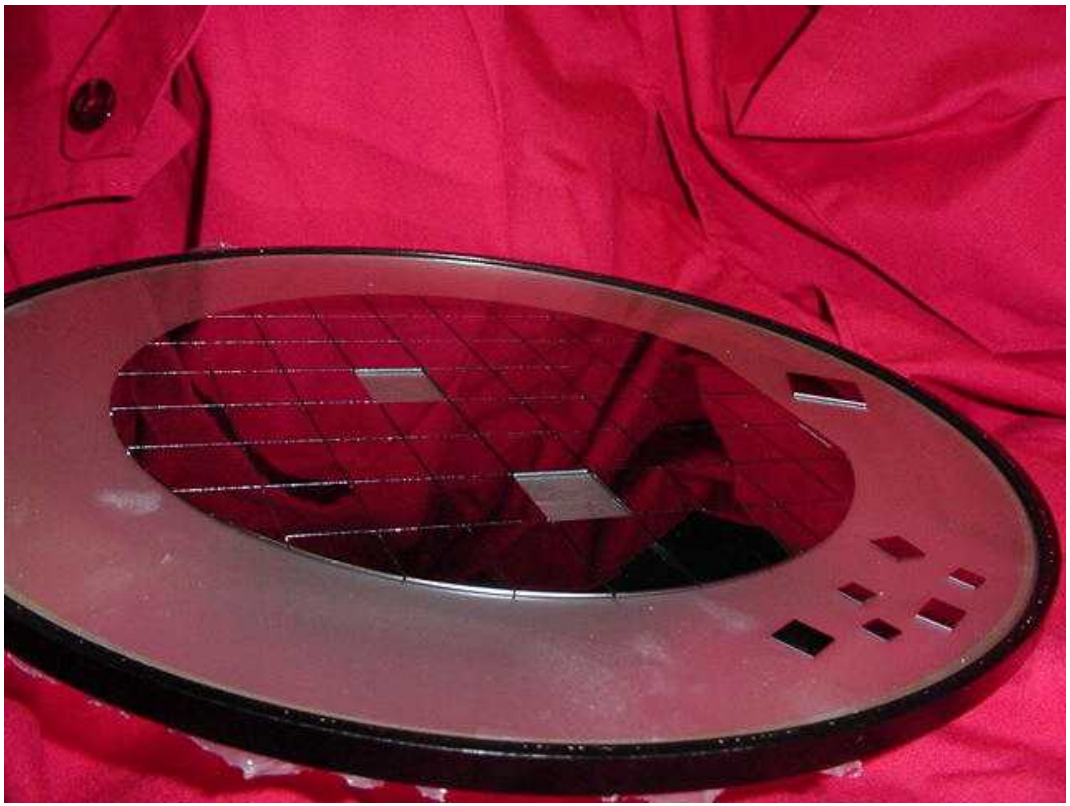
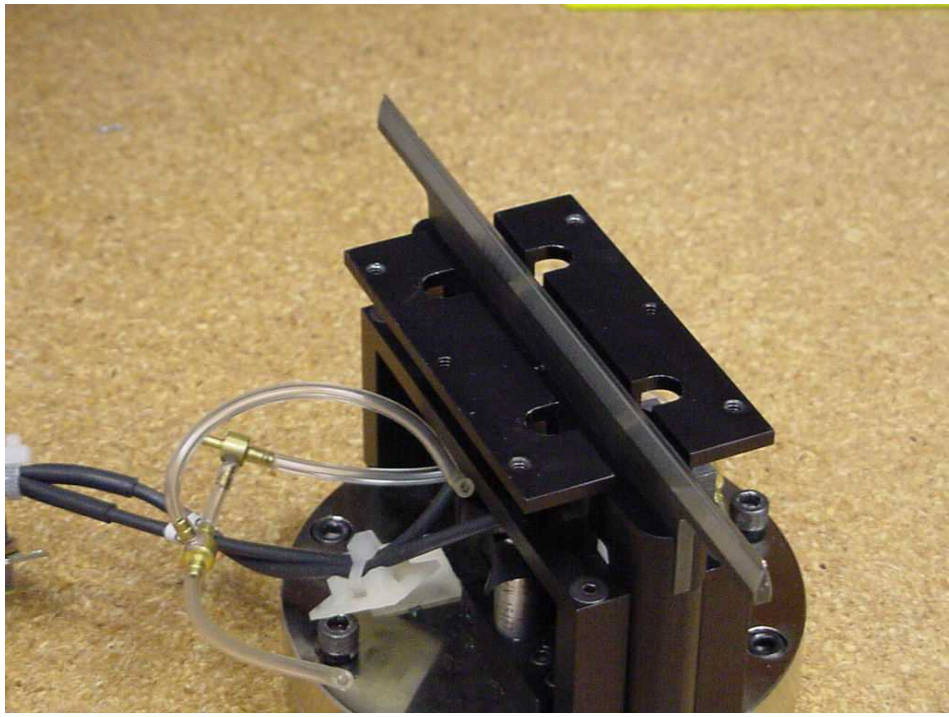
WAFERS MOUNTING



- **Wafers mounted on frame before scribing (either standard or UV tape)**

VACUUM CHUCK AND BREAKER



- Vacuum chuck

Breaking bar

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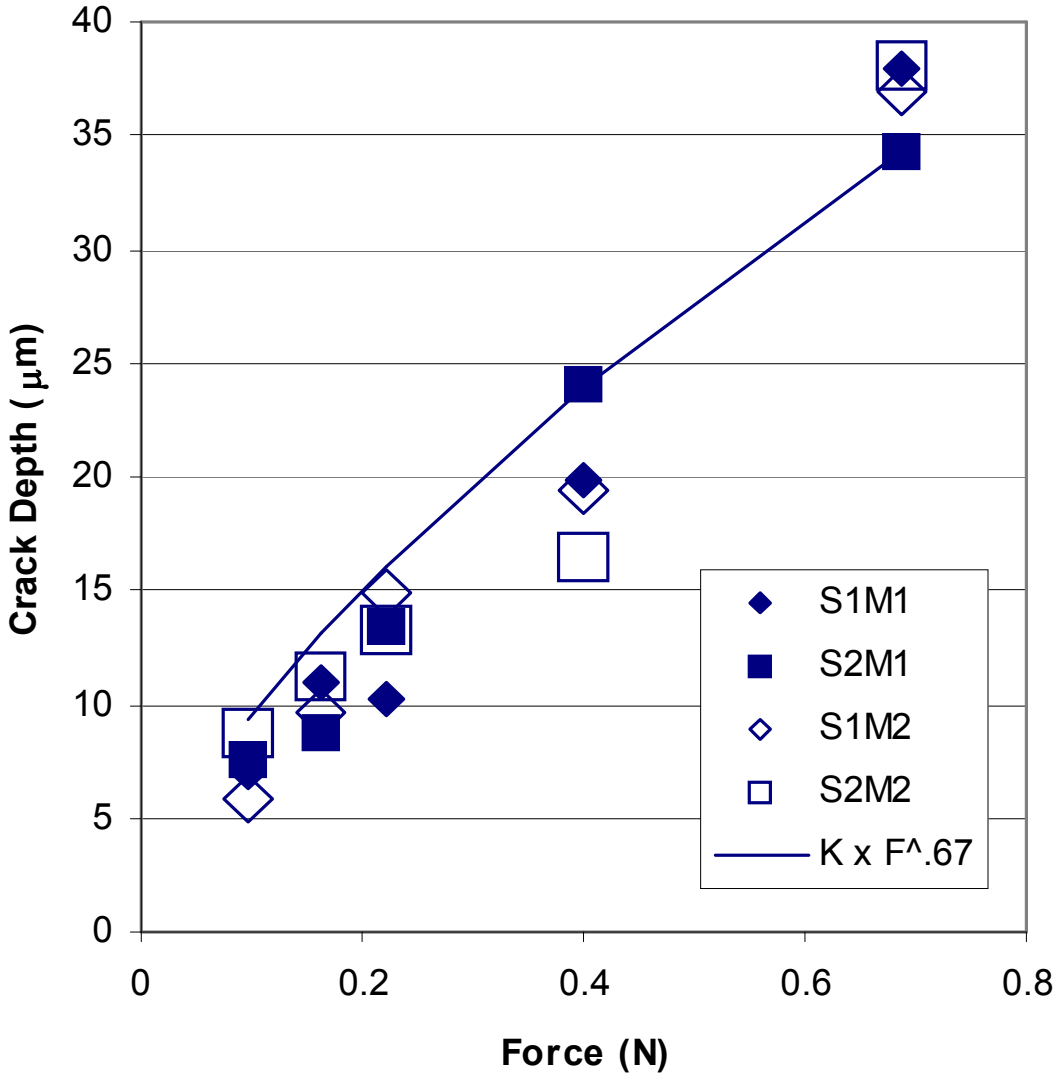
MEDIAN CRACK DEPTH

- Measurements were taken with 2 different SEMs on two different samples
- 4 samples total

$$depth = \frac{\left(2CF/K_{IC}\right)^{2/3}}{\pi}$$



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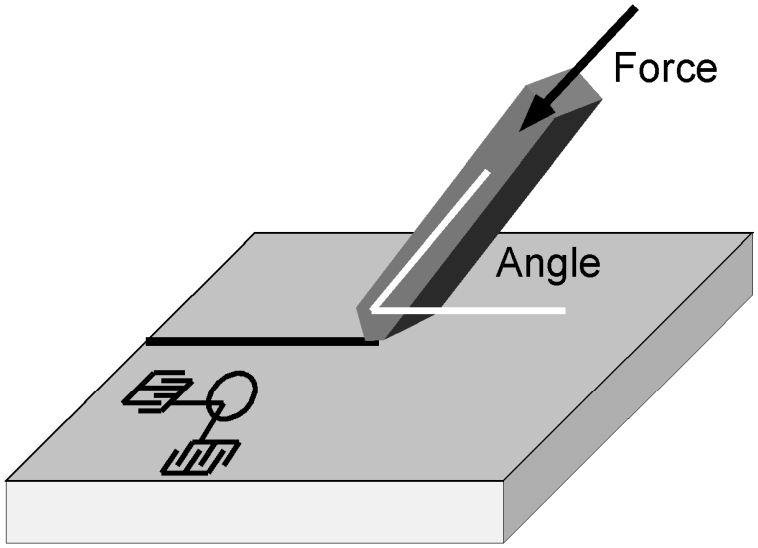
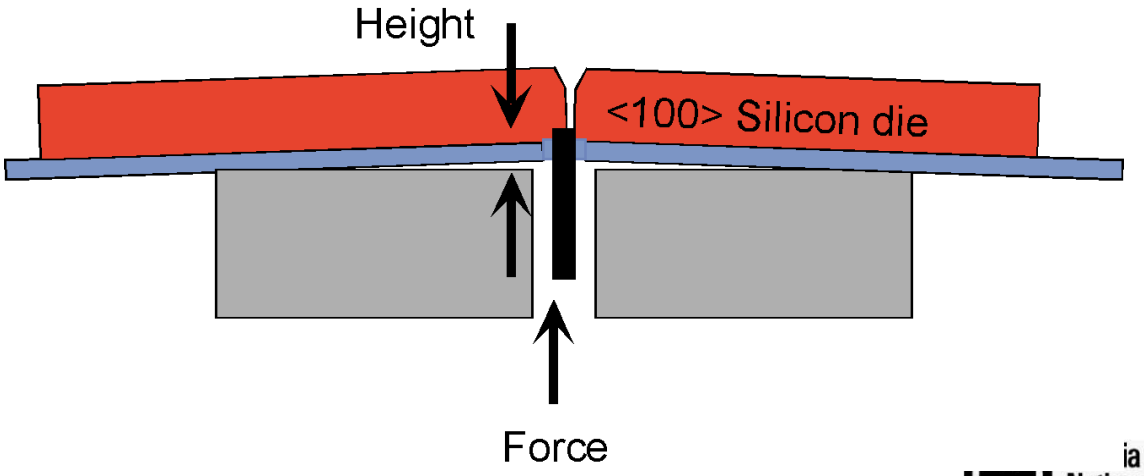
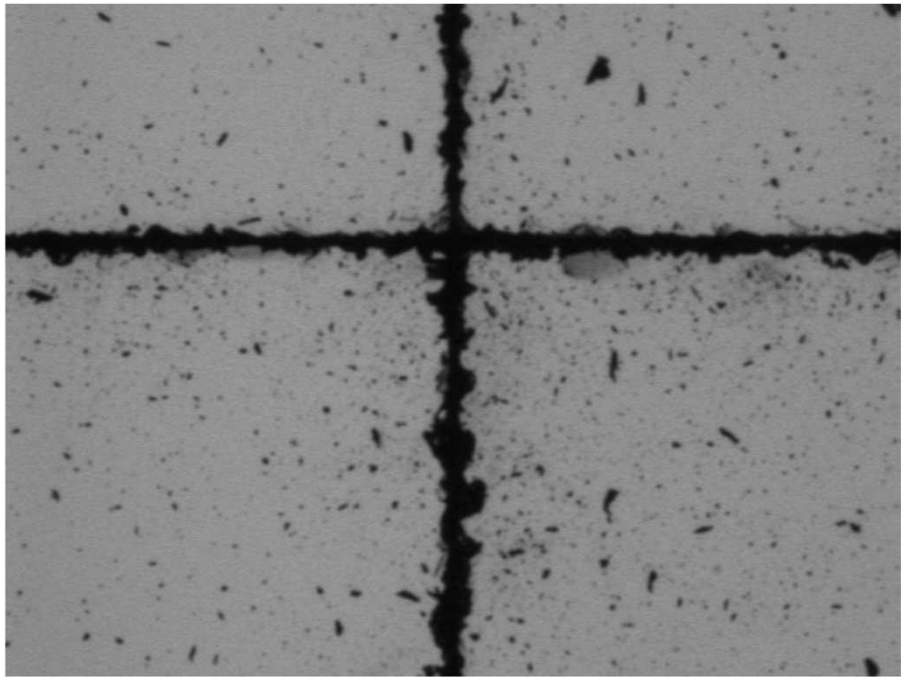
DESIGN OF EXPERIMENTS TO FIND PARAMETER IMPORTANCE

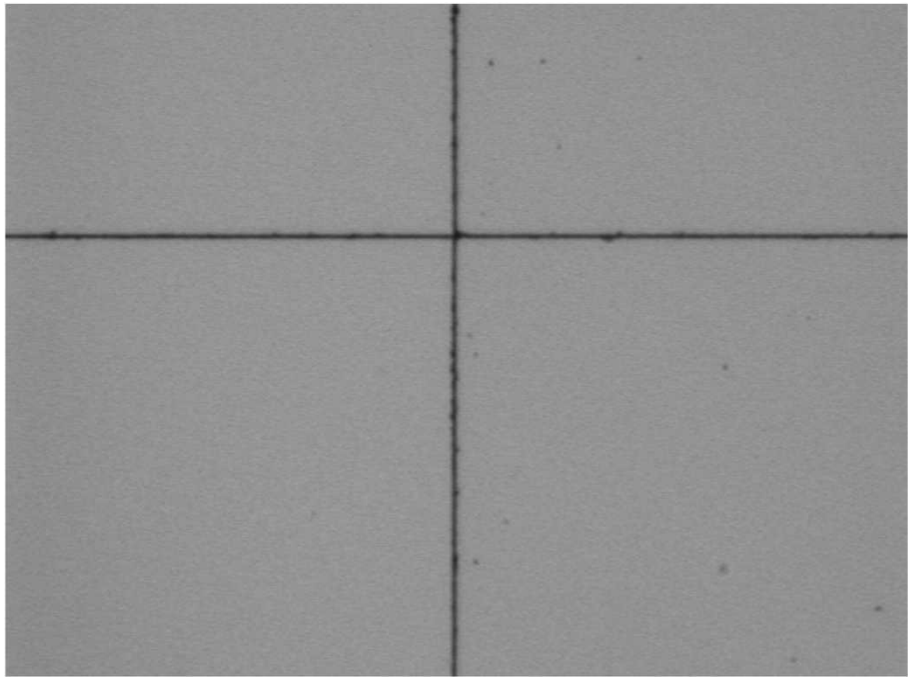
- Machine has 13 parameters
- 4 parameter full factorial
- Run 3 times in different orders
- Parameters used were scribe force, scribe angle, break pressure, and break height





TO QUANTIFY SCRIBE QUALITY





Quality 5 scribe

Quality 1 scribe

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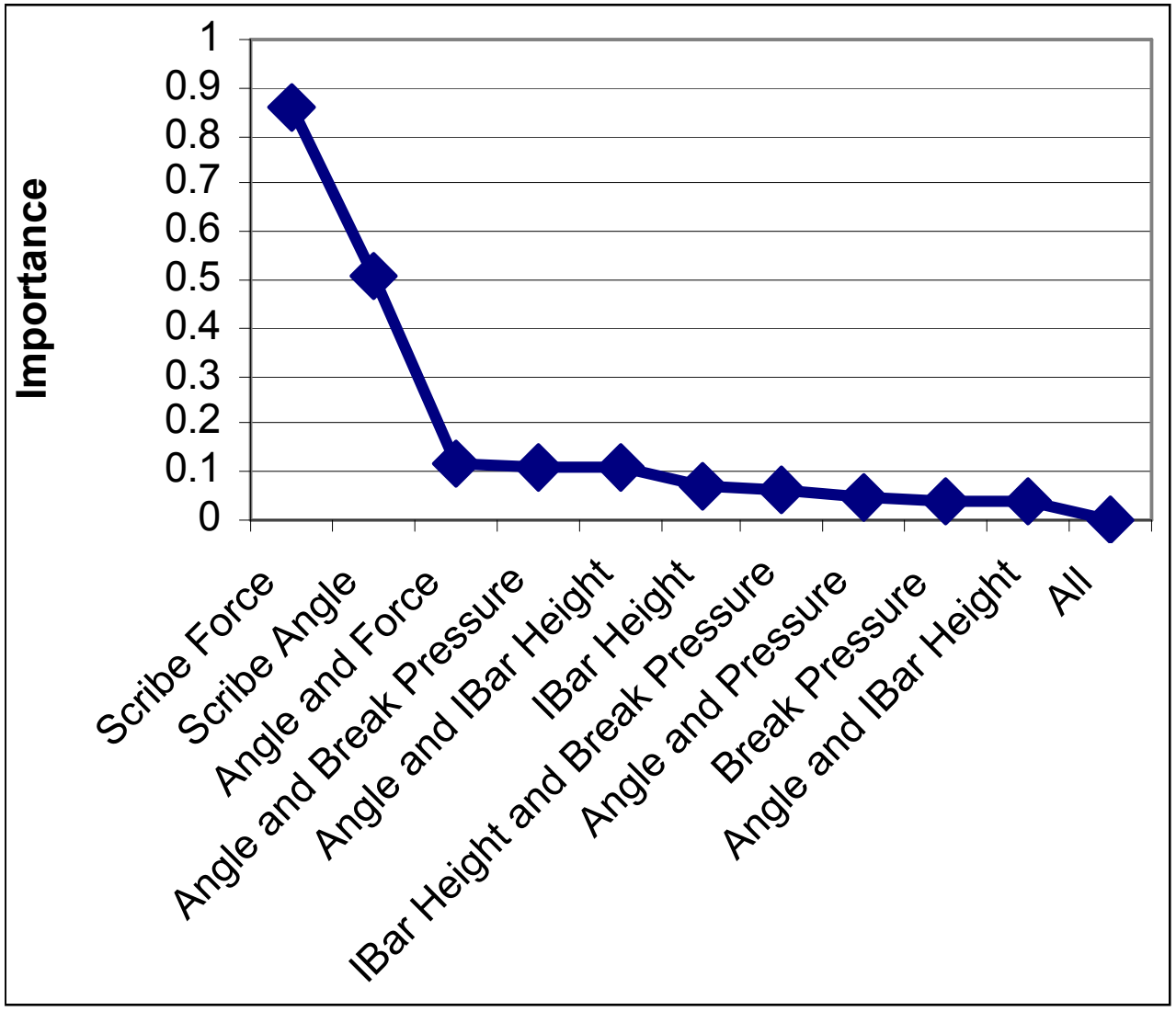
DESIGN OF EXPERIMENTS QUALITY



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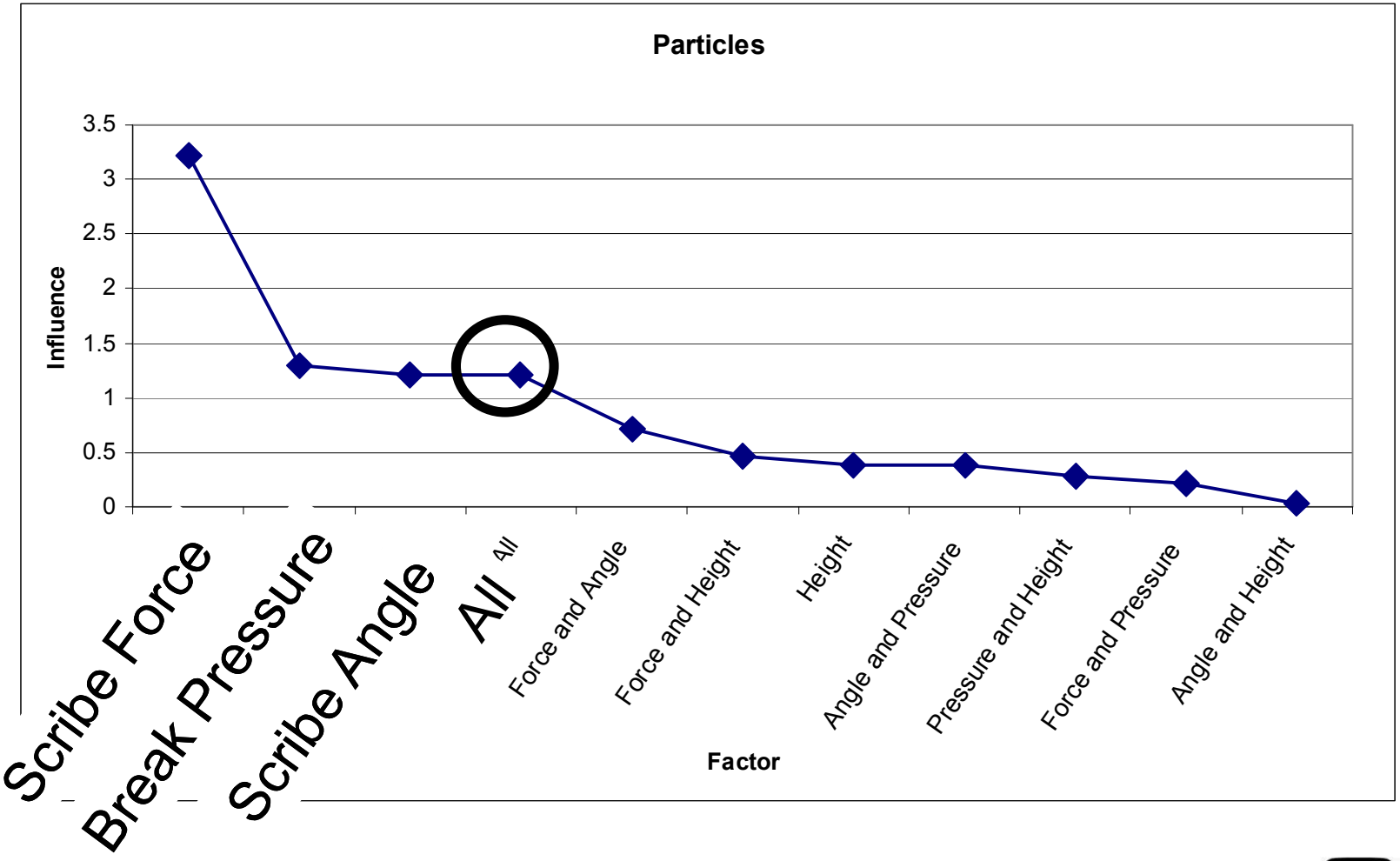
DESIGN OF EXPERIMENTS-PARTICLES



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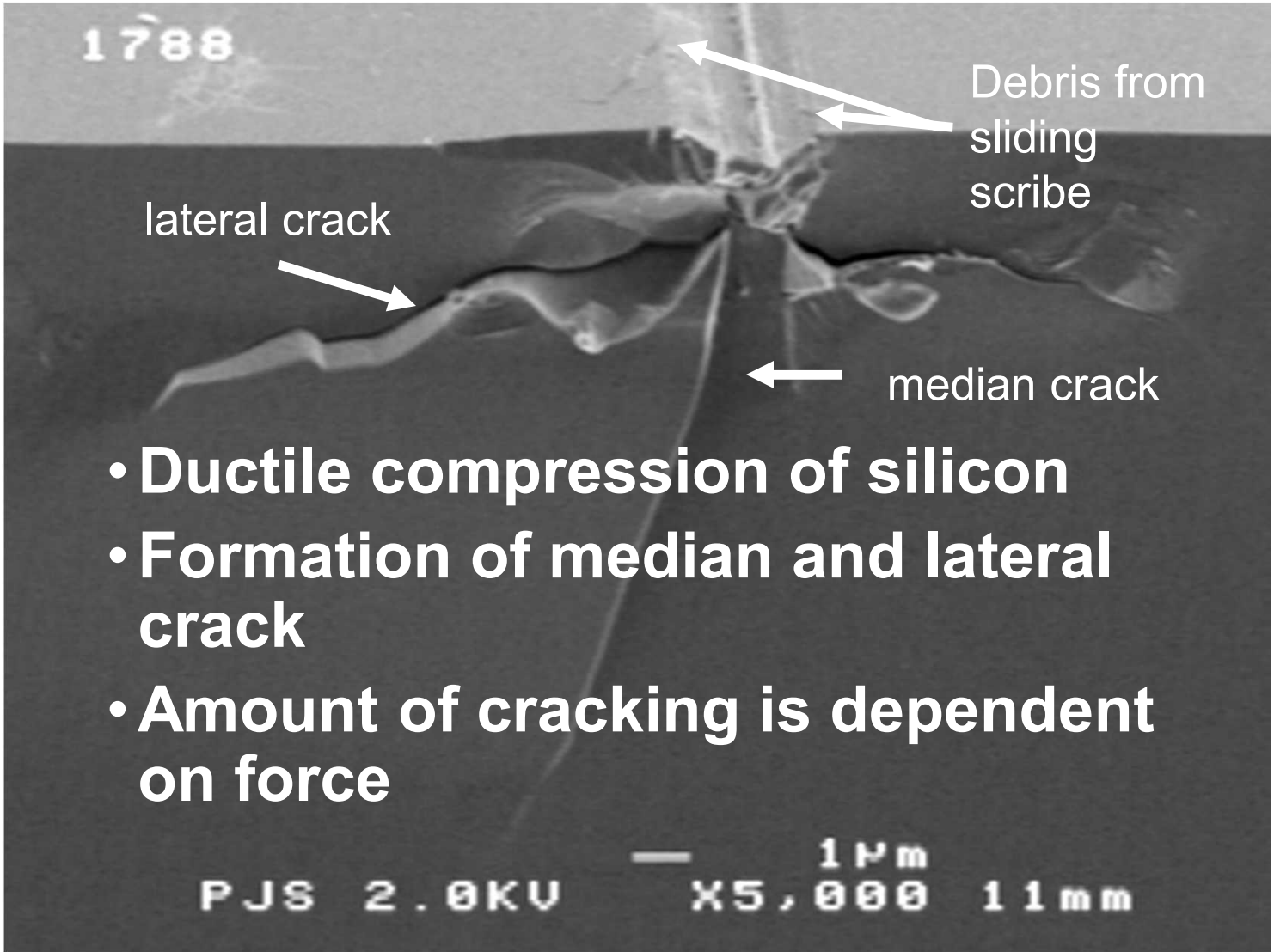
WHAT IS GOING ON DURING SCRIBING?



- **Ductile compression of silicon**
- **Formation of median and lateral crack**
- **Amount of cracking is dependent on force**

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WHAT IS GOING ON DURING SCRIBING?

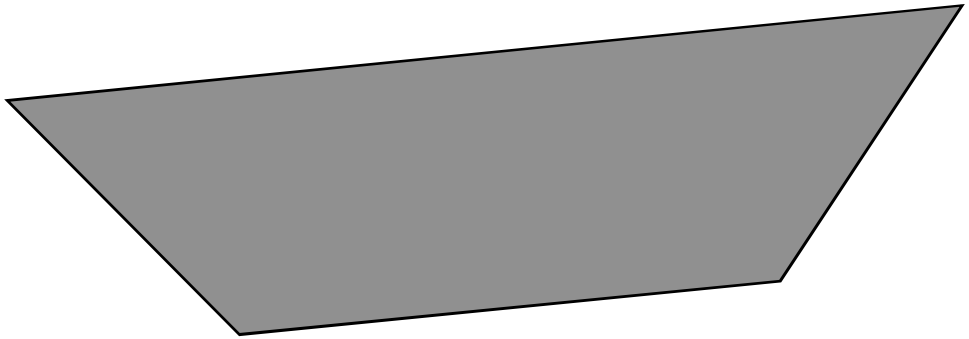
- **Diamond tip creates a median crack underneath the scribe line**

$$K = \sqrt{\frac{crack\_depth}{2 \cdot crack\_radius}}$$

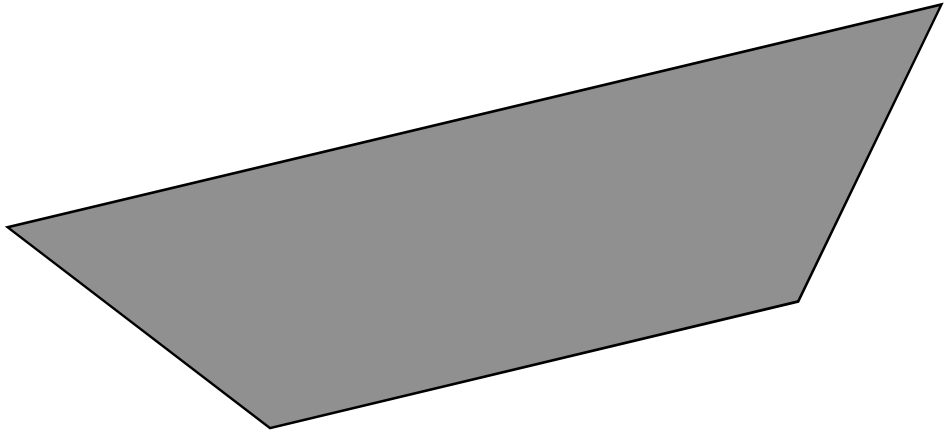
- **This creates a stress concentration at the crack tip**
- **At the tip, the crack radius is about 2 A**
- **For a 20 um deep crack, this gives a stress concentration factor of 223**

INFLUENCE OF SCRIBE ANGLE

- **Shallow Angle**



- **Sharp Angle**



- **The sharper the angle the more material is displaced**

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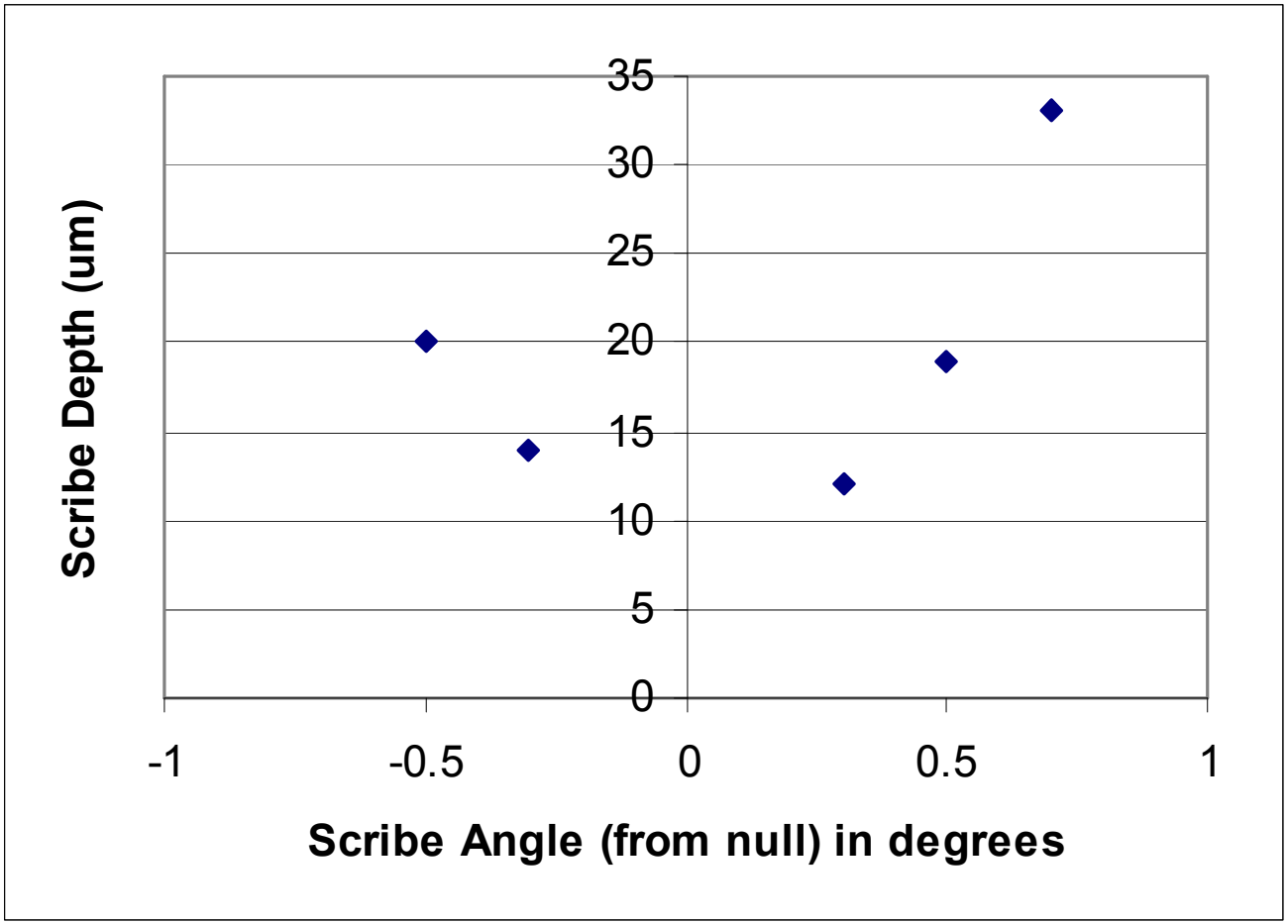
SCRIBE DEPTH VS SCRIBE ANGLE



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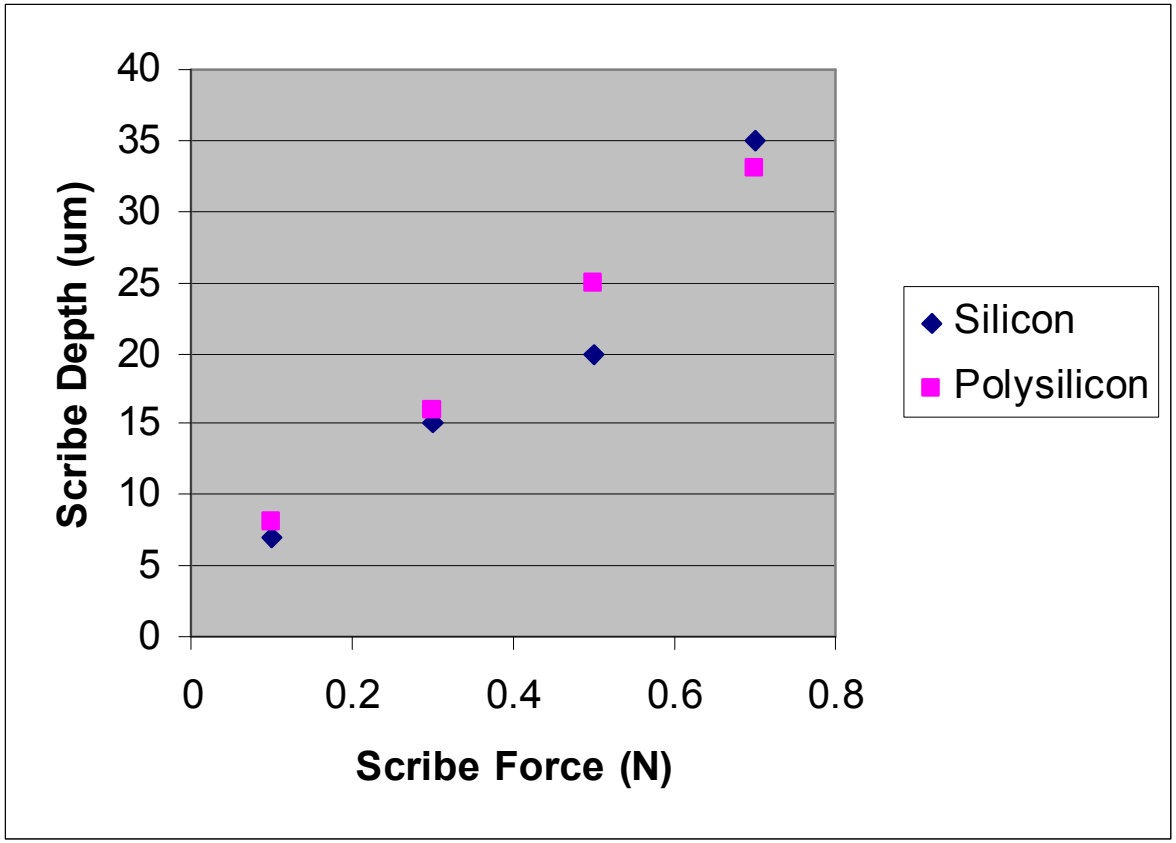
SCRIBING POLYSILICON VS SILICON



- **The two films are roughly equivalent in terms of scribe performance**

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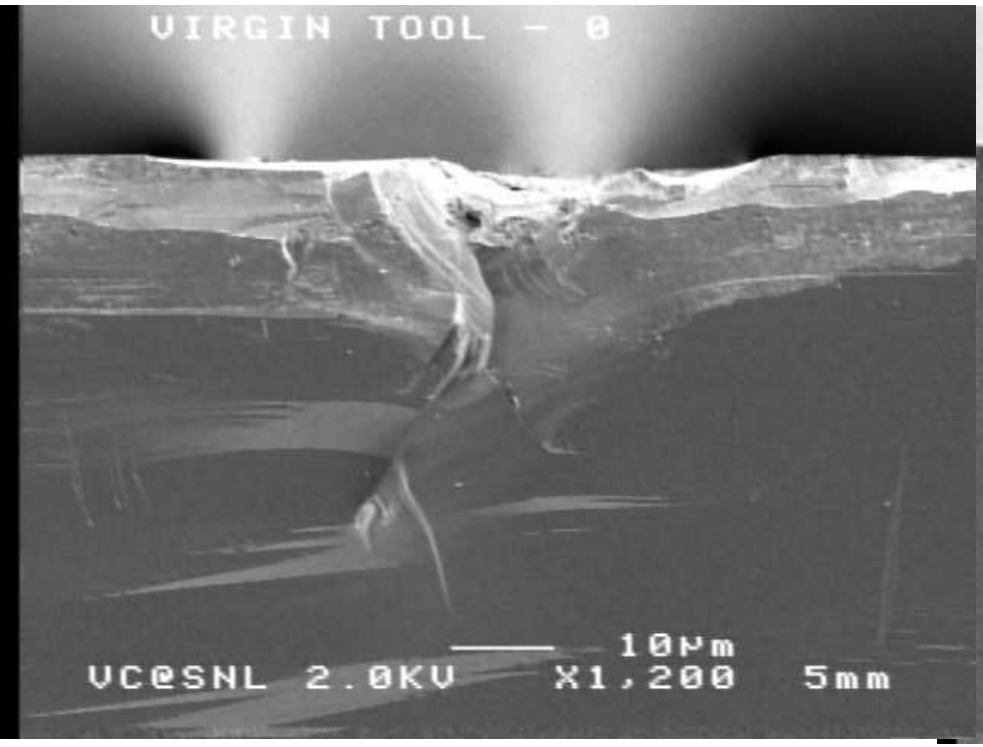
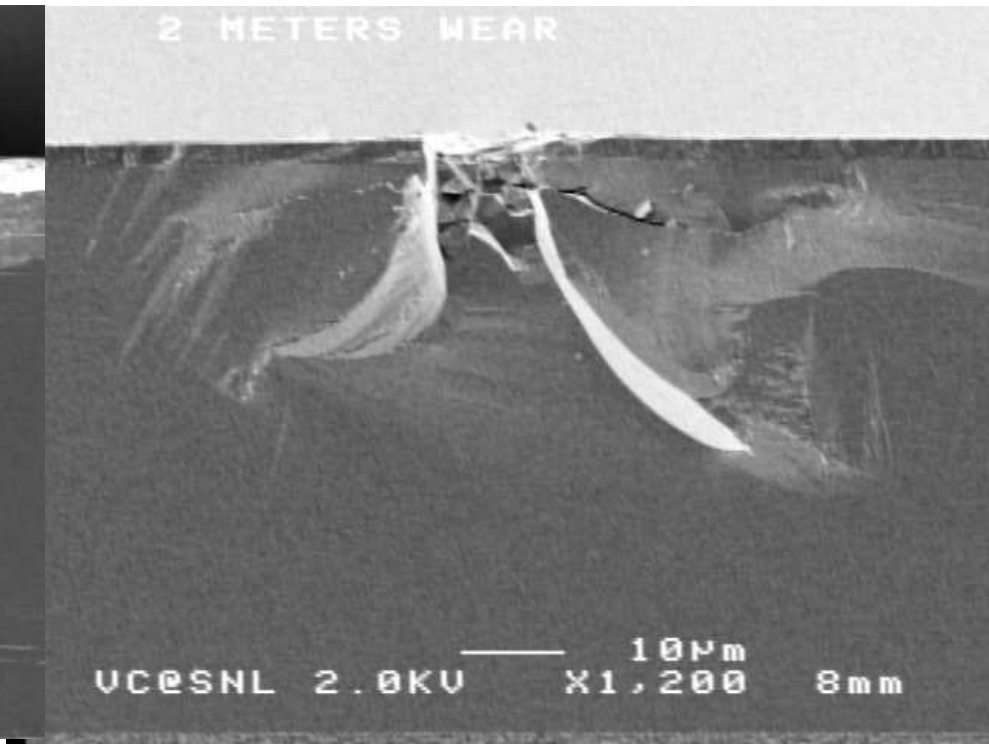
TUNGSTEN FILMS IN STREETS





Initial **2 meters of wear**

Tungsten thin film on silicon

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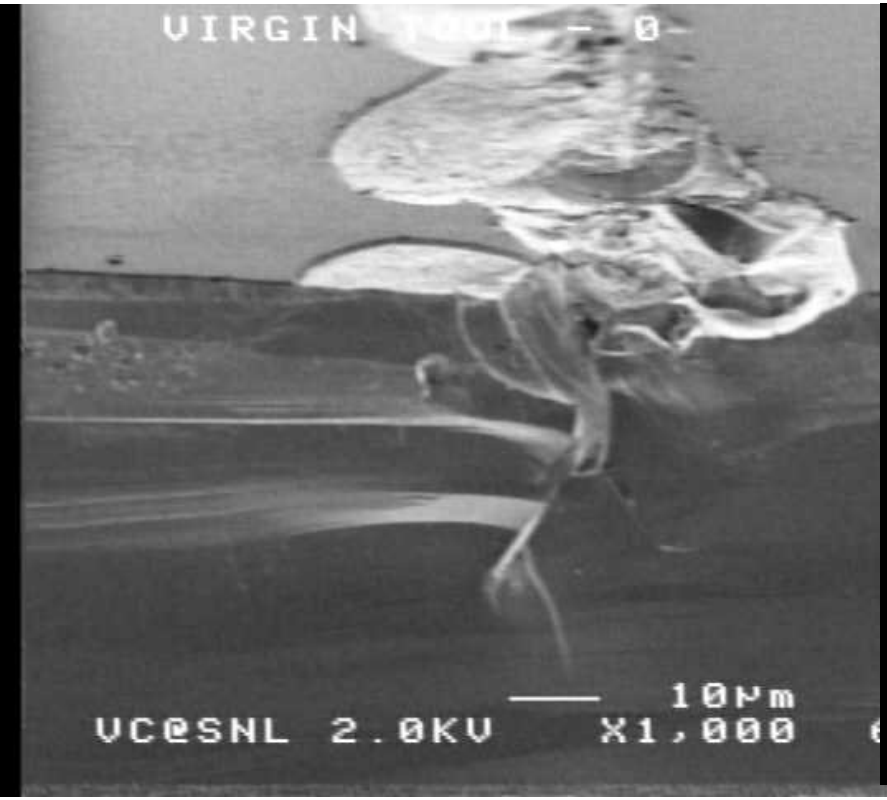
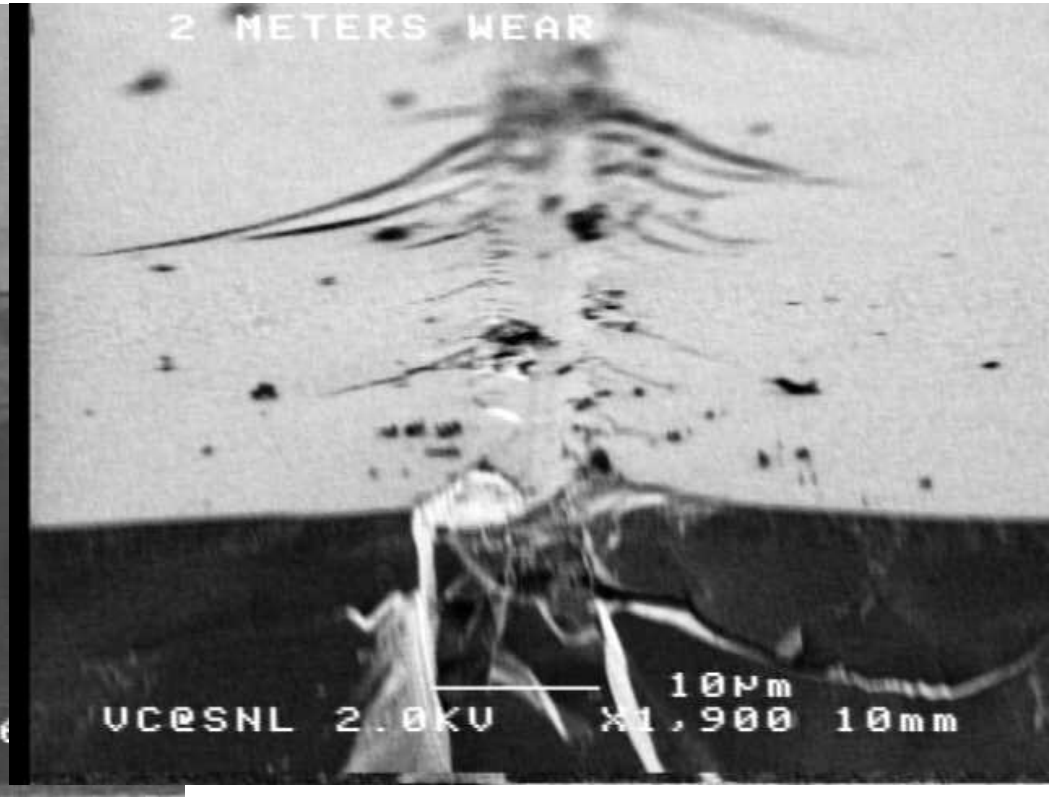
TUNGSTEN FILMS IN STREETS





Initial

2 meters of wear

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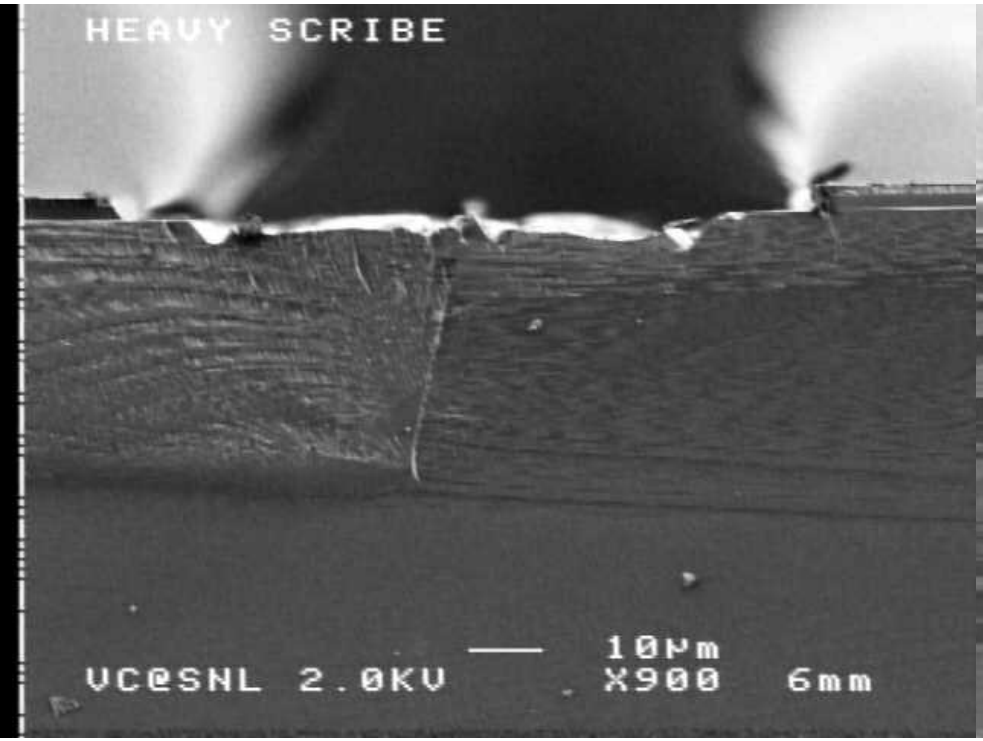
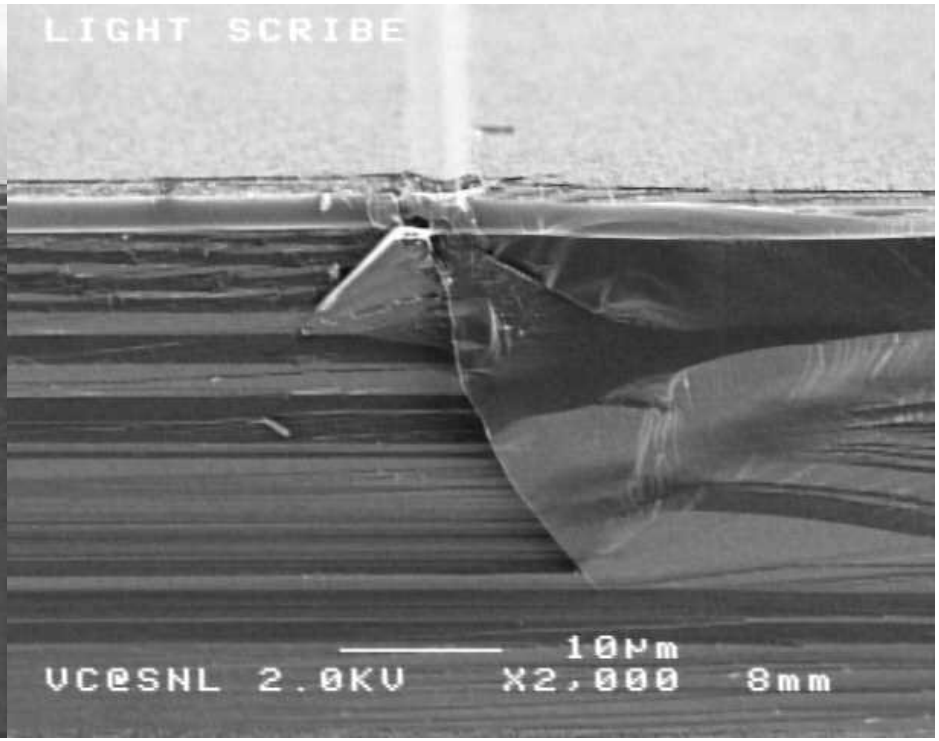
WEAR FROM Si_3N_4





virgin scribe

After 1 meter of wear (7 passes across the wafer

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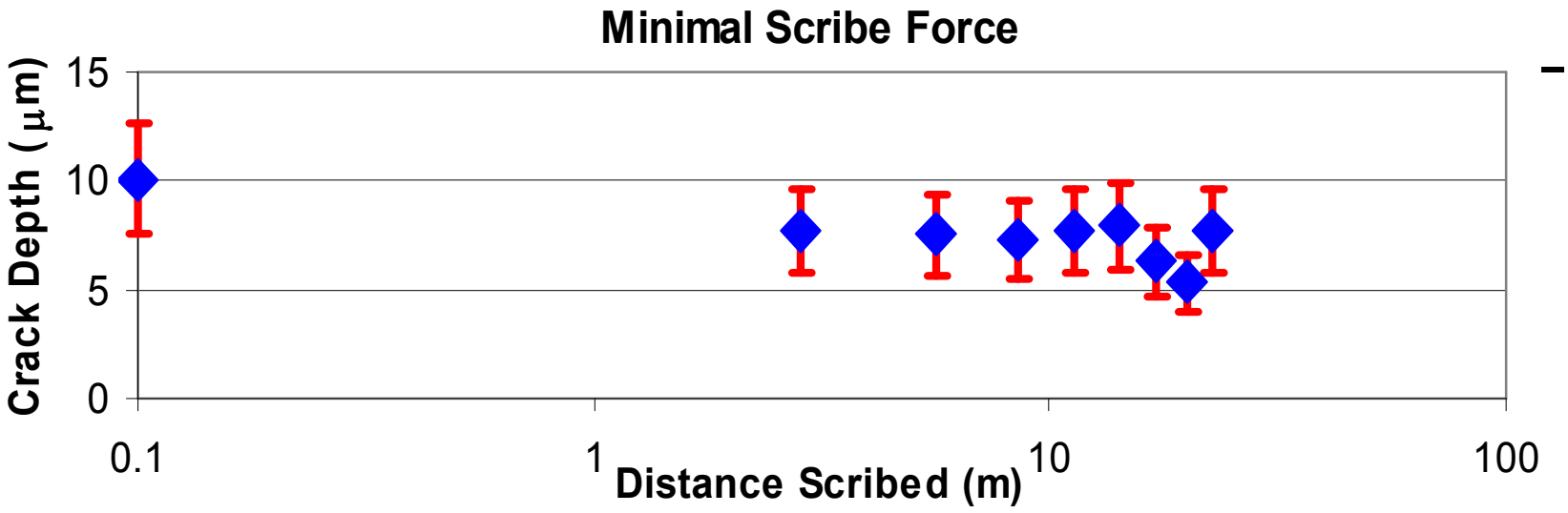
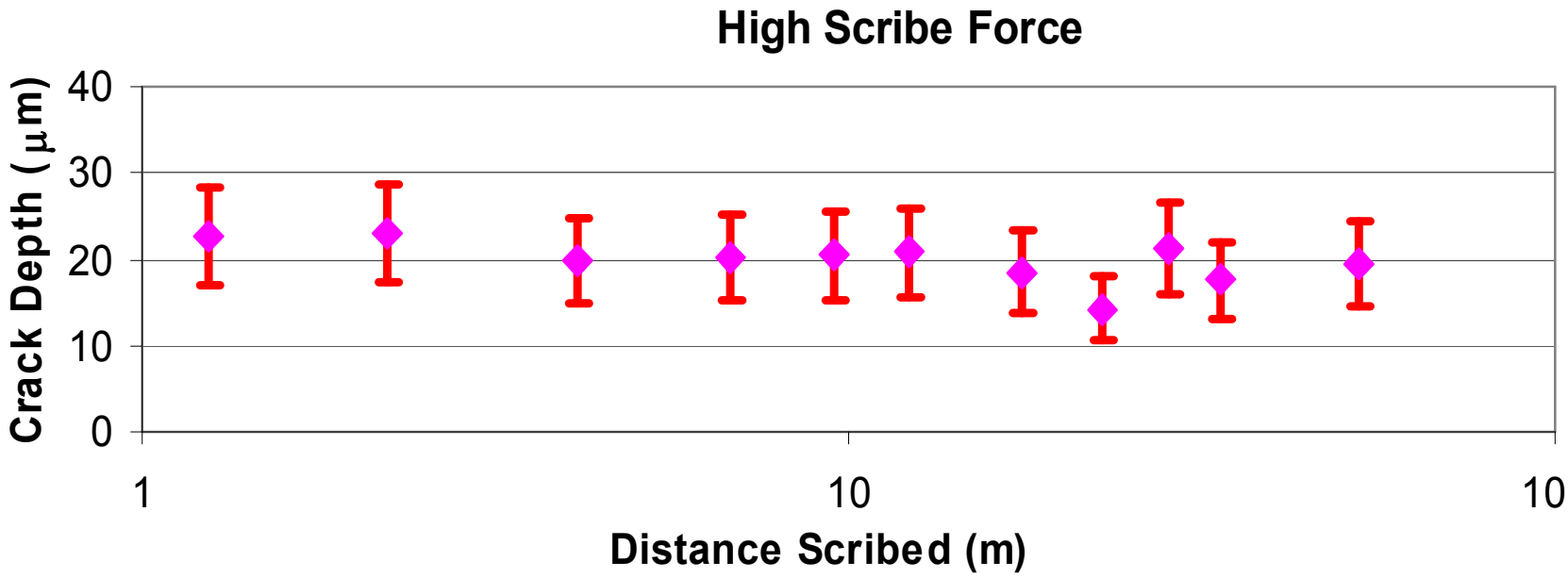
WEAR IN SCRIBE TIP ON SILICON





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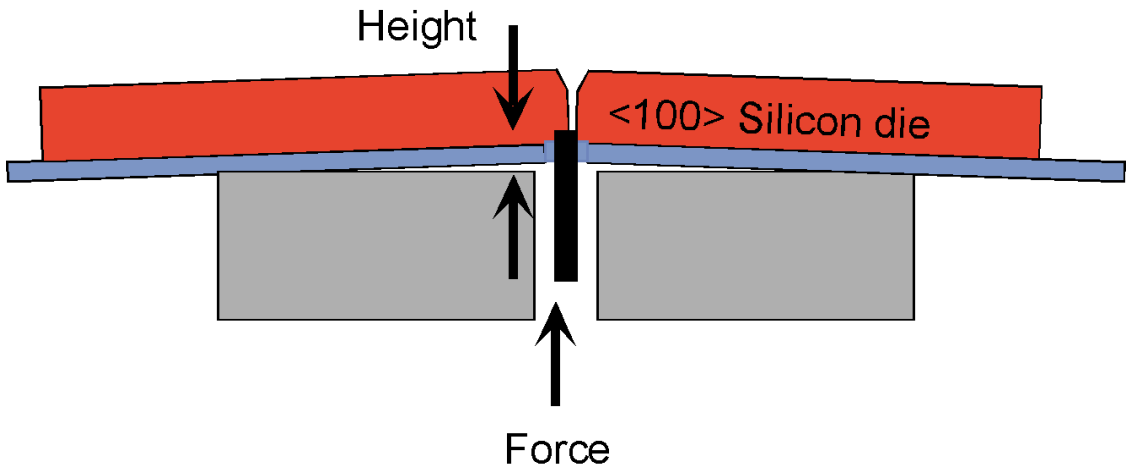
UNANSWERED QUESTION - WEAR

- **The vendor recommends that the scribe tip be replaced when the wafers stop breaking or when the scribe line becomes faint**
- **Wear in the scribe tip is one source of inconsistency in an otherwise consistent process**

WHAT IS GOING ON DURING BREAKING?

- The wafer can be modeled as a simply supported plate
- The impulse bar can be modeled as an impulse function to the silicon wafer
- If the applied stress is high enough, the wafer cracks along the scribe line



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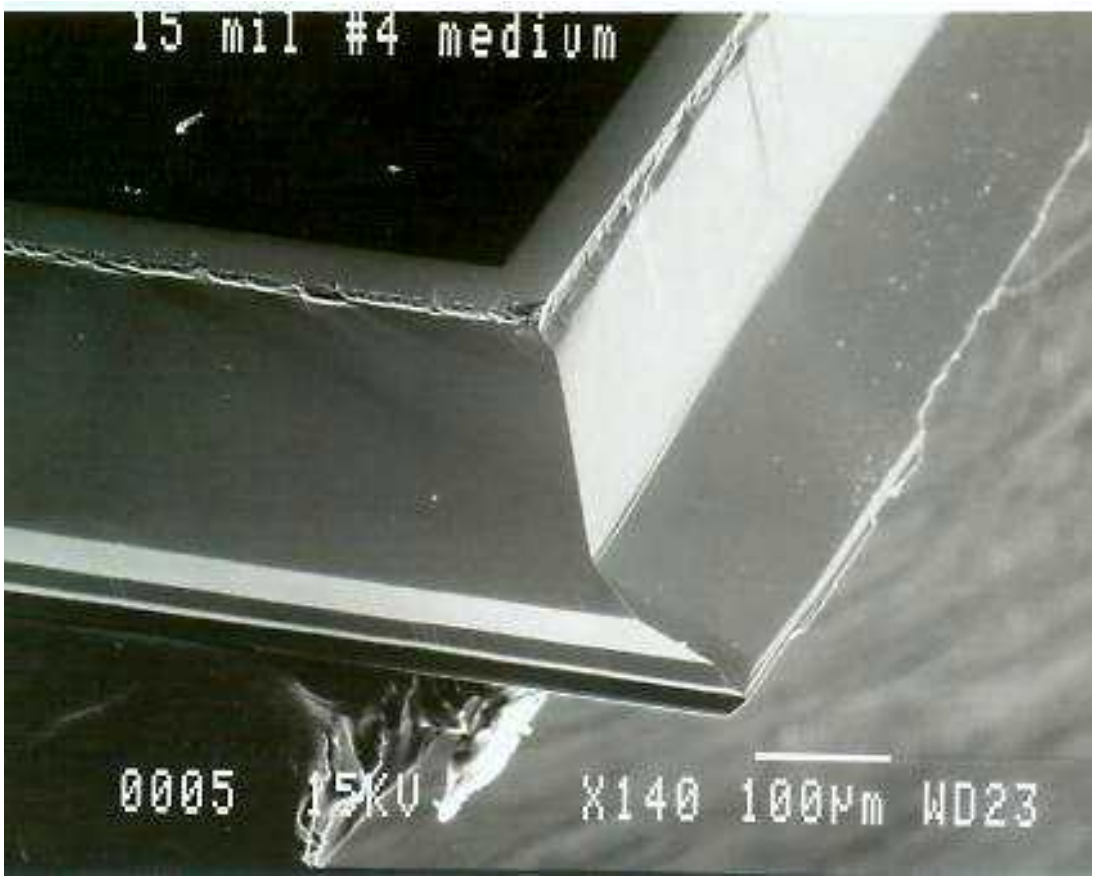
CANTILEVER CURL



- Typical result
- by non ideal forces during breaking

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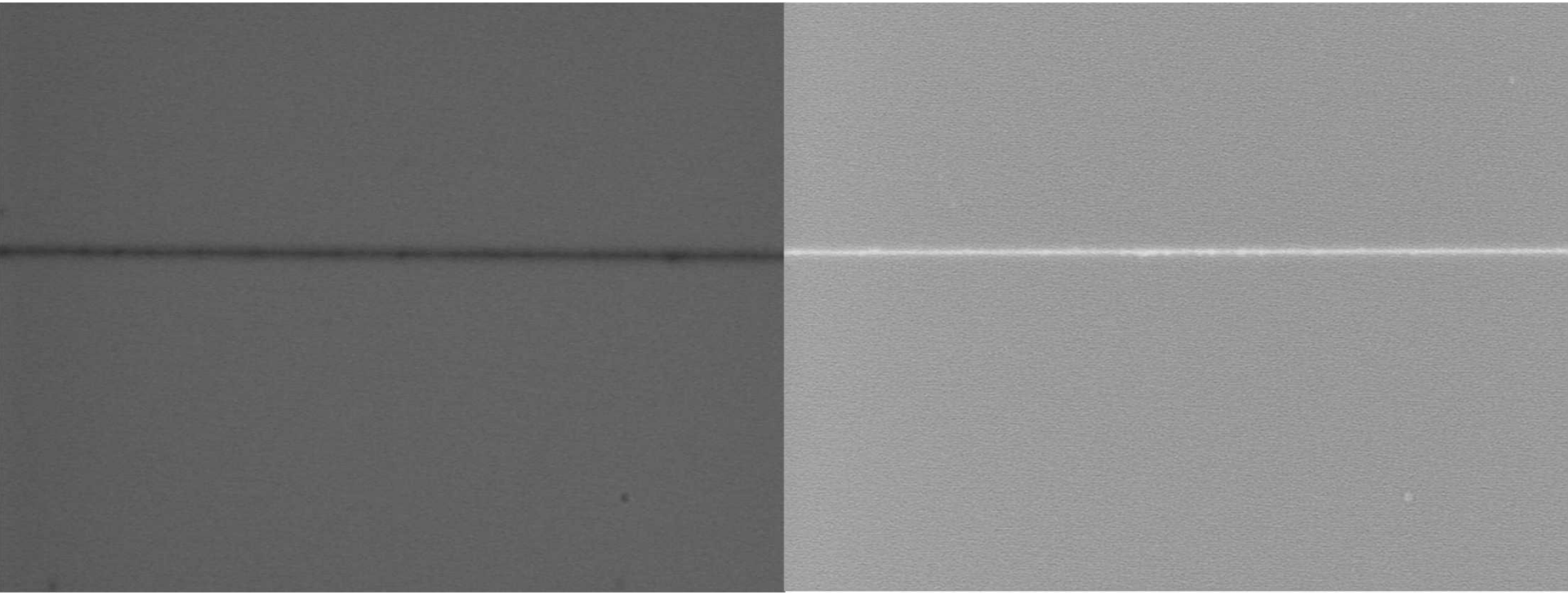
BUT DOES SCRIBING PRODUCE PARTICLES?

- **Scribe and break with optimized parameters**



- **2 different scribe lines after break**
- **Field of view is about 1.1 mm x 1.1 mm**

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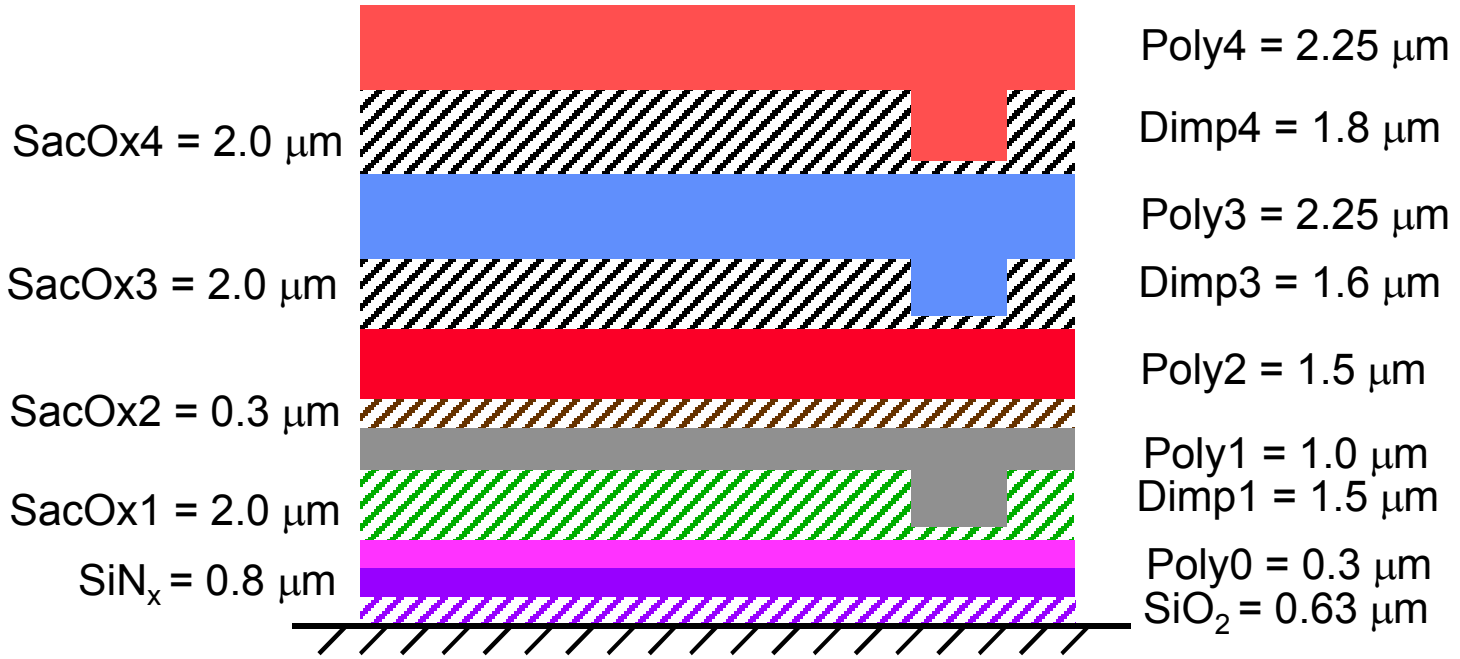
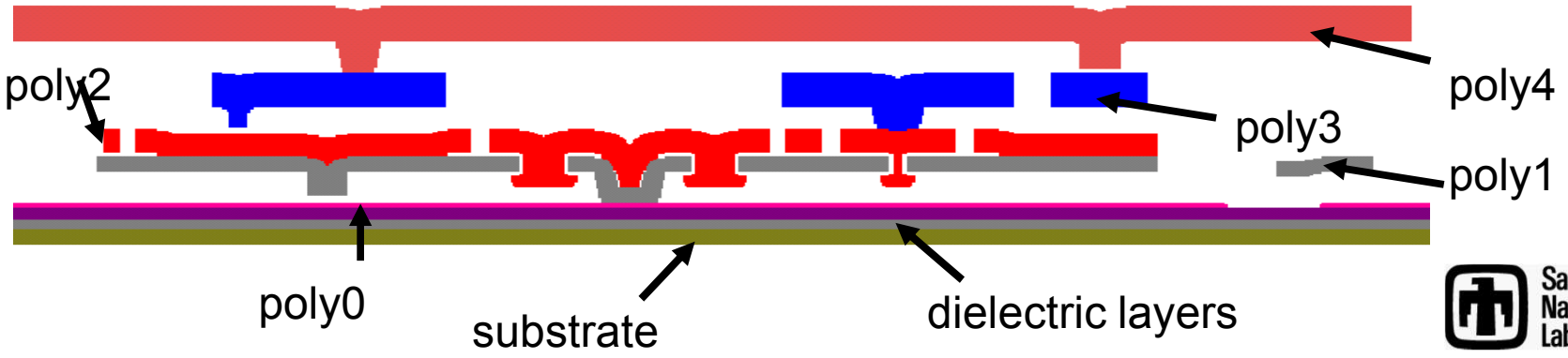
SURFACE MICROMACHINES





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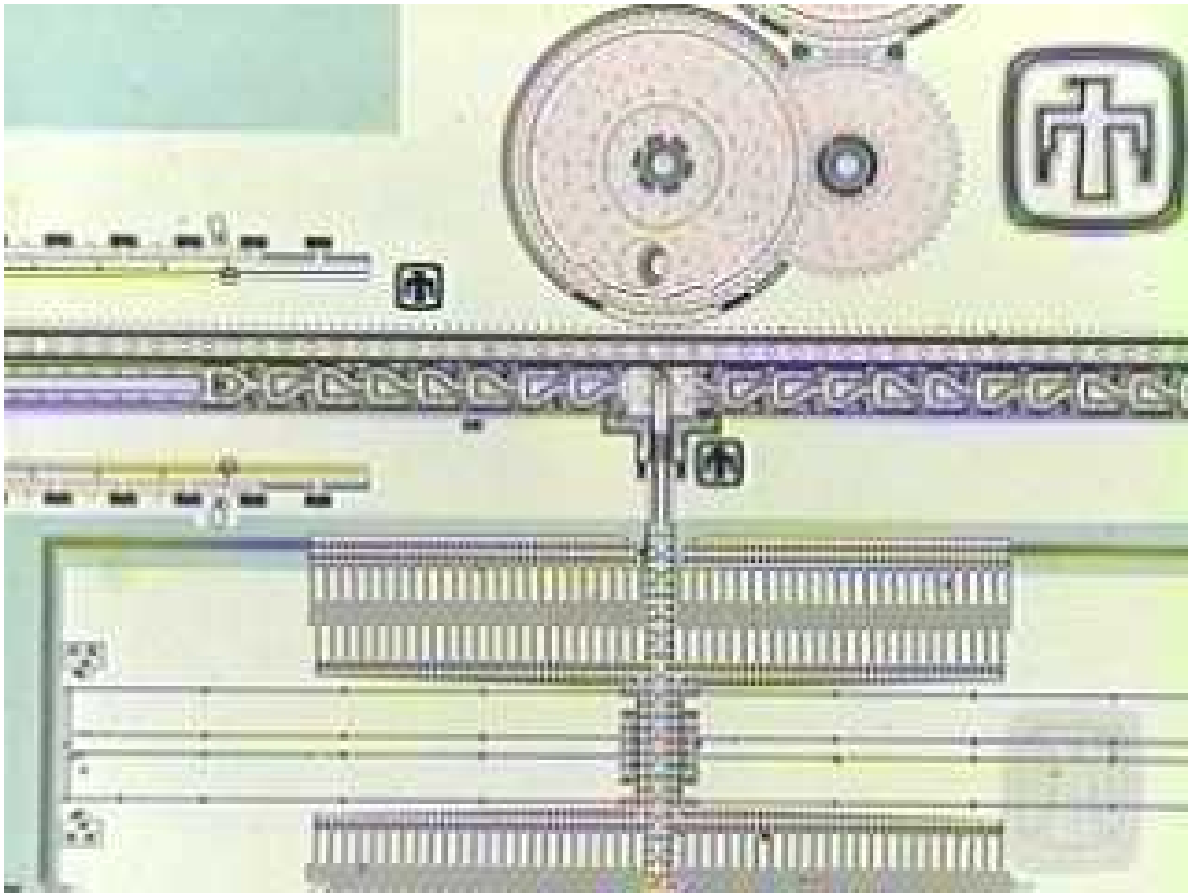
ELECTROSTATIC ACTUATORS



- **Electrostatic actuators tend to attract particles**

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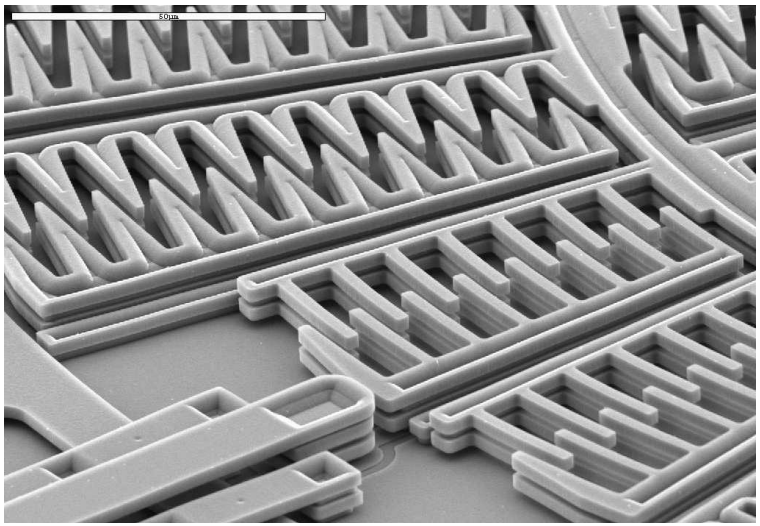
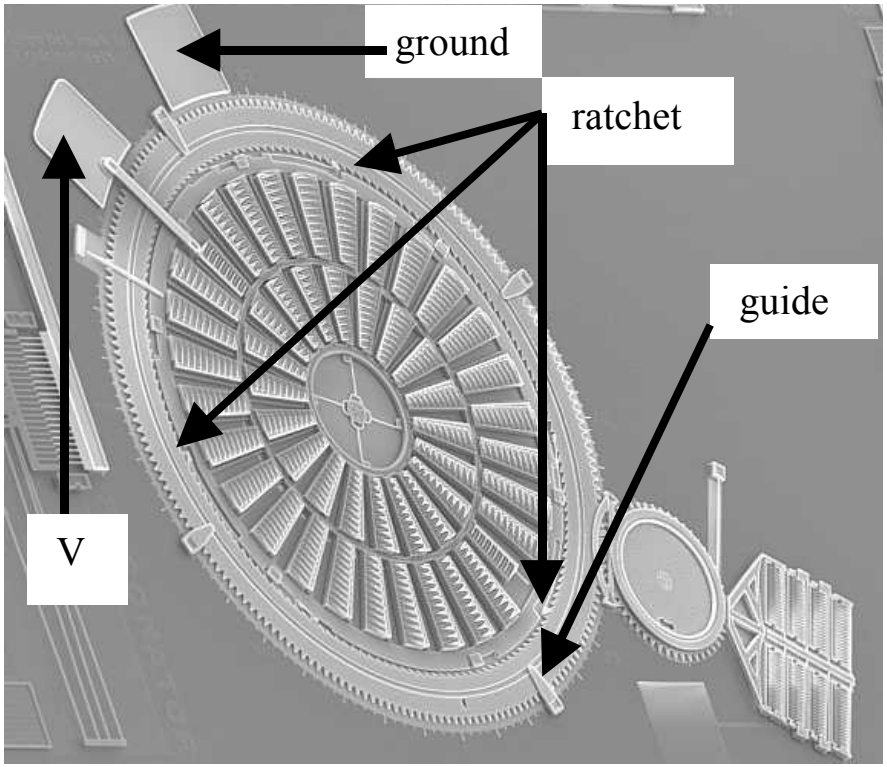
EXPERIMENTAL RESULTS

- **81% Yield on torsional ratcheting actuators (TRA)**





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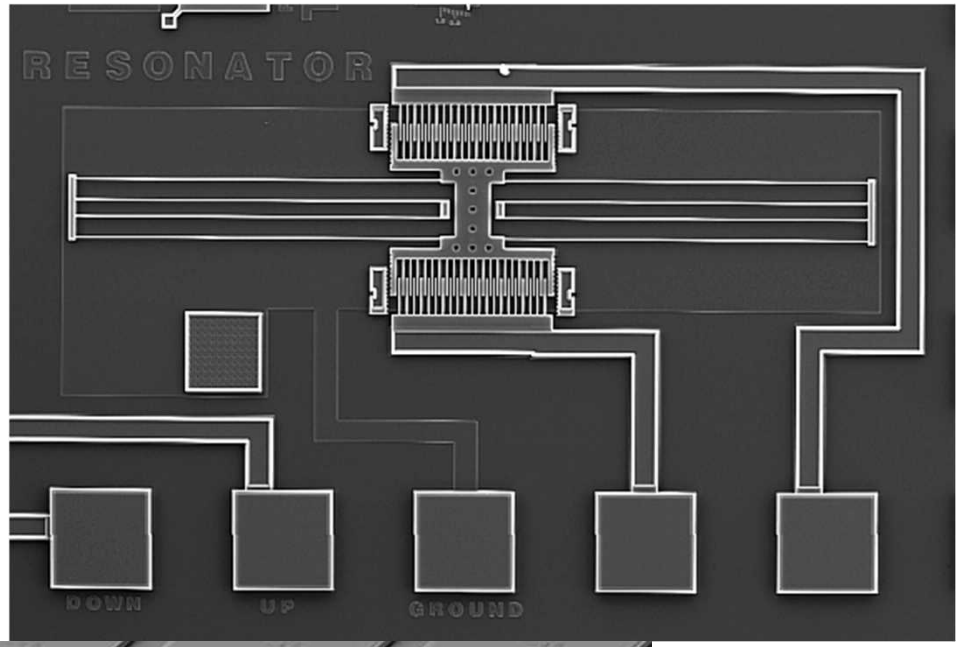
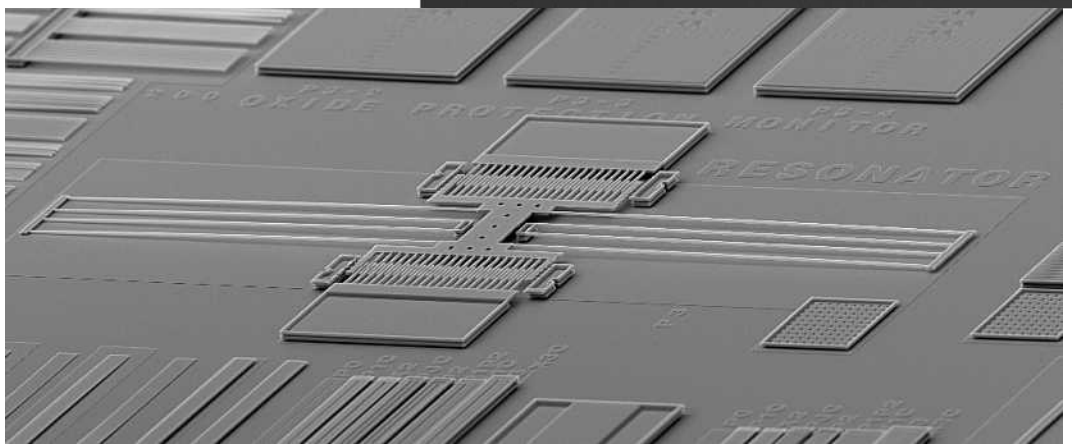
EXPERIMENTAL RESULTS

- **98% yield on resonators**





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COMPARISONS TO OTHER TECHNIQUES

- Scribe and break is an appropriate and successful technique for enabling full wafer release for SUMMiT™ V.
- However, scribe and break has some limitations
  - The ratio of die size to wafer thickness must be at least 10 to 1
  - Scribe lines must follow the crystal plane
  - Incompatibility with silicon nitride and silicon dioxide and other surface coatings

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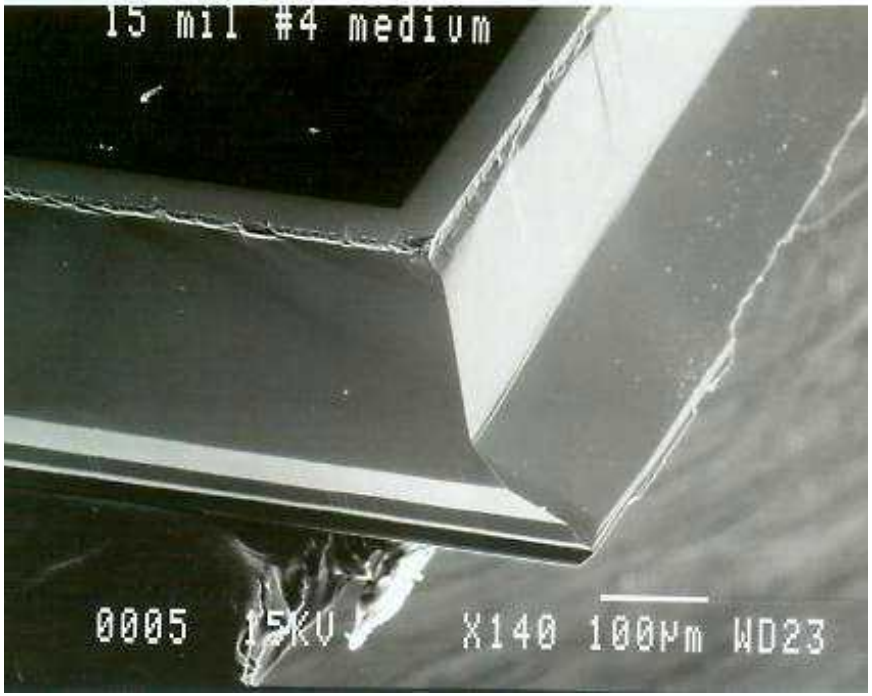
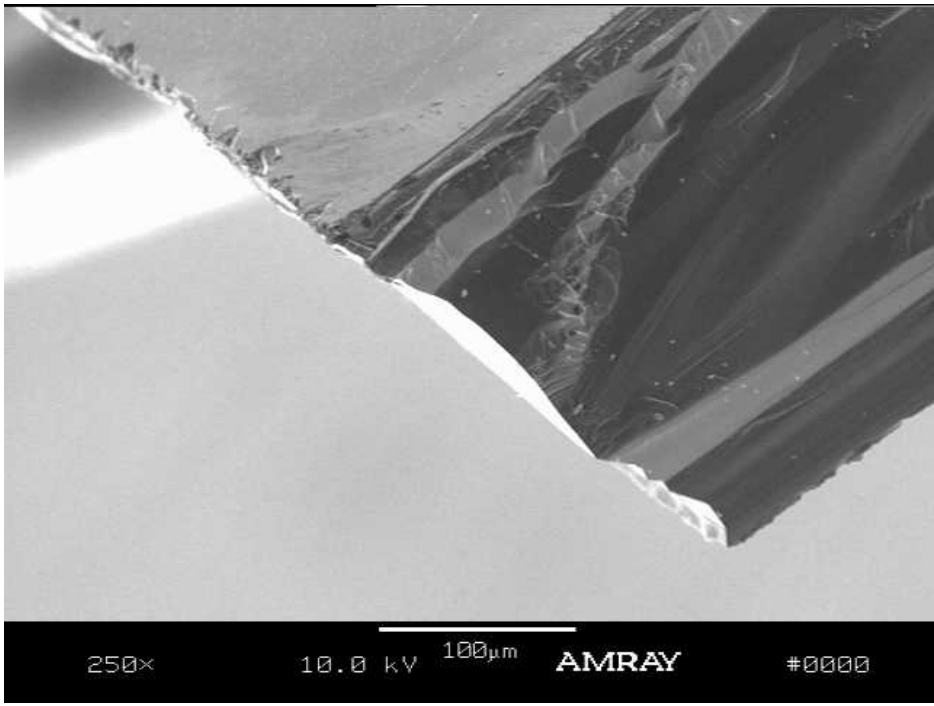
CANTILEVER CURL





- **Mostly caused by non-uniform pressure during the break**

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CONCLUSIONS

- **Outline**
  - **Why**
    - **this approach does work**
  - **Yes, we know what is going on**
    - **crack depth**
    - **design of experiments**
  - **Yes it works**
    - **Micromachines yield after scribe and break**
- **Discuss future work**

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ACKNOWLEDGEMENTS

- **Regan Stinnett, David Plummer, Mike Rightley, and Thom Fischer for funding this work**
- **Simone Smith for her processing expertise**
- **Peggy Clews, Matt Hankins and the Release/Dry/Coat Team**
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- **Jeremy Favia, Casey Stromer, Greg Alexander, and the rest of the staff of Dynatex International**
- **Rajan Tandon, Jill Glass, and Fernando Bitsie**

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