THE PRODUCTION AND PERFORMANCE OF Si/SiO2 MAGNETIC RECORDING HEAD SLIDERS

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Si Slider Project

Al_2O_3-TiC (AlTiC) Substrate → Si Substrate

Al_2O_3 Undercoat, Insulating layers, Overcoat → SiO_2

Diamond Sawing → Plasma Etching

Why Si?

- Disk drive mechanical advantages
- More sliders per wafer
- Other advantages

Today's talk:

- Processing of Si sliders
- Component and drive testing
- Advantages

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Si Slider: Past Work, Current Project

- Many proposals, projects (even 1 product) through the years:
  - --Proposal, K. Petersen, IBM, 1981
  - --Product, J. Lazzari, LETI/Silmag, 1989
  - --Unpublished work at most head manufacturers
- Many early approaches incompatible with MR-based sensor mfg.
- Other proposals and publications incompatible with head mfg.

- Current work at Hitachi GST demonstrates:
  - --Ability to make Si sliders compatible with modern sensor technology
  - --Ability to make sliders which perform like AlTiC ones
  - --Mechanical advantages of Si

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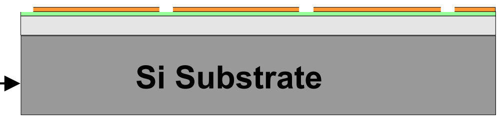
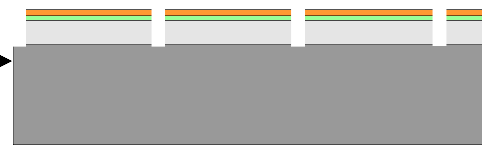
Process Flow Used to Build Si Sliders and Drives

- Wafer supplier →
- Wafer processed through wafer Line (San Jose) →
- Two-mask Step for dry processing →



- → RIE etch →



- → First mask strip, thin wafer (femto)
- → Al backside dep., wafer bond to carrier, DRIE etch →

- → Debond Individual slider bodies
- → Second mask strip, Al strip →
- Inspect, place in trays, clean →
- Ohmic contact preparation on non-ABS side of sliders
- → Lapped as individual sliders →
- ABS, overcoat processing →
- Suspend →
- Magnetic evaluation →
- Drive build and test, component test

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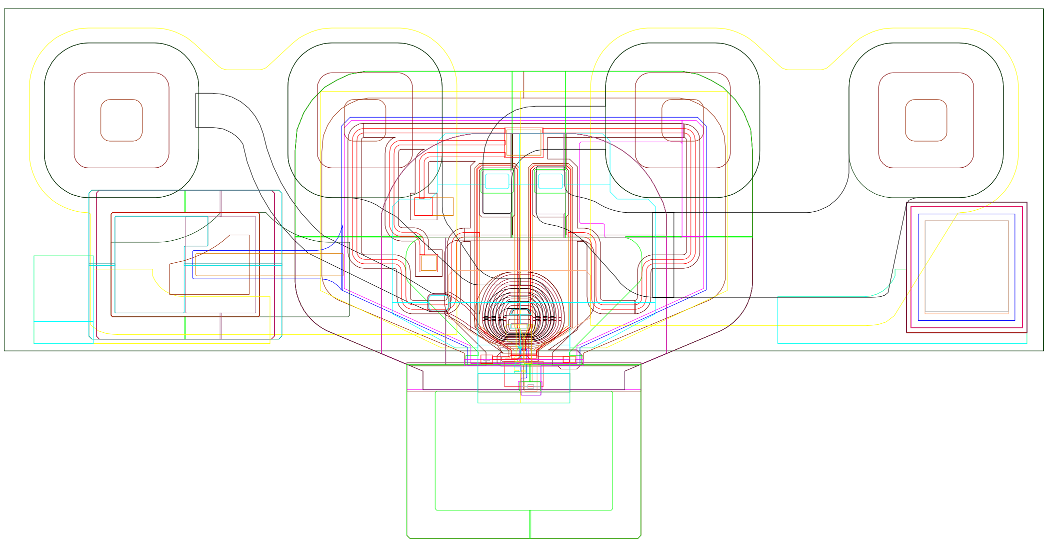
Si Wafer Processing

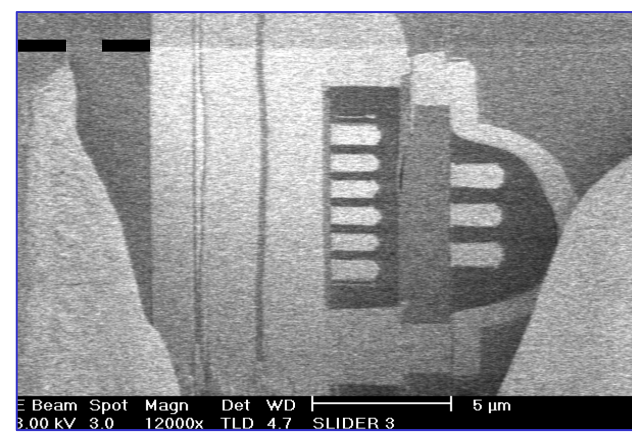
- Started with pico thickness wafers (1.2 mm), highly doped, p-type
- Specifications very similar to those for AlTiC and to the SEMI-M1 specification

- Processing through wafer line very similar to standard AlTiC processing
  - --Si yields achieved levels comparable to AlTiC yields



- No material other than SiO_2 allowed to remain in kerf to allow for plasma etching

Head Cross Section of Si CIP GMR head



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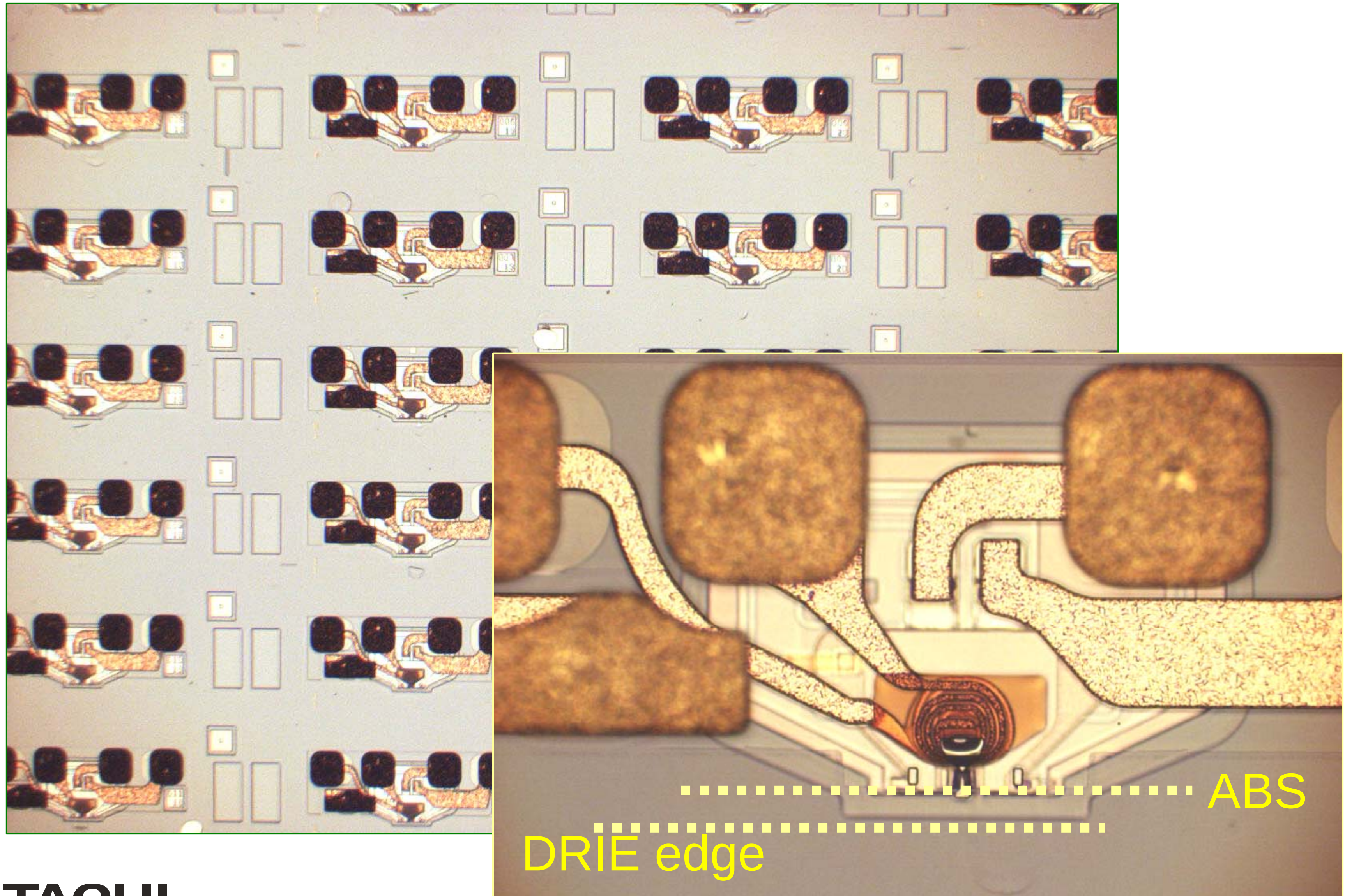
Completed Wafer



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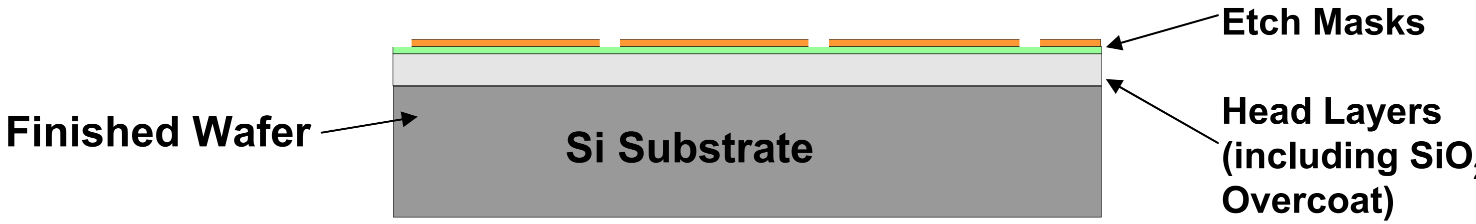
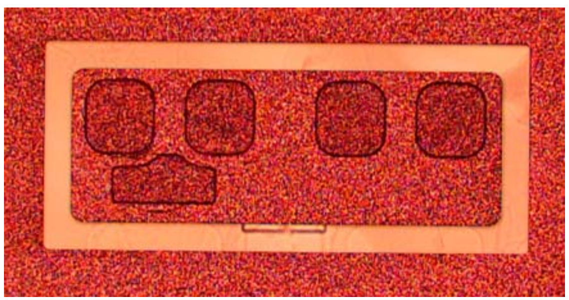
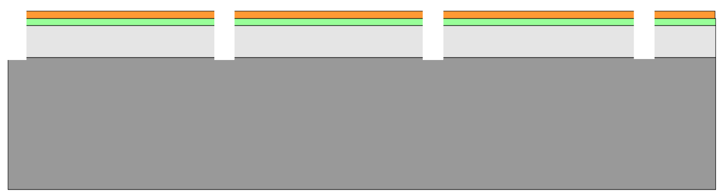
Processing after Wafer Completion

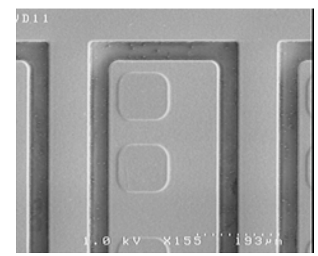
- Alumina deposition; serves as DRIE mask
- Electroplated Cu; serves as RIE mask



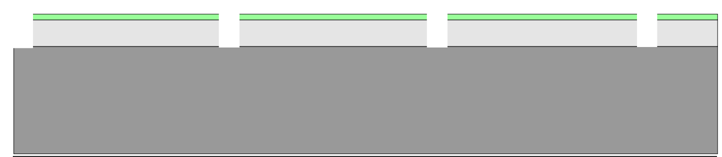


RIE through SiO_2





- Backside grind/polish to femto thickness
- Strip Cu mask, Al deposit on underside
- Mount to carrier plate



Ready for DRIE (Deep Reactive Ion Etching)

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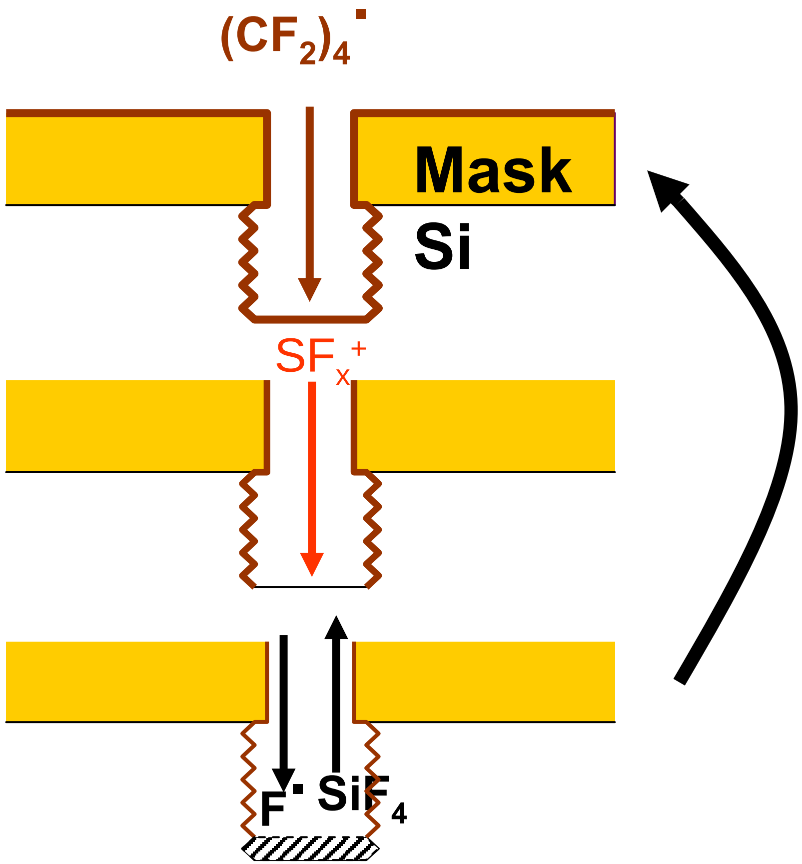
DRIE Process for Si Etching
(a.k.a. Bosch Process)

Passivation with fluorocarbon

Energetic ions remove fluorocarbon at bottom of channel

Si is etched rather isotropically, locally



Repeat cycle many times (>1000)

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DRIE Mask Material*

Etch Resistance with respect to Si

Material	Selectivity
Ni0.20Fe0.80	20,000
Ni0.80Fe0.20	10,000
Cu	3,200
Al	3,200
Al2O3 (sputtered)	3,000
Au	490
SiC	285
TiN	90
SiO2 (sputtered)	60
Resist (SU8)	24
W	8
Mo	6
Graphite	2.5

*At low acceleration voltage (platen power)

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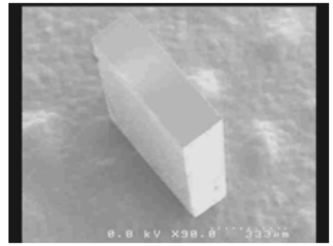
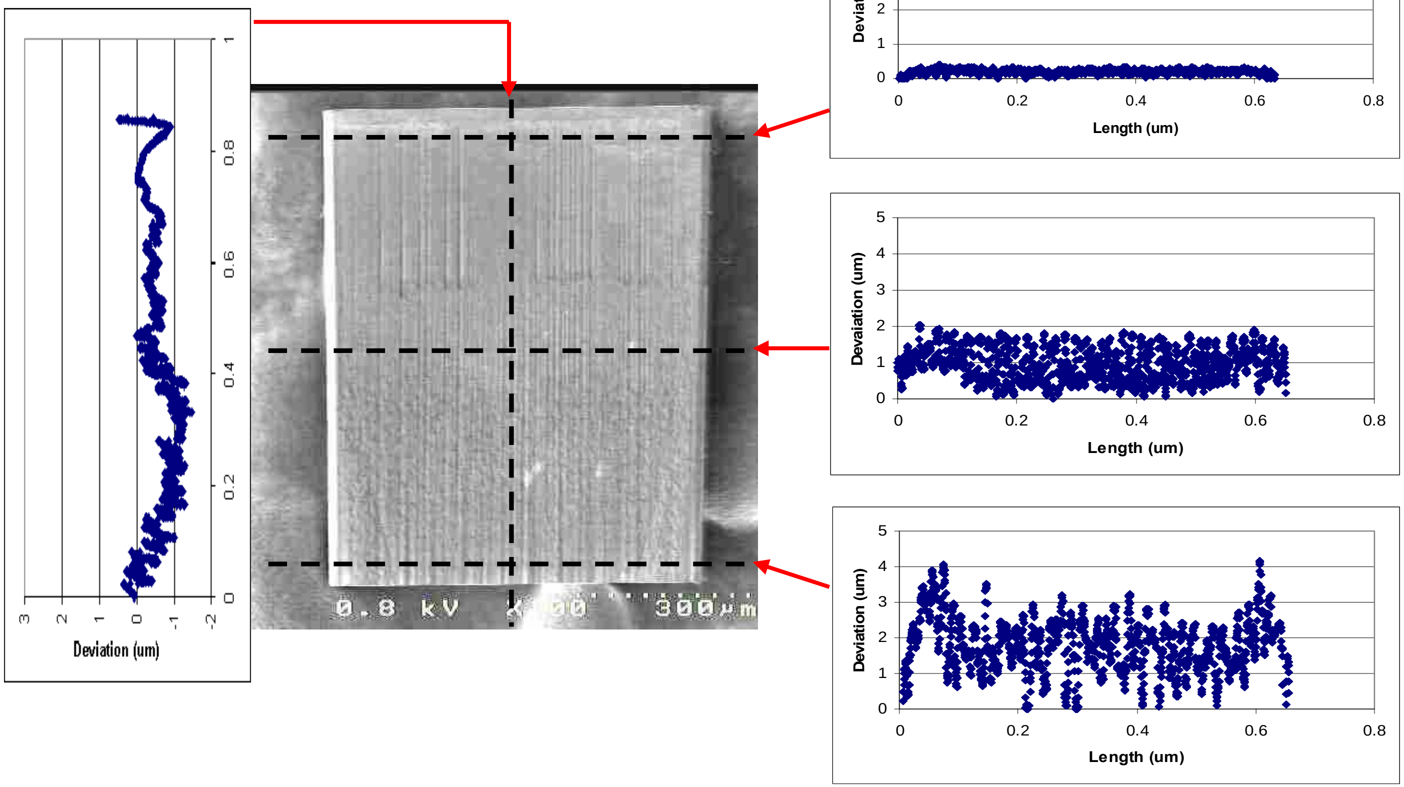
Surface Roughness after DRIE

Smooth surfaces are generated, R_a~ 1µm





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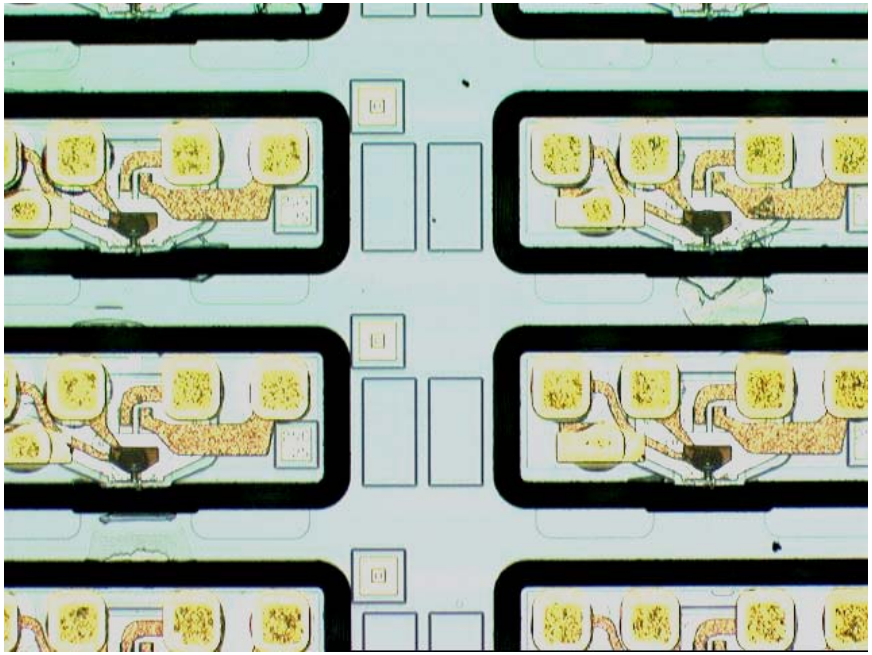
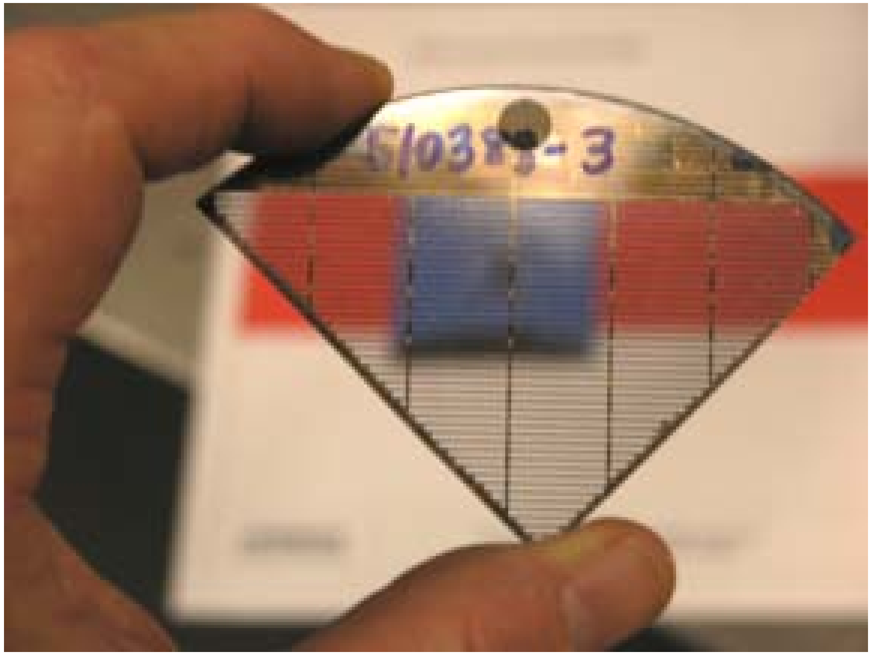
DRIE'd Wafer
(femto sliders on pico pitch)

Partially etched



Wafer remnant after sliders removed



Note: DRIE allows closer slider and row spacing ⇨ more sliders per wafer

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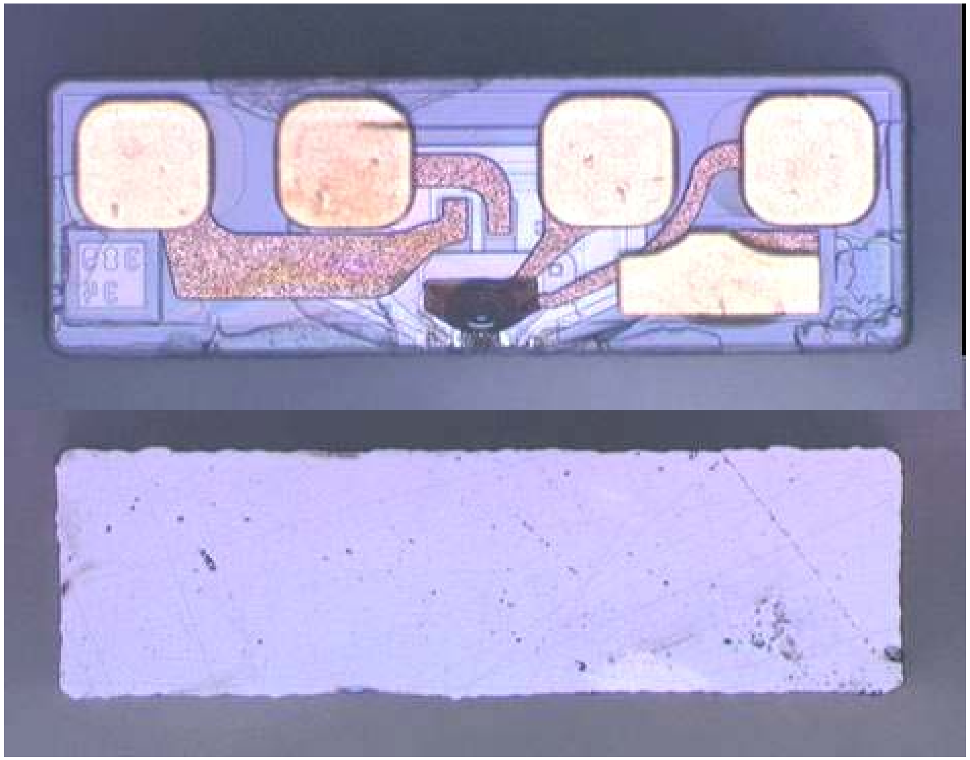
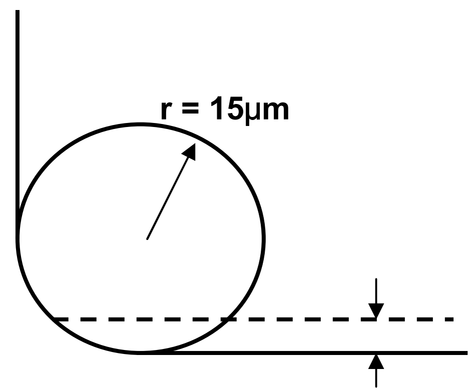
Edge Rounding Defined by DRIE Mask

Slider Top

Slider Bottom





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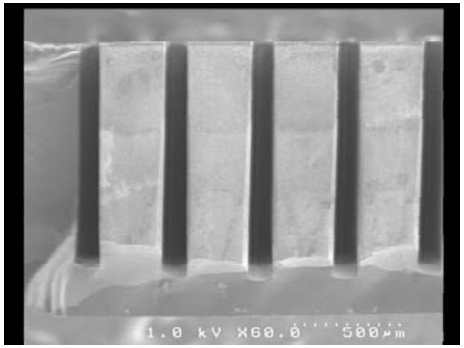
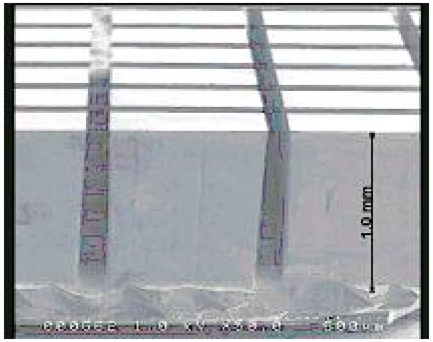
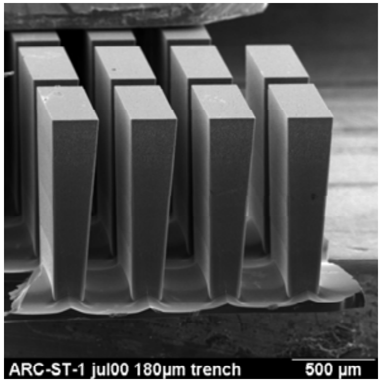
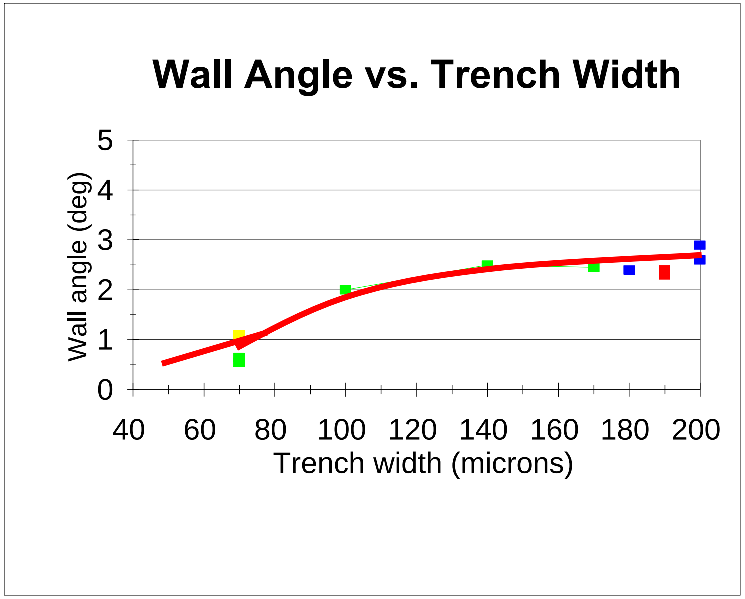
Slider Spacing can Affect Wall Angle









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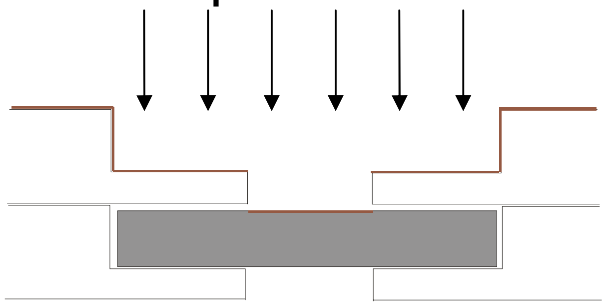
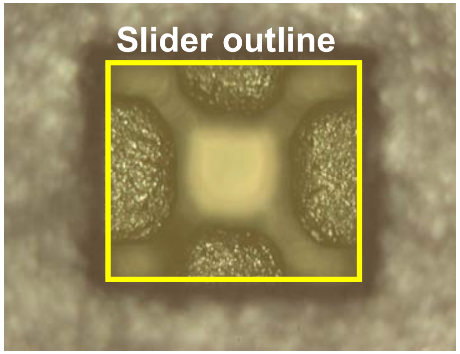
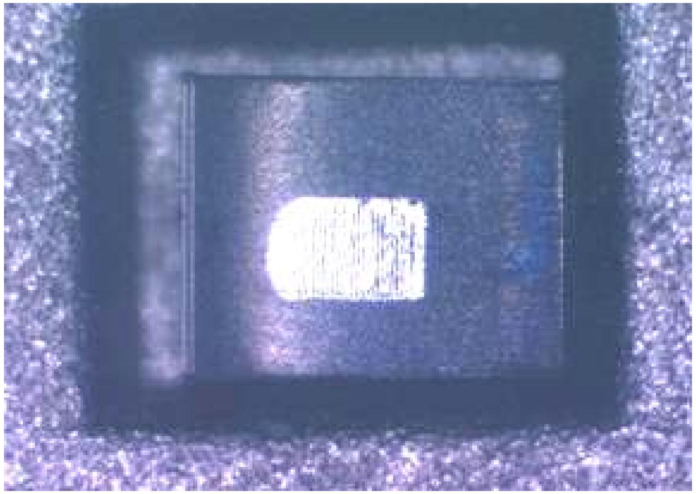
Ohmic Contact Preparation

To allow slider grounding (and to avoid Schottky barrier), need to prepare an annealed semiconductor/metal contact.

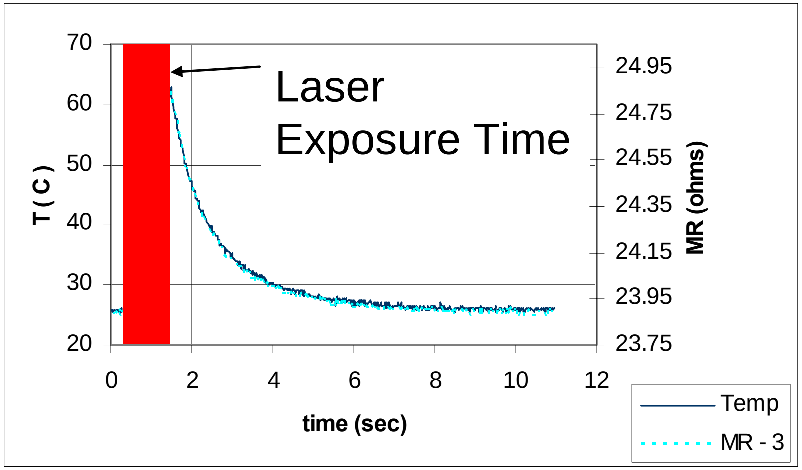




Resulting resistance after laser scan ~ 100 Ω



Slider ΔT is small



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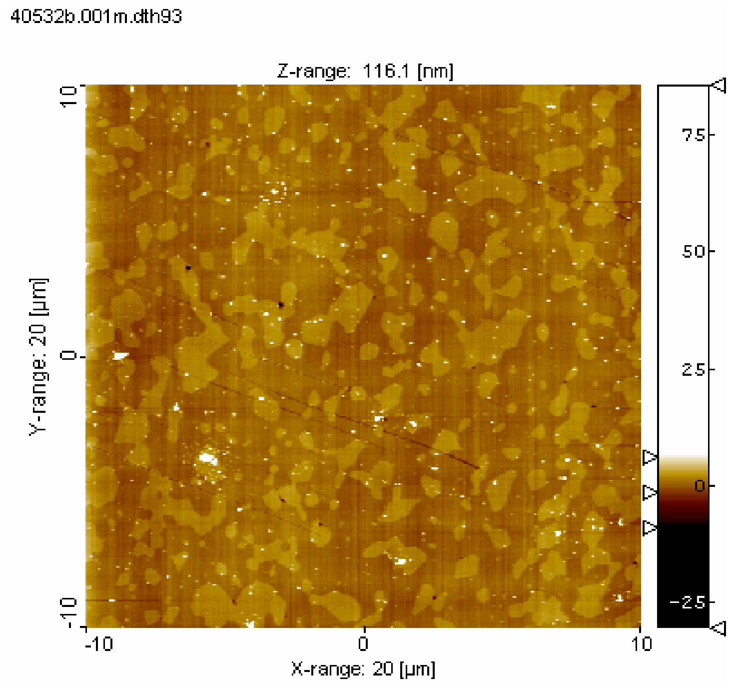
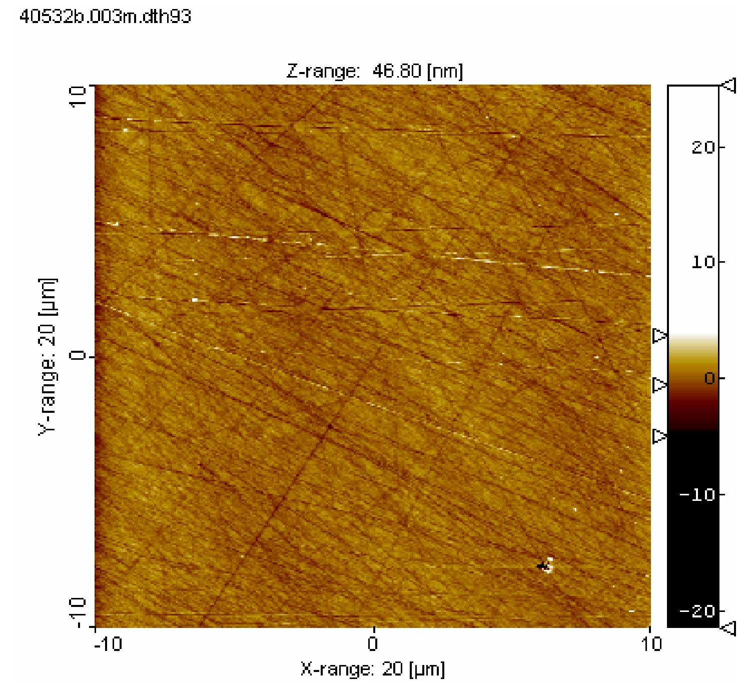
Slider Lapping

Once sliders were cleaned and metallized, they were lapped as collections of individual sliders, rather than rows.

1. Coarse lapping on tape, standard plate and slurry
2. Medium and fine lap using laboratory fixtures, Sn plate, using sensor resistance as feedback, a variety of slurries were used

Result: Si is smoother than 2-phase AlTiC (Ra 0.5 vs 0.8 nm)





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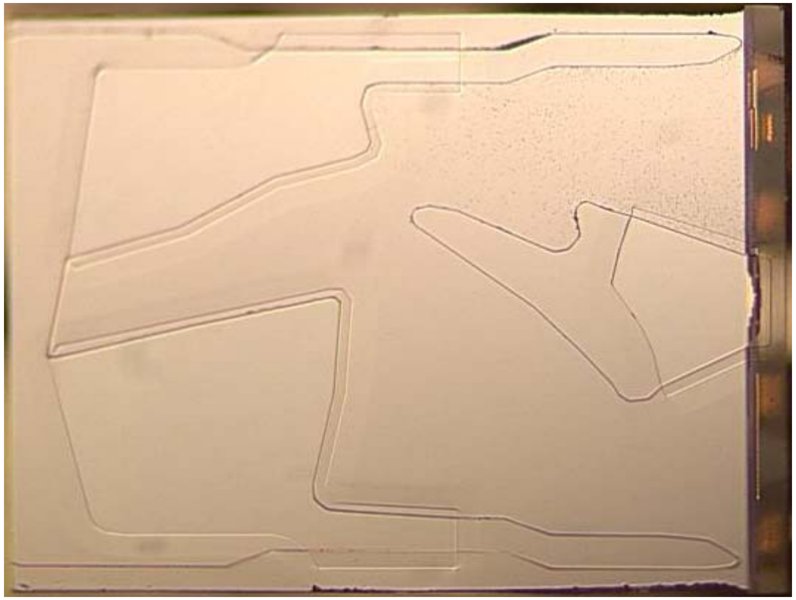
Two Different Air Bearings Were Prepared

Standard ABS processing and overcoat used
Si etches ~3X faster than AlTiC

Microdrive, for drive testing



2.5" drive, for component testing

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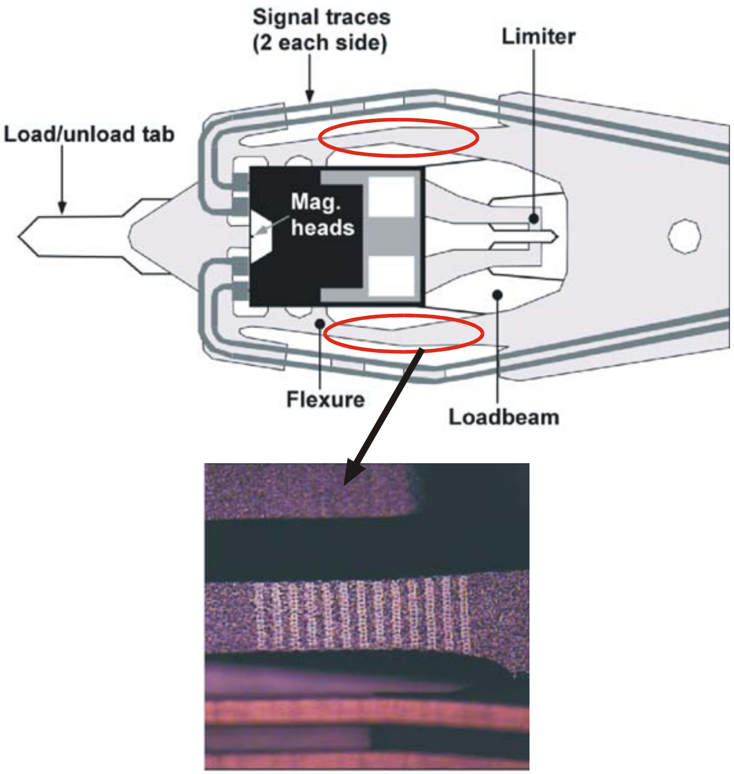
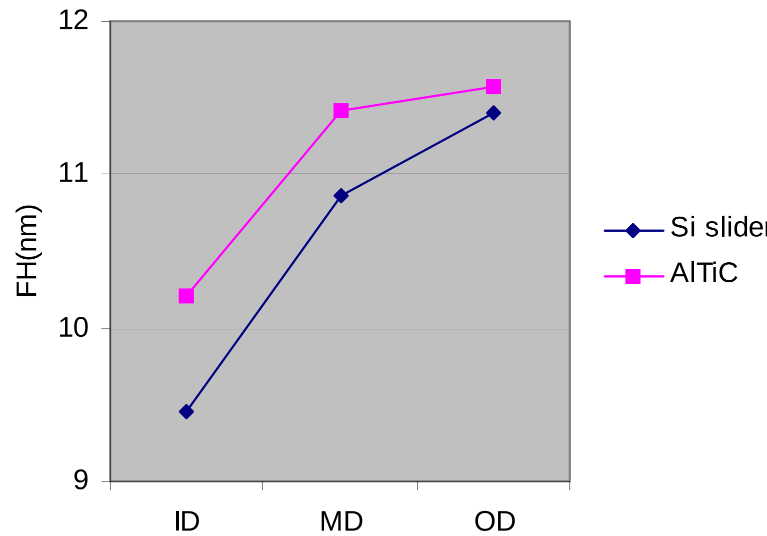
HGA Build

- PSA (pitch static attitude) adjusted
- Fly height tested
- Magnetically tested (static and dynamic)





Si and AlTiC sliders having same ABS show similar fly heights

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Drive Build and Test

Drive: 4GB Microdrive

1. Starting with standard, working drives
2. Disassemble
3. Replace Top HGA with magnetically pre-tested and screened Si HGA , manually solder
4. Reassemble, using existing servo pattern
5. Tuning required: Read/Write Offset adjustment
6. Some required increased write current, arising from the number of write coils (9 for Si head vs. 14 for Microdrive design)
7. Perform shock, various stress tests

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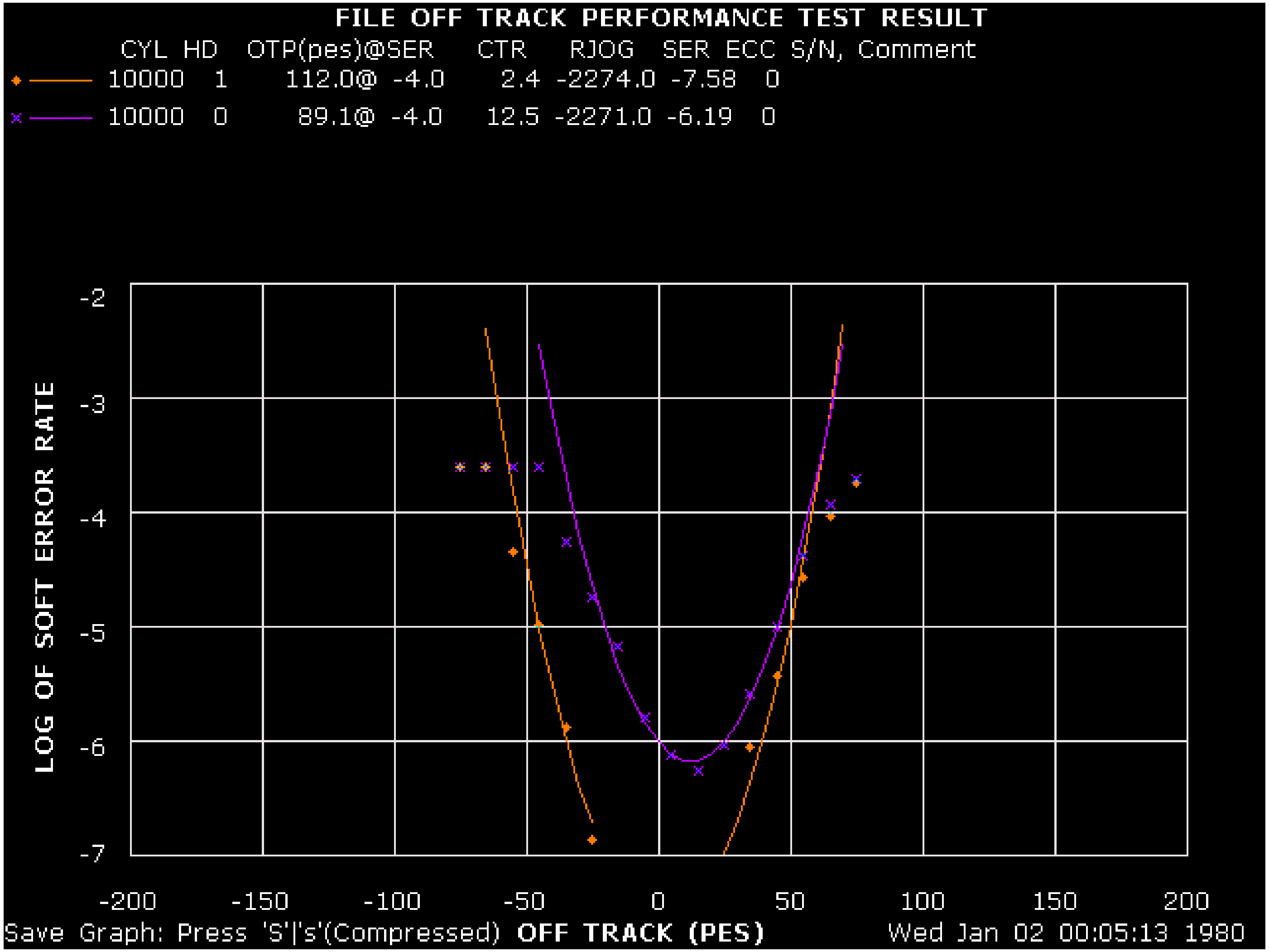
Silicon Slider in 4GB Microdrive



For one of the drives:
Orange-- Si
Purple– AlTiC

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Operating Shock Testing

Test conditions on 4 Si+AlTiC, 2 AlTiC-only operating drives:

-- Lansmont Drop Tester (Fujisawa)

-- Drop direction: bottom cover up; Si HGA down; lifts first at shock

-- 5 drops per condition

-- Read-verify after 5 drops

Failure Criteria

-- ECC correctable scratch

-- Hard error

First Tests (2 ms pulse)

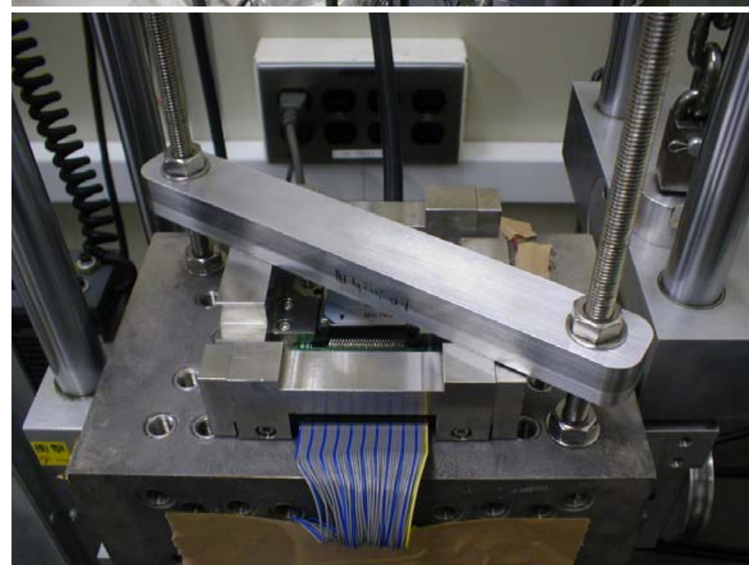
-- Acceleration: 225 G to 700 G

-- AlTiC failed at 350 G; Si passed 700 G

Second Tests (1 ms pulse)

-- Acceleration: 200 G to 1000 G

-- AlTiC failed at 350 G; Si had no hard errors at 1000 G



Si slider improves shock resistance roughly 3x over AlTiC in 4GB Microdrive

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High Temperature Testing

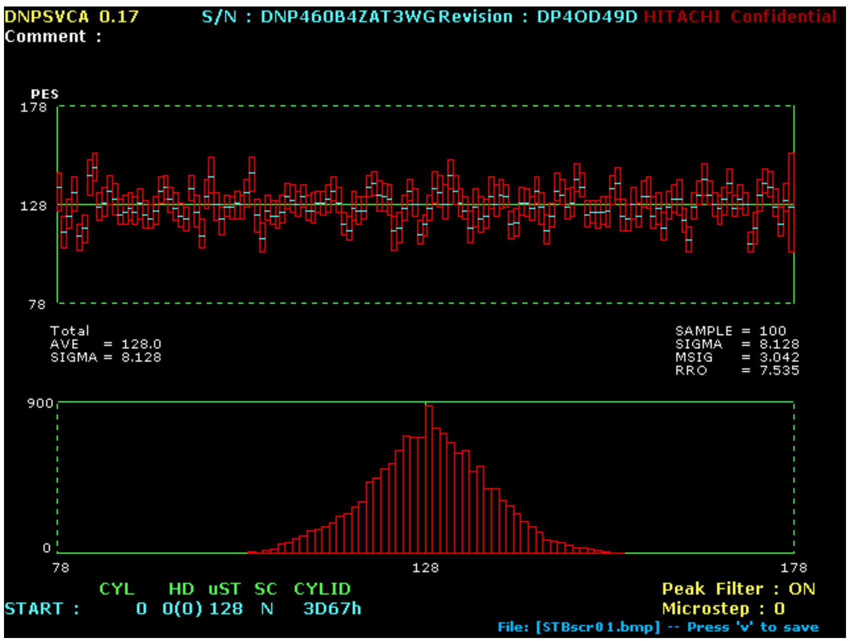
Microdrive build: **26 drives having good starting HSA's (Head Stack Assemblies)**

--All 26 drives showed track following at room temperature

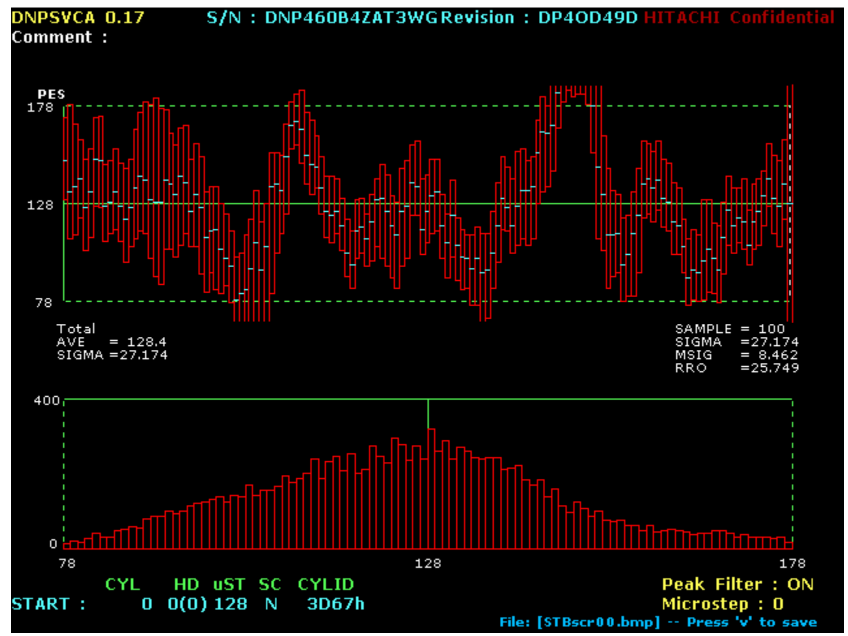
--However, virtually all drives failed at high temperature

--Reason: large thermal protrusion

RT



HT (55 deg-C)



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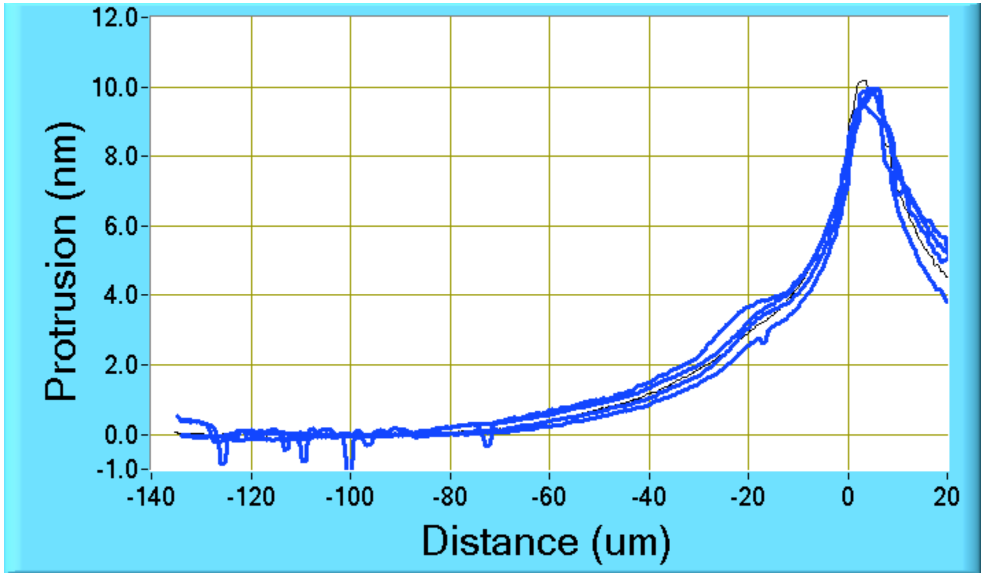
Thermal Protrusion

- Five Si heads measured at ΔT = 30 K; protrusion is 10 nm
- Note: S1 and S2 dimensions each > 10^4 μm^2
- Probably managed by shield and other design changes



V. Nikitin

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Other femto Si Slider Mechanical Testing

•Load/unload tests on data on Microdrives: no errors
 --Repeated under very aggressive L/UL conditions: no errors

•One functional 2.5" drive built
•Drive was shock tested, 2 Si heads, 2 AlTiC heads
•Compared to another AlTiC drive having equivalent ABS and media:
 --Si showed 100 G shock improvement (350 ⇨ 450 G)

•Performed operational slap tests on 2.5" drive
•Lifted slider from spinning disk, increased height; looked for hard errors
 --Si showed 2.5 x improvement over AlTiC (0.25 mm vs. 0.10 mm lift height)

•Measured P2 pitch mode
 --Observed increase (280 → 400 kHz)
 --This was expected, based on 45% reduction in slider density

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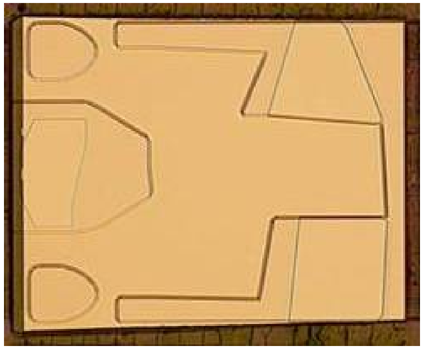
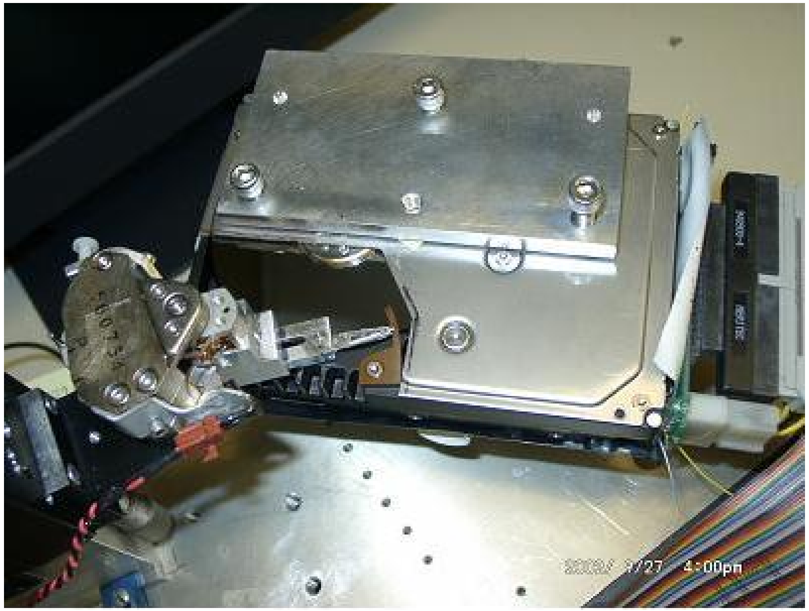
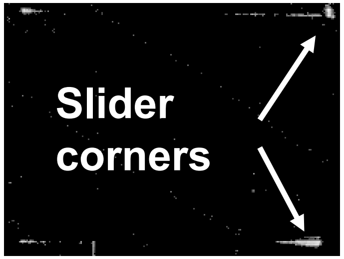
Earlier pico Si Slider Mechanical Testing



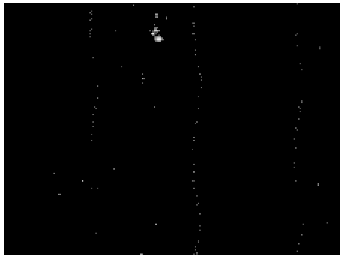
- Load/unload testing; demonstrated ability to L/UL on data
- Static slap tests; no damage with Si, severe damage with AlTiC under all conditions.
- Much improved flyability (next slide)



AlTiC



Si



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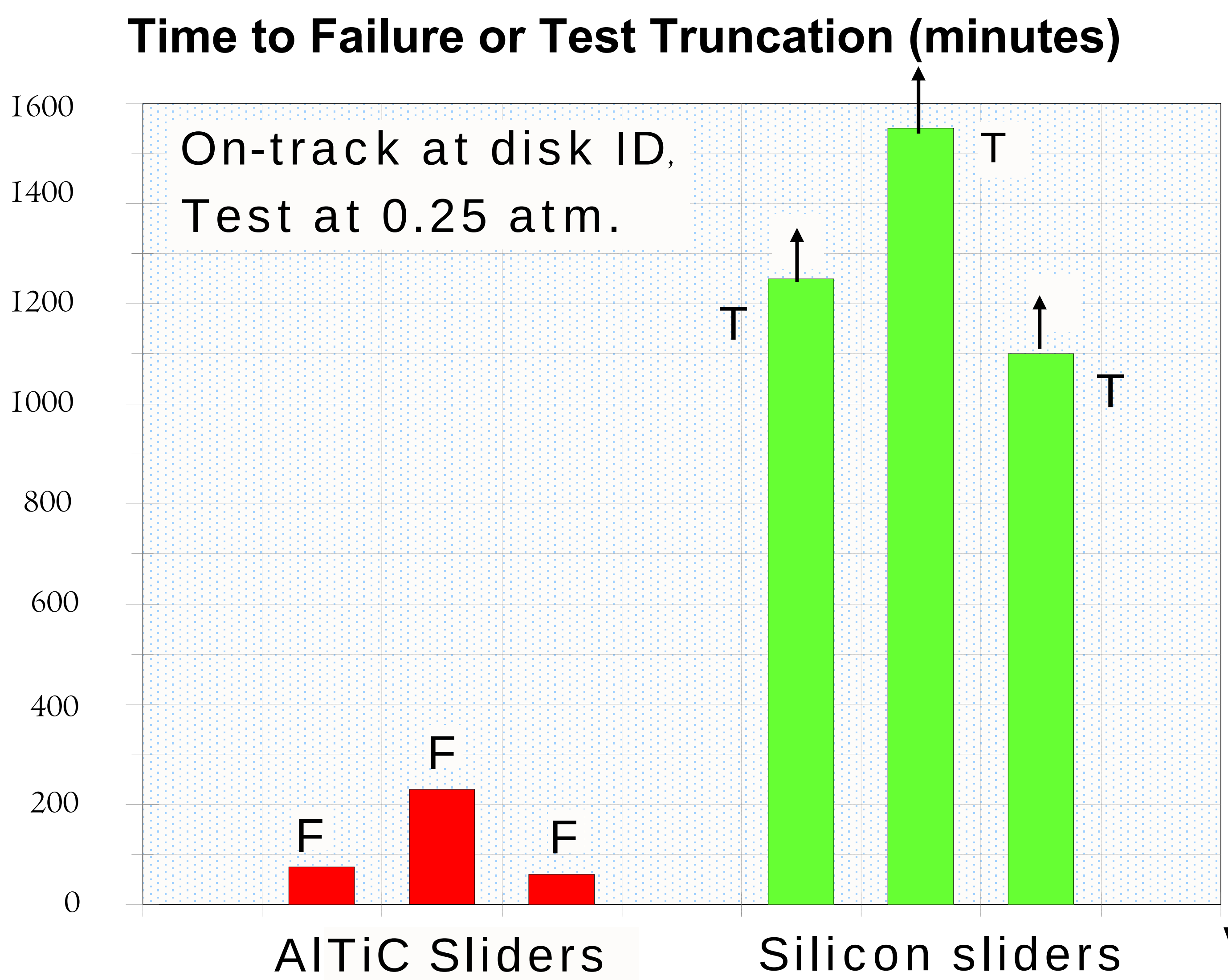
Flyability Testing



V. Raman

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Si vs AlTiC

Property	Si	AlTiC
Hardness (Gpa) (nano-hardness)	12.5	33 (TiC) 20 ($Al_2 0_3$)
Young's Modulus (GPa)	160	400
Density (g/cm$^{3)}$	2.3	4.3
Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	150	20
Linear CTE ($10^{-6}\ K^{-1}$)	2.6 (same as sputtered SiO2)	6.9

Properties in red fundamentally affect comparative Hertzian contact damage and thermal erasure

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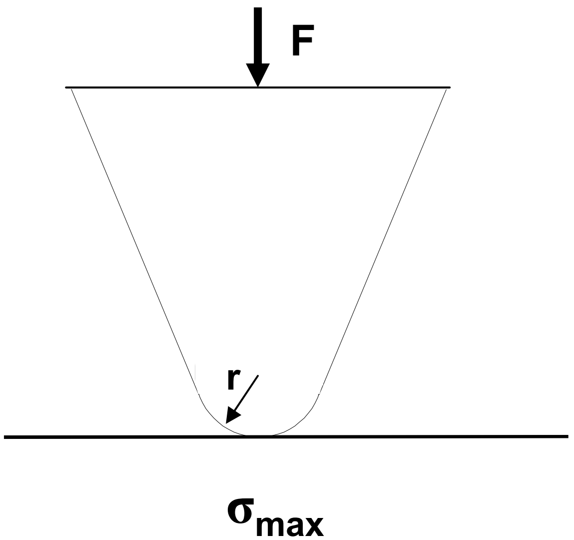
Hertzian Contact

$\sigma_{max} \sim F^{(1/3)} E^{*(2/3)} r^{(-2/3)}$

$E^* = E_D E_S/(E_D + E_S)$

Ignoring an expected increased corner radius, we would expect a >30% drop in maximum stress for Si vs AlTiC on metal disks.



Thermal Erasure

If one assumes that the local heat generation rate is proportional to the contact pressure, and heat losses are approximated as shown (after Archard, Suk et al)

$\Delta T \sim F^{(1/3)} E^{*(2/3)} r^{(-2/3)}/((\kappa c_p \rho)_S + (\kappa c_p \rho)_D)^{(1/2)}$

The advantage of Si over AlTiC is estimated to be about 2X, ignoring r.

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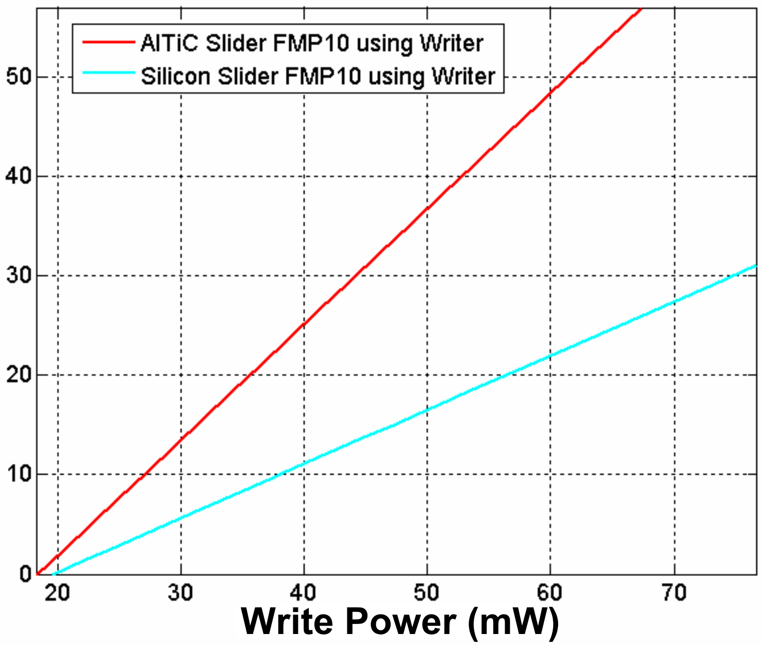
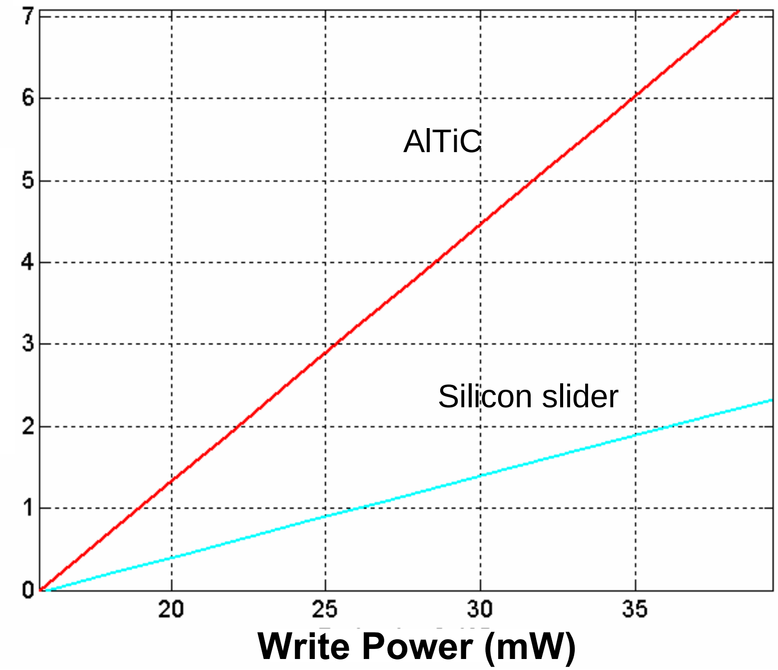
Heat Dissipation Improved with Si



Si vs AlTiC slider parked on load/unload ramp



Si vs AlTiC sliders flying over disk

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Advantages with Si

- Predicted advantages
  - --Improved shock resistance; improved HDI
  - --Ability to Load/Unload on data
  - --More heads per wafer using DRIE row and slider separation
  - --Edge rounding using DRIE
  - --Higher P2 pitch mode
  - --Increased heat dissipation
  - --Lower mass ⇨ 20% increase in microactuator servo freq.
  - --Cheaper substrates

- One other possible advantage
  - --Ability to provide active electronics in the recording head, such as ESD protection diodes

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Si Slider Summary

•Magnetic heads similar in function to AlTiC ones were made on Si substrates with SiO2 insulators, using mostly standard processing

•Si Sliders were made which perform like AlTiC ones, with demonstrated and potential advantages

--Improved shock resistance and head-disk interaction

--Ability to load/unload on data

--Improved heat dissipation

•Issues:

--Thermal protrusion is high; need some redesign

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