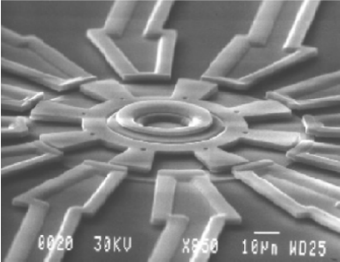
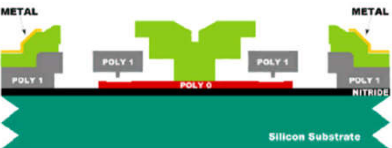


### MUMPS: MultiUser MEMS Process

- Originally created by the Microelectronics Center of North Carolina (MCNC) → now owned by MEMSCAP in France
- Three-level polysilicon surface micromachining process for prototyping and "foundry" services
- Designed to service as many users as possible; basically an attempt to provide a universal MEMS process
- 8 photomasks
- \$4,900 for 1 cm<sup>2</sup> dies

Micromotor fabricated via MUMPS

EE C245: Introduction to MEMS Design LecM 5 C. Nguyen 8/20/09 55

55

### polyMUMPS Minimum Feature Constraints

- Minimum feature size
  - Determined by MUMPS' photolithographic resolution and alignment precision
  - Violations result in missing (unanchored), under/oversized, or fused features
  - Use minimum feature only when absolutely necessary

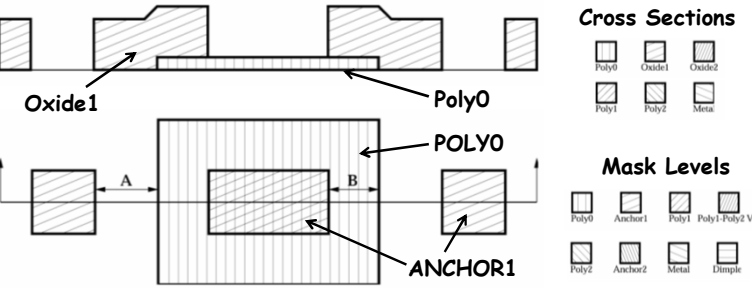
	Nominal [ $\mu\text{m}$ ]	Min Feature [ $\mu\text{m}$ ]	Min Spacing [ $\mu\text{m}$ ]
POLY0, POLY1, POLY2	3	2	2
POLY1_POLY2_VIA	3	2	2
ANCHOR1, ANCHOR2	3	3	2
DIMPLE	3	2	3
METAL	3	3	3
HOLE1, HOLE2	4	3	3
HOLEM	5	4	4

EE C245: Introduction to MEMS Design LecM 5 C. Nguyen 8/20/09 56

56

### MUMPS Design Rules (cont.)

Rule	Rule Letter	Figure #	Min. Value ( $\mu\text{m}$ )
POLY0 space to ANCHOR1	A	2.5	4.0
POLY0 enclose ANCHOR1	B	2.5	4.0
POLY0 enclose POLY1	C	2.6	4.0
POLY0 enclose POLY2	D	2.7	5.0
POLY0 enclose ANCHOR2	E	2.8	5.0
POLY0 space to ANCHOR2	F	2.8	5.0

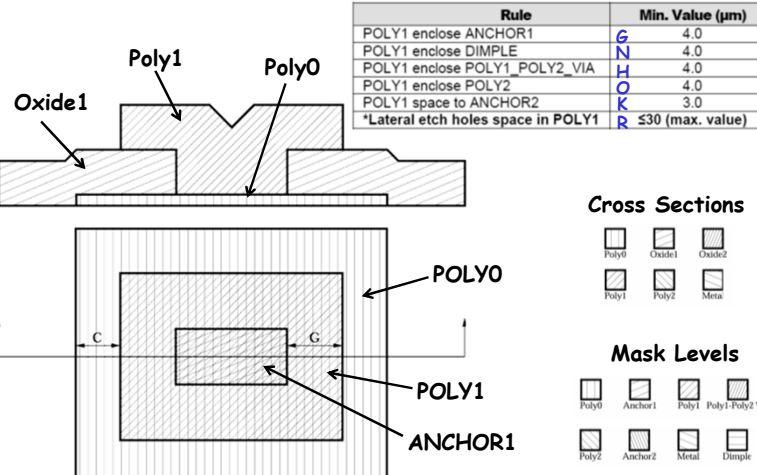


EE C245: Introduction to MEMS Design LecM 5 C. Nguyen 8/20/09 57

57

### MUMPS Design Rules (cont.)

Rule	Min. Value ( $\mu\text{m}$ )
POLY1 enclose ANCHOR1	G 4.0
POLY1 enclose DIMPLE	N 4.0
POLY1 enclose POLY1_POLY2_VIA	H 4.0
POLY1 enclose POLY2	O 4.0
POLY1 space to ANCHOR2	K 3.0
*Lateral etch holes space in POLY1	R $\leq 30$ (max. value)



EE C245: Introduction to MEMS Design LecM 5 C. Nguyen 8/20/09 58

58

### MUMPS Design Rules (cont.)

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Rule	Rule Letter	Figure #	Min. Value (µm)
POLY0 space to ANCHOR1	A	2.5	4.0
POLY0 enclose ANCHOR1	B	2.5	4.0
POLY0 enclose POLY1	C	2.6	4.0
POLY0 enclose POLY2	D	2.7	5.0
POLY0 enclose ANCHOR2	E	2.8	5.0
POLY0 space to ANCHOR2	F	2.8	5.0

Rule	Rule Letter	Figure #	Min. Value (µm)
POLY1 enclose ANCHOR1	G	2.6	4.0
POLY1 enclose DIMPLE	N	2.13	4.0
POLY1 enclose POLY1_POLY2_VIA	H	2.9, 2.11	4.0
POLY1 enclose POLY2	O	2.14	4.0
POLY1 space to ANCHOR2	K	2.11	3.0
*Lateral etch holes space in POLY1	R	2.15	≤30 (max. value)

Rule	Rule Letter	Figure #	Min. Value (µm)
POLY2 enclose ANCHOR2	J	2.7, 2.10	5.0
POLY2 enclose POLY1_POLY2_VIA	L	2.9	4.0
POLY2 cut-in POLY1	P	2.14	5.0
POLY2 cut-out POLY1	Q	2.14	4.0
POLY2 enclose METAL	M	2.12	3.0
POLY2 space to POLY1	I	2.10	3.0
HOLE2 enclose HOLE1	T	2.16	2.0
HOLEM enclose HOLE2	U	2.16	2.0
*Lateral etch holes space in POLY2	S	2.15	≤30 (max. value)

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59

### MUMPS Design Rules (cont.)

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Level 1	Level 2	Min. Feature	Min. Spacing	Enclose	Spacing	Cut-In	Cut-Out
POLY0	-	2	2				
	ANCHOR1			4/B/2.5	4/A/2.5		
	POLY1			4/C/2.6			
	ANCHOR2			5/E/2.8	5/F/2.8		
POLY1	-	2	2 / 2.5 <sup>2</sup>				
	POLY0						
	ANCHOR1			4/G/2.6			
	ANCHOR2				3/K/2.11		
	POLY2			4/O/2.14			
POLY2	-	2	2 / 2.5 <sup>2</sup>				
	POLY0						
	POLY1				3/I/2.10	5/P/2.14	4/Q/2.14
	ANCHOR2			5/J/2.7			
	METAL			3/M/2.12			
HOLEM	HOLE2			2/U/2.16			
HOLE2	HOLE1			2/T/2.16			

**TABLE 2.7.** PolyMUMPs design rule reference sheet. Table shows minimum dimensions (µm), rule name, and figure number, respectively.

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60

## The Sandia SUMMIT Process

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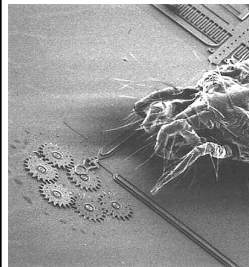
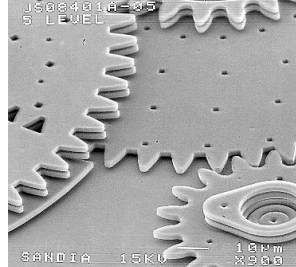
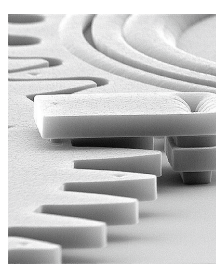
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61

## Sandia's SUMMIT V

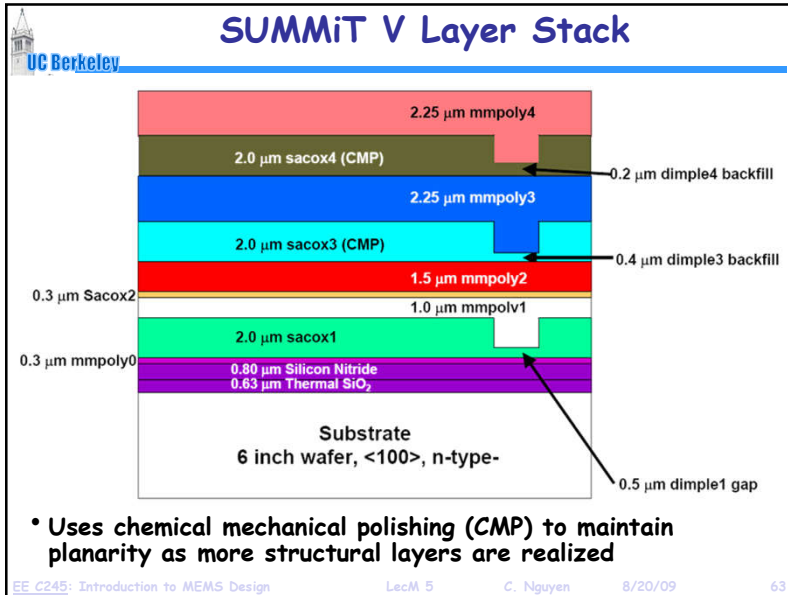
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- **SUMMIT V: "Sandia Ultra-planar Multi-level MEMS Technology 5" fabrication process**
  - ↪ Five-layer polysilicon surface micromachining process
  - ↪ One electrical interconnect layer & 4 mechanical layers
  - ↪ Uses chemical mechanical polishing (CMP) to maintain planarity as more structural layers are realized
  - ↪ 14 masks

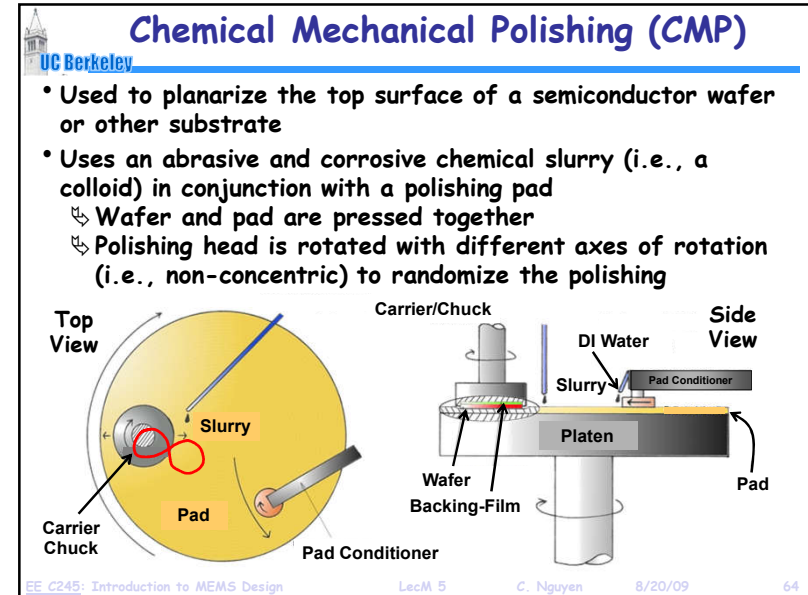




EE C245: Introduction to MEMS Design    LecM 5    C. Nguyen    8/20/09    62

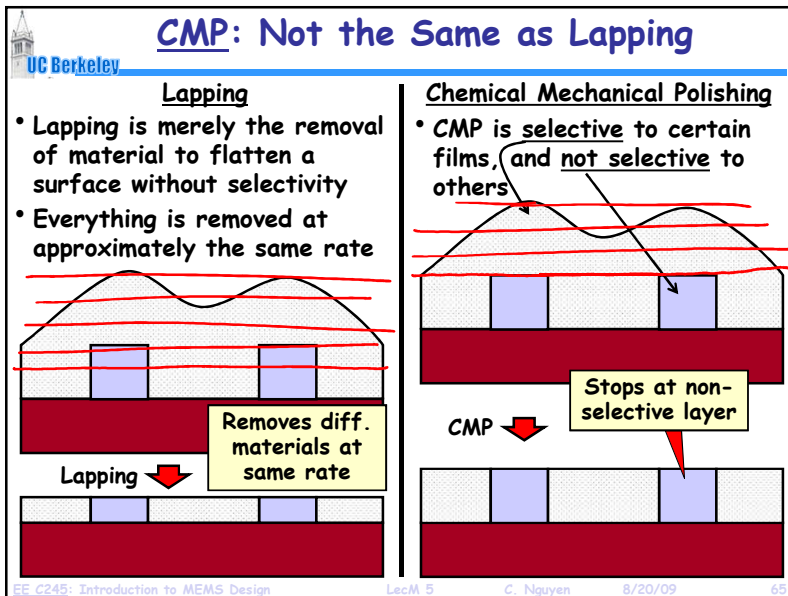
62



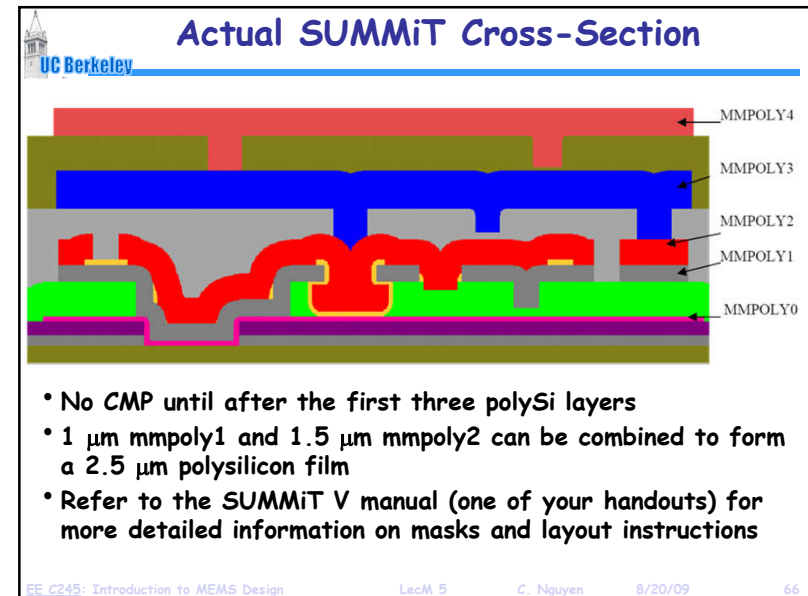
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