Microelectromechanical Systems (MEMs)
Materials for MEMs

Dr. Lynn Fuller

Webpage: http://people.rit.edu/lffeee
Microelectronic Engineering
Rochester Institute of Technology
82 Lomb Memorial Drive
Rochester, NY 14623-5604
Tel (585) 475-2035
Fax (585) 475-5041
Email: Lynn.Fuller@rit.edu
Department webpage: http://www.microe.rit.edu

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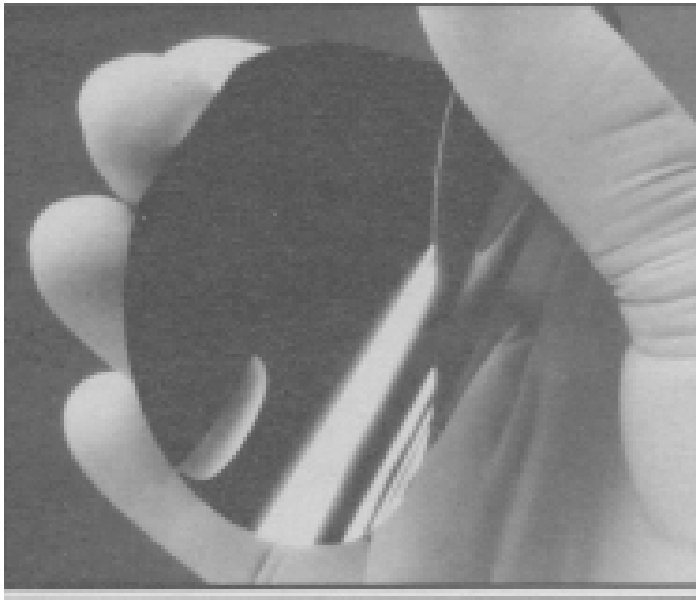
OUTLINE

Special Single Crystal Silicon Wafers
Quartz Wafers
Mechanical Properties
Thermal Properties
Electrical Properties
Optical Properties
Glass
Ceramics
Organic Materials
Solder
Wax
Epoxy

SPECIAL SINGLE CRYSTAL SILICON WAFERS



Thickness = 10 µm
Diameter 75 mm

A wide variety of thin wafers are available from Virginia Semiconductor, 1501 Powhatan St, Fredericksburg, VA 22401, Tel(540)373-2900, Fax(540)371-0371

Pure Sil, Inc., One Silicon Way, Bradford, PA 16701 Tel(814)362-3586, Fax (814)362-2135 supplies double sided polished, thinned wafers. A 4" wafer thickness=380µm, double sided polished costs $15 each in small qty.

Double sided polished wafers can be made at RIT by using CMP equipment. Polishing takes about 1 hour per wafer.

QUARTZ WAFERS

Hoya Electronics Corporation
Electronic Materials Division
2 Corporate Ave
Suite 341
Shelton, CT 06484

Product Code: QZ 4w55325-15C-STD
Standard Wafer Substrate, 4 inch quartz wafer with flat, 0.525 mm thick minimum Quantity 20 @ $39 each (Quote: August 29, 1996) Fax P.O. to (203)929-2529, Tel (203)929-1677

Quartz wafers can be made from quartz mask blanks 60 mils thick (1.524mm). Most glass shops have standard circle cutters and can easily cut and sand edges making nice substrates.

MECHANICAL PROPERTIES

	Density	Youngs Modulus	Yield Strength	Ultimate Strength	Knoop Hardness	Poisson's Ratio
	gm/cm^3	10^{12} $dyne/cm^2$	10^{10} $dyne/cm^2$		Kgm/mm^2	
Single Crystal Silicon	2.33	1.9	12	15	850	0.28
Poly Silicon	2.33	1.5	12	18	850	0.28
Silicon Dioxide	2.19	0.73	8.4	16	570	0.3
Silicon Nitride	3.44	3.85	14	28	3486	0.3
Aluminum	2.7	0.68	17		150	0.334
Nickel	8.9	2.07	59	310	112	0.31
Chrome	7.19	2.54		83	170	0.3
Copper	8.96	1.20	33	209		0.308
Gold	19.3	0.78		103		0.44
Tungsten	19.3	4.1	4	98	350	0.28
Titanium	4.5	1.05	140	220	100	0.34
Tantalum	16.6	1.86		35	124	0.35

10 $dyne/cm^2$ = 1 $newton/m^2$

Metals Handbook

THERMAL PROPERTIES

	MP °C	Coefficient of Thermal Expansion ppm/°C	Thermal Conductivity w/cmK	Specific Heat cal/gm°C
Diamond	3825	1.0	20	0.169
Single Crystal Silicon	1412	2.33	1.5	0.167
Poly Silicon	1412	2.33	1.5	0.167
Silicon Dioxide	1700	0.55	0.014	
Silicon Nitride	1900	0.8	0.185	
Aluminum	660	22	2.36	0.215
Nickel	1453	13.5	0.90	0.107
Chrome	1890	5.1	0.90	0.03
Copper	1357	16.1	3.98	0.092
Gold	1062	14.2	3.19	0.031
Tungsten	3370	4.5	1.78	0.031
Titanium	1660	8.9	0.17	0.043
Tantalum	2996	6.5	0.54	0.033
Air			0.00026	0.24
Water	0		0.0061	1.00

1 watt = 0.239 cal/sec

COEFFICIENTS OF THERMAL EXPANSION

	Thermal Expansion
Silicone Elastomers	275-300 ppm/°C
Unfilled Epoxies	100-200
Filled Epoxies	50-125
Epoxy, glass laminates	100-200
Epoxy, glass laminate, xy axis	12-16
Aluminum	20-25
Copper	15-20
Alumina Ceramic	6.3
Type 400 Steels	6.3-5.6
Glass Fabric	5.1
Borosilicate Glass	5.0
Silicon	2.4
Inconel	2.4
Nickel-iron alloy (30 Ni - 61 Fe)	1.22
Quartz	0.3

THERMAL EXPANSION

1. How much will a 500 um long bar of aluminum expand if it is heated 200 C above ambient?

DL/L = 22 ppm/C
= 22 x 200 = 4400 ppm = 4400E-6

DL = 4400E-6 x 500 um = 2.2 um

THERMAL CONDUCTIVITY

1. What is the thermal resistance to ambient for a square heater of width = 100 um built on silicon dioxide layer 1 um in thickness?

$$
\begin{aligned}
Qth \quad &= \mathbf{1/Gth \;\; t/LW = Rho_{th}\; t/LW} \\
&= \mathbf{(1/0.014)\;\; 1E\text{-}4/(100E\text{-}4)^2} \\
&= \mathbf{71.4\ K/w}
\end{aligned}
$$

ELECTRICAL PROPERTIES

	DC Resistivity ohm-cm	Permittivity Relative
Single Crystal Silicon	0.0001-1E15	11.7
Poly Silicon	0.0001-1E15	11.7
Silicon Dioxide	~1E15	3.9
Silicon Nitride	~1E15	7.5
Aluminum	2.73E-6	-
Nickel	7.16E-6	-
Chrome	13.5E-6	-
Copper	1.73E-6	-
Gold	2.25E-6	-
Tungsten	5.65E-6	
Titanium	55.4E-6	
Tantalum	0.9E-6	

RESISTANCE

1. How hot will a chrome resistance heater get if L=1000um and W=10 um get using 10 volts power supply and 1000A film thickness?

R = Rho L / Area
= 13.5E-6 1000um/(0.1umx10um)
= 135 ohms

P = V2/R = 100/135 = 0.74 w

DT= PQ **= 0.74w x 71.4 K/w = 52.8 K**
or 52.8 °C above ambient

OPTICAL PROPERTIES

Index of Refraction	n
Single Crystal Silicon	3.44
Poly Silicon	3.44
Silicon Dioxide	1.47
Silicon Nitride	1.98
Glass	~1.5

TYPES OF SILICON DIOXIDE

Thermal -Dry
Thermal - Wet
LPCVD, LTO if <400 C
LPCVD, HTO if >900 C
TEOS (no high temp anneal, short high temp anneal, long…)
PECVD TEOS (no high temp anneal, short high temp anneal, long…)
BPSG - 5%Boron/5%Phosphorous Silicon dioxide
Boron Doped Glass
Phosphorous Doped Glass

GLASS

Glass is used to seal lids on packages, form insulation for metal pins into packages.

	Working Temp °C	Thermal Expansion ppm/°C	Thermal Conductivity W/cm K
Borosilicate	1115	46	0.02
Lead Glass	560	84	
Silica Glass	1580	5.5	0.016
Soda Lime Glass	1005	92	

SPECIALTY GLASS

TEMPAX: ~matches thermal coefficient of expansion of silicon, can be used for anodic bonding (alkali rich glass)

PYREX 7740 can be used for anodic bonding

Hoya SD2

PMMA (Plexiglass)

CERAMIC

	Thermal Expansion ppm/°C	Thermal Conductivity W/m K	Youngs Modulus
AlN	2.7	150	
Alumina Al2O3	6.3	40	5.3
Beryllia BeO	7	300	
BN	3.8	60	
SiC (silicon carbide)	3.3	350	7.0
Diamond	1.0	2000	10.35

PZT (lead zicronium titinate) piezoelectric ceramic

POLYIMIDE

Polyimide has a melting point of 450 C, can be spin coated and imaged with lithographic processes making it useful for many applications.

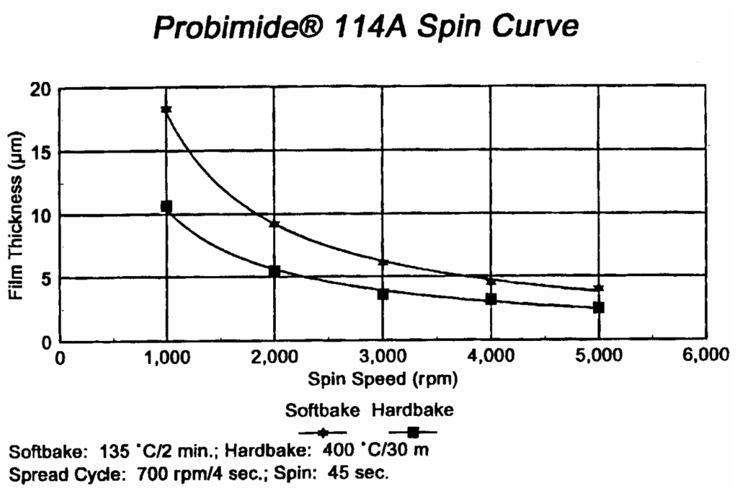
Using DuPont Corporations PI-2555 we can get film thickness between 2.5 µm @ 5000 rpm and 5.0 µm @ 1500 rpm. It is cured by placing on 120 °C hot plate for 30 min. and then on a 350 °C hot plate for 30 min. Multilayer coatings can give thickness greater than 10 µm. (a 500 gm bottle costs ~$250) Du Pont Co., Electronic Materials Division, Barley Mill Plaza, Reynolds Mill Building, Wilmington, DE 19898 (800)441-7543

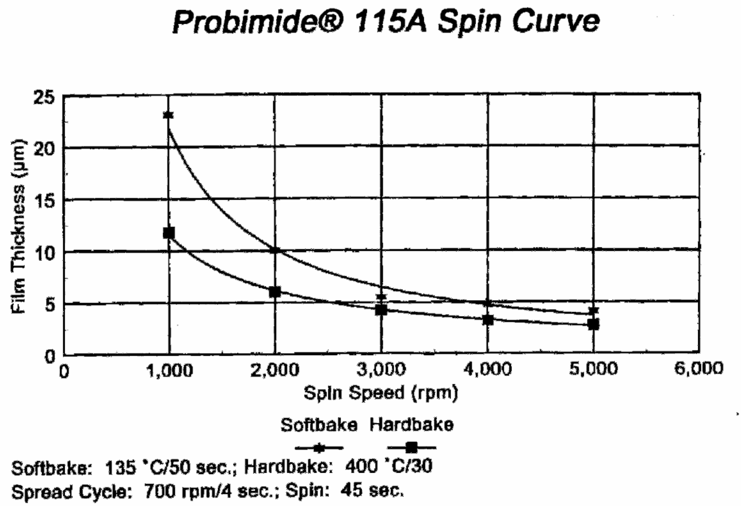
OCG Microelectronic Materials, Belgium, makes a polyimide "Probimide 114A and 114A" which we have used. OCG Microelectronic Materials, 200 Massasoit Ave, East Providence, RI 02914 (Contact Henry Harding, Portsmouth, NH) 603-430-9849 or HAHarding@aol.com

These film are easily imaged using an aluminum barrier layer and conventional photoresist (such as Shipley System-8) followed by Oxygen Reactive Ion Etch.

OCG Probimide 114A and 115A

Process:
Spin 1000 rpm, 45 seconds
Softbake 135 C, 2 min
Hardbake 400 C, 30 min





SOLDER

	Solidus	Liquidus
70Sn/30Pb	183 °C	193 °C
63Sn/37Pb	183	183
60Sn/40Pb	183	190
50Sn/50Pb	183	216
40Sn/60Pb	183	238
10Sn/75Pb	268	302
42Sn/58Bi	138	138
70In/30Pb	160	174
70Sn/18Pb/12In	162	162
90Pb/5In/2.5Ag	300	310
97.5Pb/2.5Ag	303	303

WAX FOR WORKING WITH WAFERS & PIECES

Mr. Roger Young (716)235-7698 or (800)724-7447, Fax (716)235-7254,
J.H. Young Co.
8 Symington Place
Rochester, NY 14611-2409

Makes adhesives, pitches and wax for stacking, blocking of etch, bonding for polishing, etc. Product 7036 dissolves in Acetone and melts at about 100 °C. The price per stick is $10. They make ten or more products of various hardness, melting temperatures, etc., that dissolves in a variety of solvents.

Example: For stacking wafer pieces on a full wafer for processing. Place a full wafer on aluminum foil on a hot plate set at 150 °C, rub the wax stick on the surface to deposit some wax, use a microscope slide to scrape off excess wax leaving a smooth thin layer. Place wafer pieces on the wax, press down, remove and cool, rinse off excess wax in acetone. Remove pieces by heating and cleaning with acetone, alcohol, DI water.

EPOXY MATERIALS

Master Bond Inc
154 Hobart St.
Hackensack, NJ 07601

(201) 343-8983
Offers over 100 different epoxy products, adhesives, sealants and coating.

Product Name	Mix Ratio	Viscosity RT, cps	Set-up time, RT	Cure Schedule	Applications
EP21TPND	100/100	thixotropic	30min	48hrs@RT+2hrs@200F	Polysulfide modified, Fuel and oil resistant sealant
EP30LTE	100/10	17,000	30min	24hrs@RT+3hrs@200F	Exceptionalyy low coefficient of expansion, low shrinkage
EP30	100/10	2000	25min	24hrs@RT+2hrs@200F	Clear system for optical and fiber optic bonding
EP77M-F	100/100	paste	8min	1hr@150F+8hr@300F	Electrically conductive silver filled epoxy
EP121AO	100/80	50,000	15hrs	3hrs@200F+9hrs@200F	Thermally conductive potting and encapsulation
SuperGel#7	100/100	500	3hrs	60hrs@RT+3hrs@200C	Soft resilient, transparent epoxy gel
SteelMaster 43HT	100/20	Thixotropic	25 min	24hr@RT+2hr@200C	Machinable, stainless steel filled

http://www.masterbond.com

EPOXY TECHNOLOGY, INC.

14 Fortune Drive
Billerica, MA 01821-3972
(508) 667-3805

$100/oz.

REFERENCES

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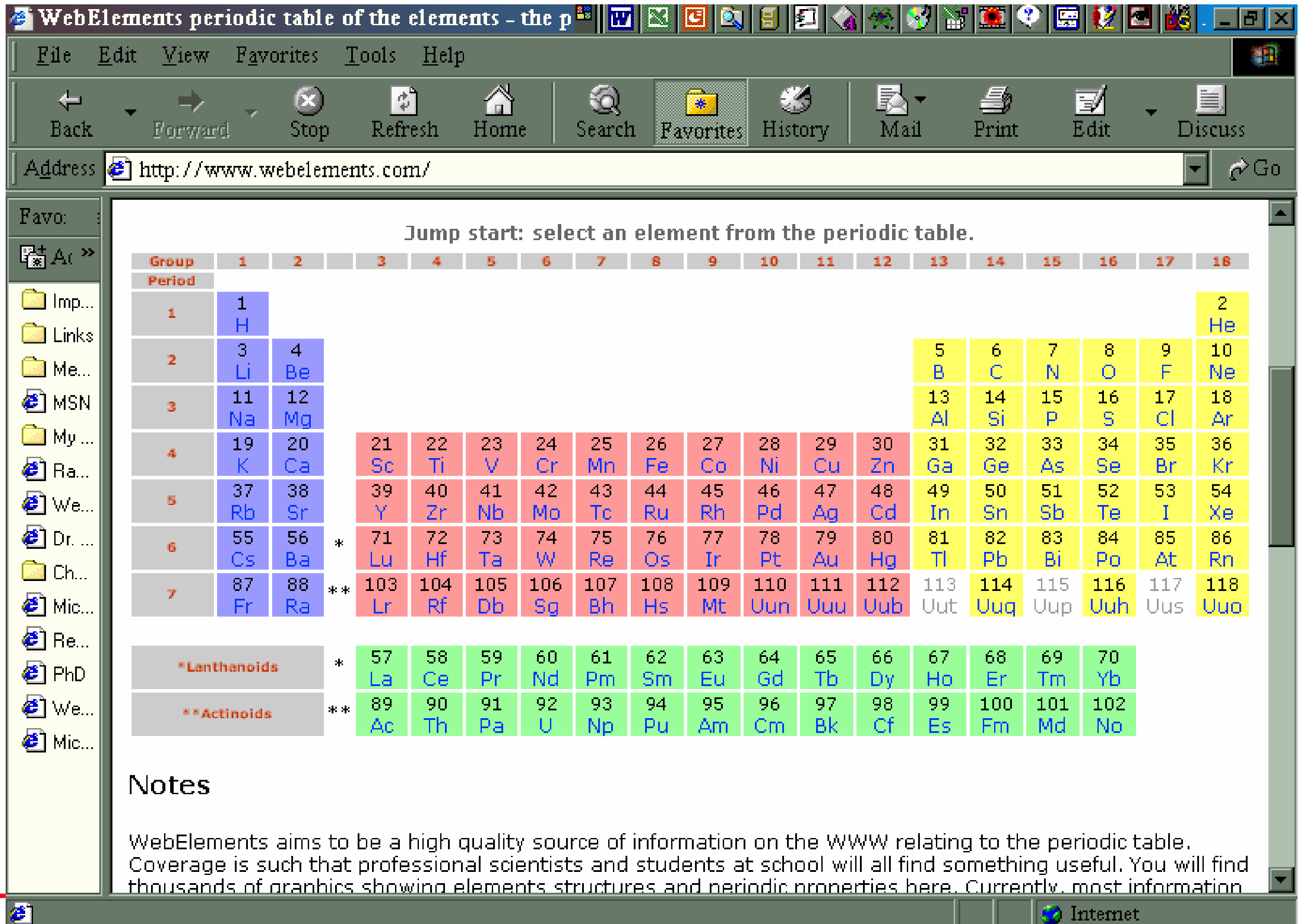

Jump start: select an element from the periodic table.

Group / Period	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
*Lanthanoids			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
**Actinoids			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

Notes

WebElements aims to be a high quality source of information on the WWW relating to the periodic table. Coverage is such that professional scientists and students at school will all find something useful. You will find thousands of graphics showing elements structures and periodic properties here. Currently, most information

HOMEWORK – MEMS MATERIALS

1. Calculate how much the distance between two points on a silicon wafer 6 inches apart will increase for a 2°C increase in wafer temperature.

2. A square 100 µm by 100 µm polysilicon resistor is built on a 1 µm thick silicon dioxide layer. How much power (in watts) must be dissipated in the resistor to heat the resistor 175 °C above ambient?

3. Compare problem 2 to a similar heater built of polysilicon suspended in air, 1 µm above the silicon substrate.

4. Which material is the hardest, strongest, lightest, best thermal conductor, worst thermal conductor, largest thermal expansion, smallest thermal expansion. Give parameter values and units for the material.