

Filename: • WAFER-MAKING-LOCKLAB-V3.1

## Timing

Wafer coating through soft bake: 1 hr, 15 min

Exposure and developing: 1 hr

Profilometer measurements: 10 min / wafer

## SU-8 resists

Decant into 50 mL light-proof centrifuge tubes (allow 24 hours for bubbles to rise).

## Things to bring

- Protocol
- Reading material for down time
- Wafers if needed
- Empty wafer shipping box if needed

Wafer supplier: University Wafer																				
Best																				
Qty	ID	Diam	Type	Dosant	Orien	Res (Ohm-cm)	Thick (um)	Polish	Grade	Lead Time	Quantity	1 Unit Price	5 Unit Price	10 Unit Price	25 Unit Price	50 Unit Price	100 Unit Price	200 Unit Price	500 Unit Price	Description
500	695	76.2mm	N	P	<100>	1 - 10	380um	SSP	Prime	In stock	600	\$28.90	\$25.90	\$13.90	\$10.50	\$9.90	\$9.50	\$8.90		Silicon wafers.

OK																				
Qty	ID	Diam	Type	Dosant	Orien	Res (Ohm-cm)	Thick (um)	Polish	Grade	Lead Time	Quantity	1 Unit Price	5 Unit Price	10 Unit Price	25 Unit Price	50 Unit Price	100 Unit Price	200 Unit Price	500 Unit Price	Description
500	1080	76.2mm	ANY		ANY	ANY	380um	SSP	MECH	In stock	1540	\$15.00	\$10.00	\$7.90	\$5.50	\$4.00	\$4.50	\$3.90		MECHANICAL GRADE, Post quality, 500" 5x 9"

## Setup

- Put gloves on.
- Turn on the three hotplates (power switches AND **heater icon on display**) Deg C: 65, 95, 150.
- Turn on the UV light power supply and aligner's power strip (if planning to expose in the same session).
- Find a timer.

Start plasma cleaning the wafers<sup>1</sup> (insert a shipping box containing 4-6 wafers; 10 min minimum plasma exposure). [Optional: after plasma cleaning, remove dust with water rinse. If needed, rub the wafer under running water with a glove finger. Dry uncovered, 150 C for 5 min. Return wafers to the shipping box and keep covered at all times.]

### Plasma cleaner instructions

Turn the valve on the chamber door clockwise until it points downwards.  
Close the chamber and turn on the vacuum pump and RF power.  
Wait 10 seconds, then turn the valve clockwise until it stops, pointing left.  
Wait 10 seconds, then turn RF knob to HIGH  
Expose for at least 10 min, then: RF off, pump off, and slowly vent the chamber

- Cover a 2 ft long workspace with foil.
- Find the spatula.
- Top up all solvent squirt bottles (PGMEA, IPA, EtOH, Acetone, Water).

<sup>1</sup> Optional: solvent prewash Acetone/MeOH/IPA/H2O/blow/5 min @ 150 C covered

- Cover the spinner basin with foil (see textbox).

- Covering the basin with foil
- Remove the basin from the spinner table. Cover with foil. Open the hole with a razor blade, or by punching it through.

- Install the chuck.
- Turn the vacuum supply on.

### Programming the spinner


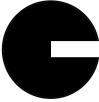
These instructions assume you are using the south spinner.

Thickness $\mu\text{m}$	speed (2025)	speed (2035)	speed (2050)	speed (2075)	Energy $\text{mJ}/\text{cm}^2$
5					102
10					122
15					136
20	3996				144
25	3503				150
30	2998				154
35	2482	3690			157
40	2058	3199	4018		161
45	1869	2832	3660		166
50	1741	2515	3327		172
55	1622	2225	3020		179
60	1501	2008	2738	4026	187
65	1378	1888	2483	3646	194
70	1252	1818	2253	3324	201
75	1124	1740	2056	3060	207
80	995	1657	1938	2854	213
85		1574	1880	2701	219
90		1491	1833	2559	224
95		1409	1788	2420	228
100		1327	1740	2283	232
105		1245	1688	2148	236
110		1163	1634	2034	239
115		1082	1580	1959	241
120		1001	1526	1915	244
125			1473	1877	246
130			1420	1842	249
135			1367	1806	252
140			1314	1770	255
145			1262	1732	258
150			1209	1694	262
155			1157	1655	266
160			1105	1616	271
165			1053	1577	276
170			1001	1538	283
175				1500	289
180				1461	295
185				1422	302
190				1384	308
195				1345	314
200				1307	320

- Consult Table 2 for the actual spin speed ( $x$ ) needed to achieve the desired feature height.
- Consult Appendix 1 to find the nominal spin seed  $x'$  to be entered in the program for the south spinner.

- Enter the program.
- Center a dummy wafer on the chuck.
- Run the program and take a tachometer reading during step 2.
- Correct the spin speed as needed:  $x' = 0.98x + 2.99$

Step	Time	RPM	Ramp
1	10	500	100
2	30	$x'$	300
3	0	Any	Any

Dummy wafers for tachometer readings	
<p>Electrical tape</p> 	
Tape pattern on chuck for tachometer measurements	Better: Black wafer with strip of reflective tape provided with tachometer

### Wafer coating

- Remove a wafer from the shipping box. Blow with N<sub>2</sub>. Place on the chuck.
- Apply ~ 5 mL of SU-8 to the center of the wafer.
- Immediately activate the spinner (foot switch), to avoid "coffee ring effect."
- Transfer the wafer to the workspace (do this by hand).
- Immediately cover the wafer with a glass petri lid.
- Repeat with three more wafers (hotplates hold four wafers).

<p><u>SU-8 best practice</u></p> <p>Avoid bubbles by pouring slowly with the SU-8 containing as close to the wafer as possible.</p> <p>At the end of the pour, break any filaments using a quick lateral movement.</p> <p>Air bubbles can be removed before spinning by sucking them out with a syringe fitted with a large (17 g) stub needle.</p> <p>"Slow is smooth and smooth is fast."</p>
<p><u>Vacuum lock interrupt of spinner program</u></p> <p>To test whether vacuum *can* reach the chuck, power off the spinner. Test for vacuum at the hole in the chuck. If there's vacuum, then the problem is with the spinner, which, when powered on, takes control of the vacuum going to the chuck.</p>

### Soft bake

Baking times and temperatures are given in Table 3. After the last step, place wafers on the workspace and cover with a glass lid. Allow to cool for 1 min, then return them to the shipping box.

Soft bake best practice

Transfer wafers from workspace to hotplates, and between hotplates, using the spatula (do not use forceps, which leave marks and can generate filaments that fall back on on the wafer).

Keep wafers covered at all times during the soft bake.

Wafers can be stored in the dark for several days before exposure and development.

Wipe uncured SU-8 off the back of wafers (PGMEA), if needed. Significant amounts of hardened resist on the back can cause wafers to crack during exposure.

Common failure modes: (i) glass petri plates become sticky, stick to hands, fall on wafers. To fix, hold the petri plate down with the spatula before pulling hand away; (ii) spatula skids across the top of the wafer instead of sliding underneath.

11 um	3 minutes 75°C
17 um	3 minutes 75°C
40-90 um	6 minutes 65°C 15 minutes 95°C

[Cleanup: remove resist from the spatula (PGMEA).]

**Exposure**

- Turn on the UV power supply. Wait at least 6 min before the next step.
- Put on UV protective eyewear.
- Measure the light power (13 - 14 mW/cm<sup>2</sup> is typical).

Power measurement

The power meter is in a drawer near the mask aligner closest to the light-proof entry.

Set the mask aligner's toggle switch to ON.

The shutter is opened by pressing the yellow button, or by moving the stage under the light source.

Hold the light detector under the source at the height reached by a wafer when place on the stage.

- Compute exposure time based on SU-8 thickness, or consult Appendix 2.

Computing exposure time

- t* Exposure time
- E* Exposure energy (mJ/cm<sup>2</sup>; see Table 1)
- I* Irradiance (mW/cm<sup>2</sup>)
- F* Safety factor (1.7)

$$t = \frac{FE}{I}$$

Example (70 um SU-8,  $I = 14 \text{ mW/cm}^2$ ):

$$t = \frac{1.7 \cdot 201 \text{ (mJ/cm}^2\text{)}}{14 \text{ (mW/cm}^2\text{)}} = 24.4 \left( \frac{\text{J}}{\text{W}} \right) = 24.4 \left( \frac{\text{J}}{\text{J/s}} \right) = 24.4 \text{ (s)}$$

- Set the desired exposure time on the front panel of the aligner.
- Place the vacuum platform on the aligner stage and connect it to the vacuum source.
- Ensure that the vacuum platform is concentric with light source.
- Ensure that the coated wafers are protected from light.
- Place a wafer in the depression in the platform, SU-8 side up.
- Place the mask on top of the wafer, emulsion down (text not reversed).
- Turn the vacuum on.
- Say, "Exposing!" to anyone in the room.
- Slide the stage under the light source. The light will come on.
- Return the wafer to the shipping box.
- Repeat with the other three wafers.

### Hard bake

Baking times and temperatures are given in Table 3. After the last step, place wafers on the workspace. Allow to cool for 1 min.

11 um	3 minutes 75°C
17 um	3 minutes 75°C
40-90 um	3 minutes 65°C 10 minutes 95°C

### Developing

- Cover with foil a 2 ft long workspace in front of the hood in the photolithography room.
- Remove the rotating stage from the cupboard and place it in the hood.
- Move the PGMEA vat from its storage location to the workspace.
- Open the lid of the vat, lift and drain the rack, then load the wafers into it. Close the vat.
- Place the vat on the rotating stage in the hood for 10 min (it is stored in the one of the Lockery Lab cabinets).
- Remove a wafer from the vat and rinse it (Clean PGMEA, IPA, EtOH, Water).
- Place it on the workspace and cover it with a glass lid.
- Repeat with the other wafers.

#### Developing best practice

PGMEA should be captured for disposal in a labeled bottle; it should not go down the sink.

Test completeness of development by aiming the first shot of IPA at a non-critical part of the wafer. If a milky film appears, more development is required.

### Annealing

- Place the wafers, covered, on the 150 C hotplate for 3 min. This step heals cracks and removes halos around features.
- Cool for 1 min on the workspace.
- Return the wafer to the shipping box.

### Profilometry (draft instructions)

- Login to the Dektak Stylus Profilometer.
- Put gloves on.
- Wake the computer.
- Enter scan parameters (Window > Scan Routines).

Typical scan parameters

Distance: 1000 – 2500  $\mu\text{m}$   
Duration: 10 – 25 sec  
Mode: hills only  
Amplitude: 2560  $\text{\AA}$   
Force: 10 mg

- Prepare the profilometer (Window > Sample positioning).
- Turn on light
- Tower up.
- Center the platform underneath the stylus.
- Center the wafer on the platform.
- Tower down.
- Press SCAN.

After the scan, the measurement window will pop up. Cursors can be moved using the mouse or on-screen scroll buttons. Move them to regions representing the wafer surface and the top of the resist layer. Record the y-axis difference between the two cursor positions. (Values are given in Angstroms. To convert to  $\mu\text{m}$ , move the decimal point four places to the left). If needed, move to a different location on the wafer and repeat. Repeat on other wafers as needed. When finished, tower up. Turn off light. Close lid. Logout.

**Appendix 1**

**Look-up table of nominal spin speeds**

Lokey Lab  
 South spinner  
 Desired speed / Programmed speed

1000/983	1001/984	1002/985	1003/986	1004/987	1005/988	1006/989	1007/990	1008/991	1009/992
1010/993	1011/994	1012/995	1013/996	1014/997	1015/998	1016/999	1017/1000	1018/1001	1019/1002
1020/1003	1021/1004	1022/1005	1023/1006	1024/1007	1025/1007	1026/1008	1027/1009	1028/1010	1029/1011
1030/1012	1031/1013	1032/1014	1033/1015	1034/1016	1035/1017	1036/1018	1037/1019	1038/1020	1039/1021
1040/1022	1041/1023	1042/1024	1043/1025	1044/1026	1045/1027	1046/1028	1047/1029	1048/1030	1049/1031
1050/1032	1051/1033	1052/1034	1053/1035	1054/1036	1055/1037	1056/1038	1057/1039	1058/1040	1059/1041
1060/1042	1061/1043	1062/1044	1063/1045	1064/1046	1065/1047	1066/1048	1067/1049	1068/1050	1069/1051
1070/1052	1071/1053	1072/1054	1073/1055	1074/1056	1075/1056	1076/1057	1077/1058	1078/1059	1079/1060
1080/1061	1081/1062	1082/1063	1083/1064	1084/1065	1085/1066	1086/1067	1087/1068	1088/1069	1089/1070
1090/1071	1091/1072	1092/1073	1093/1074	1094/1075	1095/1076	1096/1077	1097/1078	1098/1079	1099/1080
1100/1081	1101/1082	1102/1083	1103/1084	1104/1085	1105/1086	1106/1087	1107/1088	1108/1089	1109/1090
1110/1091	1111/1092	1112/1093	1113/1094	1114/1095	1115/1096	1116/1097	1117/1098	1118/1099	1119/1100
1120/1101	1121/1102	1122/1103	1123/1104	1124/1105	1125/1105	1126/1106	1127/1107	1128/1108	1129/1109
1130/1110	1131/1111	1132/1112	1133/1113	1134/1114	1135/1115	1136/1116	1137/1117	1138/1118	1139/1119
1140/1120	1141/1121	1142/1122	1143/1123	1144/1124	1145/1125	1146/1126	1147/1127	1148/1128	1149/1129
1150/1130	1151/1131	1152/1132	1153/1133	1154/1134	1155/1135	1156/1136	1157/1137	1158/1138	1159/1139
1160/1140	1161/1141	1162/1142	1163/1143	1164/1144	1165/1145	1166/1146	1167/1147	1168/1148	1169/1149
1170/1150	1171/1151	1172/1152	1173/1153	1174/1154	1175/1154	1176/1155	1177/1156	1178/1157	1179/1158
1180/1159	1181/1160	1182/1161	1183/1162	1184/1163	1185/1164	1186/1165	1187/1166	1188/1167	1189/1168
1190/1169	1191/1170	1192/1171	1193/1172	1194/1173	1195/1174	1196/1175	1197/1176	1198/1177	1199/1178
1200/1179	1201/1180	1202/1181	1203/1182	1204/1183	1205/1184	1206/1185	1207/1186	1208/1187	1209/1188
1210/1189	1211/1190	1212/1191	1213/1192	1214/1193	1215/1194	1216/1195	1217/1196	1218/1197	1219/1198
1220/1199	1221/1200	1222/1201	1223/1202	1224/1203	1225/1203	1226/1204	1227/1205	1228/1206	1229/1207
1230/1208	1231/1209	1232/1210	1233/1211	1234/1212	1235/1213	1236/1214	1237/1215	1238/1216	1239/1217
1240/1218	1241/1219	1242/1220	1243/1221	1244/1222	1245/1223	1246/1224	1247/1225	1248/1226	1249/1227
1250/1228	1251/1229	1252/1230	1253/1231	1254/1232	1255/1233	1256/1234	1257/1235	1258/1236	1259/1237
1260/1238	1261/1239	1262/1240	1263/1241	1264/1242	1265/1243	1266/1244	1267/1245	1268/1246	1269/1247
1270/1248	1271/1249	1272/1250	1273/1251	1274/1252	1275/1252	1276/1253	1277/1254	1278/1255	1279/1256
1280/1257	1281/1258	1282/1259	1283/1260	1284/1261	1285/1262	1286/1263	1287/1264	1288/1265	1289/1266
1290/1267	1291/1268	1292/1269	1293/1270	1294/1271	1295/1272	1296/1273	1297/1274	1298/1275	1299/1276
1300/1277	1301/1278	1302/1279	1303/1280	1304/1281	1305/1282	1306/1283	1307/1284	1308/1285	1309/1286
1310/1287	1311/1288	1312/1289	1313/1290	1314/1291	1315/1292	1316/1293	1317/1294	1318/1295	1319/1296
1320/1297	1321/1298	1322/1299	1323/1300	1324/1301	1325/1301	1326/1302	1327/1303	1328/1304	1329/1305
1330/1306	1331/1307	1332/1308	1333/1309	1334/1310	1335/1311	1336/1312	1337/1313	1338/1314	1339/1315
1340/1316	1341/1317	1342/1318	1343/1319	1344/1320	1345/1321	1346/1322	1347/1323	1348/1324	1349/1325
1350/1326	1351/1327	1352/1328	1353/1329	1354/1330	1355/1331	1356/1332	1357/1333	1358/1334	1359/1335
1360/1336	1361/1337	1362/1338	1363/1339	1364/1340	1365/1341	1366/1342	1367/1343	1368/1344	1369/1345
1370/1346	1371/1347	1372/1348	1373/1349	1374/1350	1375/1350	1376/1351	1377/1352	1378/1353	1379/1354
1380/1355	1381/1356	1382/1357	1383/1358	1384/1359	1385/1360	1386/1361	1387/1362	1388/1363	1389/1364
1390/1365	1391/1366	1392/1367	1393/1368	1394/1369	1395/1370	1396/1371	1397/1372	1398/1373	1399/1374
1400/1375	1401/1376	1402/1377	1403/1378	1404/1379	1405/1380	1406/1381	1407/1382	1408/1383	1409/1384
1410/1385	1411/1386	1412/1387	1413/1388	1414/1389	1415/1390	1416/1391	1417/1392	1418/1393	1419/1394
1420/1395	1421/1396	1422/1397	1423/1398	1424/1399	1425/1399	1426/1400	1427/1401	1428/1402	1429/1403
1430/1404	1431/1405	1432/1406	1433/1407	1434/1408	1435/1409	1436/1410	1437/1411	1438/1412	1439/1413
1440/1414	1441/1415	1442/1416	1443/1417	1444/1418	1445/1419	1446/1420	1447/1421	1448/1422	1449/1423
1450/1424	1451/1425	1452/1426	1453/1427	1454/1428	1455/1429	1456/1430	1457/1431	1458/1432	1459/1433
1460/1434	1461/1435	1462/1436	1463/1437	1464/1438	1465/1439	1466/1440	1467/1441	1468/1442	1469/1443
1470/1444	1471/1445	1472/1446	1473/1447	1474/1448	1475/1448	1476/1449	1477/1450	1478/1451	1479/1452
1480/1453	1481/1454	1482/1455	1483/1456	1484/1457	1485/1458	1486/1459	1487/1460	1488/1461	1489/1462
1490/1463	1491/1464	1492/1465	1493/1466	1494/1467	1495/1468	1496/1469	1497/1470	1498/1471	1499/1472
1500/1473	1501/1474	1502/1475	1503/1476	1504/1477	1505/1478	1506/1479	1507/1480	1508/1481	1509/1482
1510/1483	1511/1484	1512/1485	1513/1486	1514/1487	1515/1488	1516/1489	1517/1490	1518/1491	1519/1492
1520/1493	1521/1494	1522/1495	1523/1496	1524/1497	1525/1497	1526/1498	1527/1499	1528/1500	1529/1501
1530/1502	1531/1503	1532/1504	1533/1505	1534/1506	1535/1507	1536/1508	1537/1509	1538/1510	1539/1511
1540/1512	1541/1513	1542/1514	1543/1515	1544/1516	1545/1517	1546/1518	1547/1519	1548/1520	1549/1521
1550/1522	1551/1523	1552/1524	1553/1525	1554/1526	1555/1527	1556/1528	1557/1529	1558/1530	1559/1531
1560/1532	1561/1533	1562/1534	1563/1535	1564/1536	1565/1537	1566/1538	1567/1539	1568/1540	1569/1541
1570/1542	1571/1543	1572/1544	1573/1545	1574/1546	1575/1546	1576/1547	1577/1548	1578/1549	1579/1550
1580/1551	1581/1552	1582/1553	1583/1554	1584/1555	1585/1556	1586/1557	1587/1558	1588/1559	1589/1560
1590/1561	1591/1562	1592/1563	1593/1564	1594/1565	1595/1566	1596/1567	1597/1568	1598/1569	1599/1570
1600/1571	1601/1572	1602/1573	1603/1574	1604/1575	1605/1576	1606/1577	1607/1578	1608/1579	1609/1580
1610/1581	1611/1582	1612/1583	1613/1584	1614/1585	1615/1586	1616/1587	1617/1588	1618/1589	1619/1590
1620/1591	1621/1592	1622/1593	1623/1594	1624/1595	1625/1595	1626/1596	1627/1597	1628/1598	1629/1599
1630/1600	1631/1601	1632/1602	1633/1603	1634/1604	1635/1605	1636/1606	1637/1607	1638/1608	1639/1609
1640/1610	1641/1611	1642/1612	1643/1613	1644/1614	1645/1615	1646/1616	1647/1617	1648/1618	1649/1619
1650/1620	1651/1621	1652/1622	1653/1623	1654/1624	1655/1625	1656/1626	1657/1627	1658/1628	1659/1629
1660/1630	1661/1631	1662/1632	1663/1633	1664/1634	1665/1635	1666/1636	1667/1637	1668/1638	1669/1639
1670/1640	1671/1641	1672/1642	1673/1643	1674/1644	1675/1644	1676/1645	1677/1646	1678/1647	1679/1648
1680/1649	1681/1650	1682/1651	1683/1652	1684/1653	1685/1654	1686/1655	1687/1656	1688/1657	1689/1658
1690/1659	1691/1660	1692/1661	1693/1662	1694/1663	1695/1664	1696/1665	1697/1666	1698/1667	1699/1668
1700/1669	1701/1670	1702/1671	1703/1672	1704/1673	1705/1674	1706/1675	1707/1676	1708/1677	1709/1678
1710/1679	1711/1680	1712/1681	1713/1682	1714/1683	1715/1684	1716/1685	1717/1686	1718/1687	1719/1688
1720/1689	1721/1690	1722/1691	1723/1692	1724/1693	1725/1693	1726/1694	1727/1695	1728/1696	1729/1697
1730/1698	1731/1699	1732/1700	1733/1701	1734/1702	1735/1703	1736/1704	1737/1705	1738/1706	1739/1707
1740/1708	1741/1709	1742/1710	1743/1711	1744/1712	1745/1713	1746/1714	1747/1715	1748/1716	1749/1717
1750/1718	1751/1719	1752/1720	1753/1721	1754/1722	1755/1723	1756/1724	1757/1725	1758/1726	1759/1727
1760/1728	1761/1729	1762/1730	1763/1731	1764/1732	1765/1733	1766/1734	1767/1735	1768/1736	1769/1737
1770/1738	1771/1739	1772/1740	1773/1741	1774/1742	1775/1742	1776/1743	1777/1744	1778/1745	1779/1746
1780/1747	1781/1748	1782/1749	1783/1750	1784/1751	1785/1752	1786/1753	1787/1754	1788/1755	1789/1756
1790/1757	1791/1758	1792/1759	1793/1760	1794/1761	1795/1762	1796/1763	1797/1764	1798/1765	1799/1766
1800/1767	1801/1768	1802/1769	1803/1770	1804/1771	1805/1772	1806/1773	1807/1774	1808/1775	1809/1776







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**Appendix 2**

Exposure times

Safety\_factor

1.7

Irradiance (mW/cm <sup>2</sup> )	SU-8 Thickness (um)	Energy (mJ/cm <sup>2</sup> )	Exposure duration (s)
10	10	122	21
10	20	144	24
10	30	154	26
10	40	161	27
10	50	172	29
10	60	187	32
10	70	201	34
10	80	213	36
10	90	224	38
10	100	232	39
11	10	122	19
11	20	144	22
11	30	154	24
11	40	161	25
11	50	172	27
11	60	187	29
11	70	201	31
11	80	213	33

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11	90	224	35
11	100	232	36
12	10	122	17
12	20	144	20
12	30	154	22
12	40	161	23
12	50	172	24
12	60	187	26
12	70	201	28
12	80	213	30
12	90	224	32
12	100	232	33
13	10	122	16
13	20	144	19
13	30	154	20
13	40	161	21
13	50	172	22
13	60	187	24
13	70	201	26
13	80	213	28
13	90	224	29
13	100	232	30

Irradiance (mW/cm <sup>2</sup> )	SU-8 Thickness (um)	Energy (mJ/cm <sup>2</sup> )	Exposure duration (s)
14	10	122	15
14	20	144	17
14	30	154	19
14	40	161	20
14	50	172	21
14	60	187	23
14	70	201	24
14	80	213	26
14	90	224	27
14	100	232	28
15	10	122	14
15	20	144	16
15	30	154	17
15	40	161	18
15	50	172	19
15	60	187	21
15	70	201	23
15	80	213	24
15	90	224	25

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15	100	232	26
16	10	122	13
16	20	144	15
16	30	154	16
16	40	161	17
16	50	172	18
16	60	187	20
16	70	201	21
16	80	213	23
16	90	224	24
16	100	232	25
17	10	122	12
17	20	144	14
17	30	154	15
17	40	161	16
17	50	172	17
17	60	187	19
17	70	201	20
17	80	213	21
17	90	224	22
17	100	232	23

Irradiance (mW/cm <sup>2</sup> )	SU-8 Thickness (um)	Energy (mJ/cm <sup>2</sup> )	Exposure duration (s)
18	10	122	12
18	20	144	14
18	30	154	15
18	40	161	15
18	50	172	16
18	60	187	18
18	70	201	19
18	80	213	20
18	90	224	21
18	100	232	22
19	10	122	11
19	20	144	13
19	30	154	14
19	40	161	14
19	50	172	15
19	60	187	17
19	70	201	18
19	80	213	19

19	90	224	20
19	100	232	21
20	10	122	10
20	20	144	12
20	30	154	13
20	40	161	14
20	50	172	15
20	60	187	16
20	70	201	17
20	80	213	18
20	90	224	19
20	100	232	20

### Appendix 3

Michael Rios writes:

For popping bubbles on the programmatic cycle: I wait until the 95 part of the cycle and about a minute in after it reaches temp. I have not tested extensively but my observation is that if you pop them at room temp or even 65 (depending on SU-8 and bubble depth and size) the SU-8 may make a divot that does not normalize fast enough and leaves a trace (no idea how it affects height - but you can see it). At 95 the SUN is fluid enough that it normalizes the surface or "heals" with minimal trace (or none at all). It also reduces chances of generating a "spike" that folds over and makes a new bubble when running at this temp.

There is technique to the bubble popping. You have to get close to the wafer, so you have to monitor your breathing (I exhale completely prior to this for steadiness during this and so I don't send particles onto the wafer) a face mask would also be a good idea provided it is cleanroom suitable, you also need to be aware of the depth of the bubble, you can view from a 45 degree angle and rotate the wafer to get an idea of where the bubble is before you attempt to pop it. You pop the bubble by inserting the razor blade corner first straight down and then pull the blade straight up and out quickly to prevent a fold. I think you would see even better results with a heated blade that is closer to the SUN temp during that step. It is very hands on and tedious - but it worked.

### Appendix 4

Michael Rios writes:

I believe the machines do spin high, so if you are going off of the machine readout and not using an isolated gauge then you are spinning about 20-50rpm higher than you think you are. You must also pay attention to the ramp step. Sometimes we ramp up at 100rpm/s and sometimes 300rpm/s - this can affect height as well so you will want to make sure that is set correctly. I believe the higher ramp RPM helps with thicker SU-8.

A few notes on how I run these:

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- I only trust the tachometer for RPM - so I use the gauge on the equipment just to set it and as a reference of the amount of correction that needs to be made. For example: *I set the primary spin at 2000rpm, the tachometer reports back 2018rpm but the equipment readout reports 1998rpm - in the case I will lower the machine command rpm to 1980rpm. I then will recheck with the tachometer to verify. Further adjustments can be made this way until you get within 2-3rpm of the target.* I attempt to get as close as possible to the true RPM I am working towards, based on the tachometer. I take 2 readings, set everything, and confirm with a 3rd reading before running. - I have found redundancy equals success with SU-8.
- SU-8 is produced in small batches and I believe there is some variability that can occur between batches. Documentation from Microchem suggests this as well by stating that RPM speeds are recommendations that will need to be adjusted. The manufacturer also recommends verifying numbers between SU-8 lot #'s - for this reason it is good to do test runs.
- Here is how I do a test run: *Fabricate 3-4 wafers, however, adjust the primary spin speed for each one by 50 to 100rpm (this is dependent on height and SU8 used, you have to estimate) - continue fabrication of these wafers until development. Measure the wafers and mark them in order of height. Determine the height that is closest to target and use that RPM. If the height is between two of the different RPMs, adjust to an RPM between those. You can then run wafers using the numbers determined.*
- Test runs are the best way to really nail down your heights and so I do them regularly now and am able to achieve better numbers more consistently.