BiTS

Burn-in & Test Socket Workshop 2000

Session 5

Mechanical Aspects

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BURN-IN & TEST
SOCKET WORKSHOP

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Presentations

“Effects Of Gold Plated Contacts In BGA Burn-in Sockets”

Alfred Sugarman, Loranger International Corp.
Ariane Loranger, Loranger International Corp.

“Challenges of Burn-in Socket Design For Fine Pitch (0.5mm) CSP/uBGA”

Yoshinori Egawa, Yamaichi Electronics USA, Inc.
Shunji Abe, Yamaichi Electronics, Inc. - Japan

“A Closed Loop Geometric Tolerance Socket Design Process For Area Array IC Packages”

Gordon A. Vinther
Everett Charles Technologies

EFFECTS OF GOLD PLATED CONTACTS IN BGA BURN-IN SOCKETS

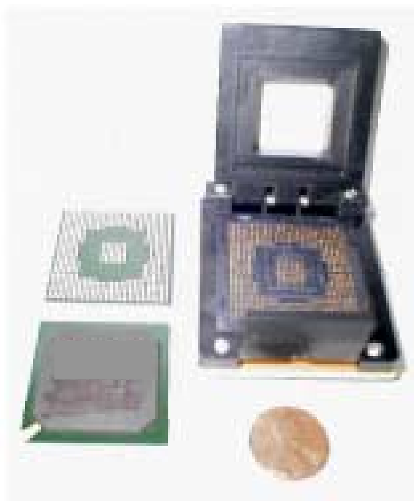
By Ariane Loranger and Alfred Sugarman

Presented At The Burn-In & Test Socket Workshop (BiTS), February 27-29, 2000, Mesa, AZ

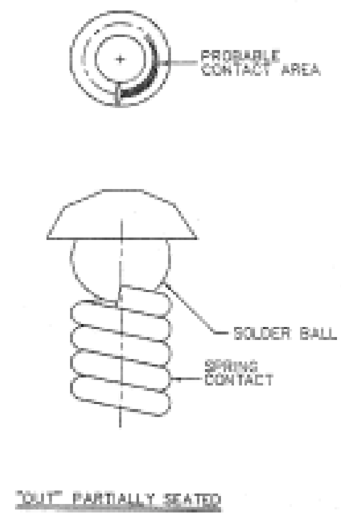
Overview Of Presentation

- Description of Burn-in Socket
- Discussion of Contact Area and Witness Marks
- Gold Content In Solder Balls From Calculation and Elemental Analysis
- Effects of Gold In Solder
- Summary and Conclusions

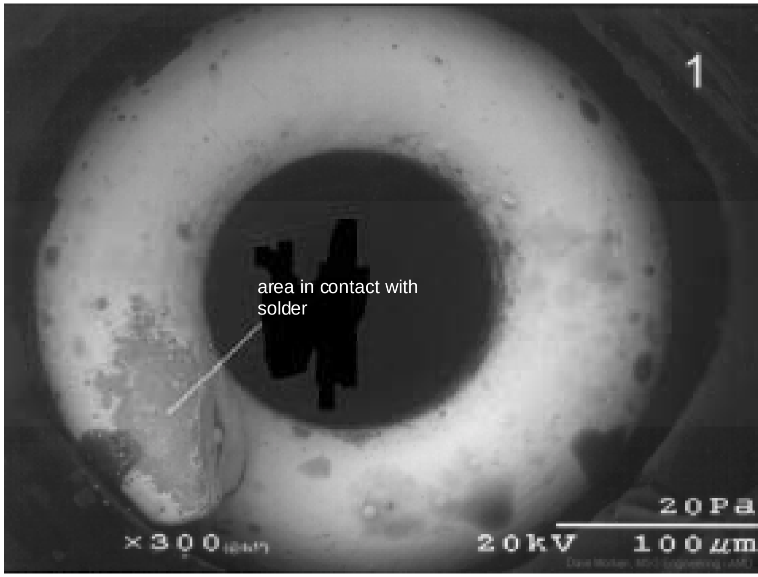
DESCRIPTION OF BURN-IN SOCKET



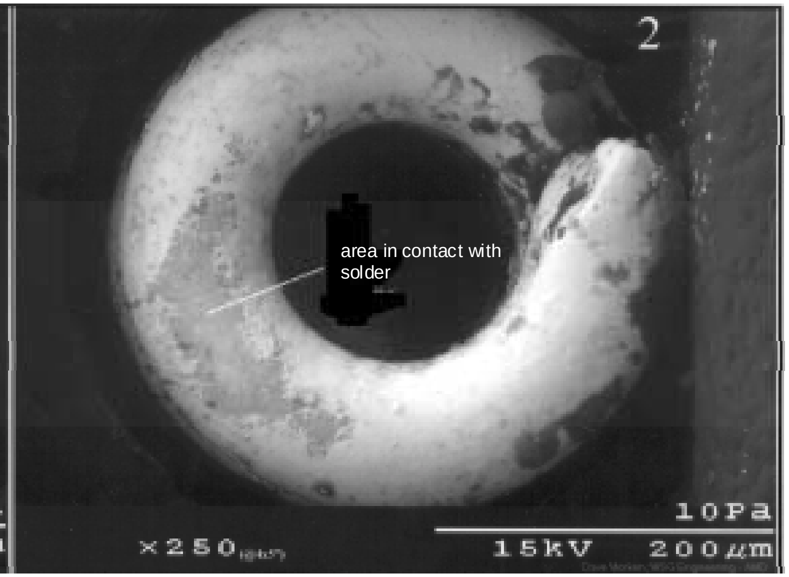
Typical BGA Package and Socket. Picture #1. To left of socket is shown the top and bottom sides of an appropriate device.



Typical Socket Contact Interface to the BGA Ball. Figure A.

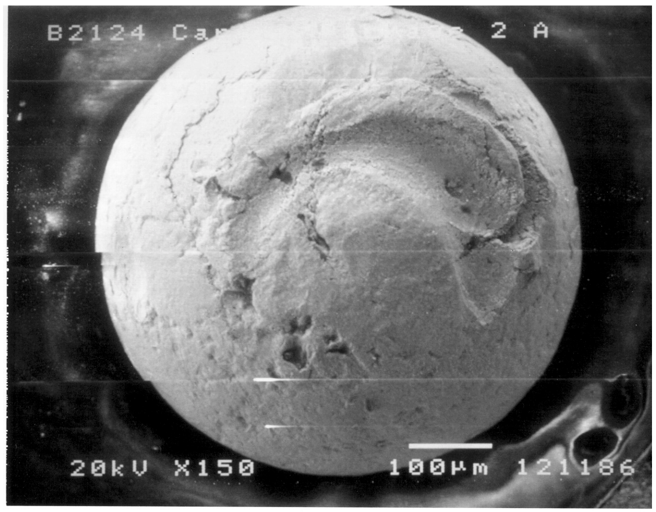


Picture #2



Picture #3

Contacts in BGA socket burned in at 125°C for 1,000 hours. Areas designated by line were in contact with solder.



Solder ball on BGA burned in at 125°C. Notice the witness mark left by the contact. The dark areas on the solder are artifacts present before burn-in. Picture #4

Loranger International Corporation

TABLE 1. CALCULATED MAX % GOLD FOR DIFFERENT CONTACT AND BALL SIZES IN LORANGER SOCKETS

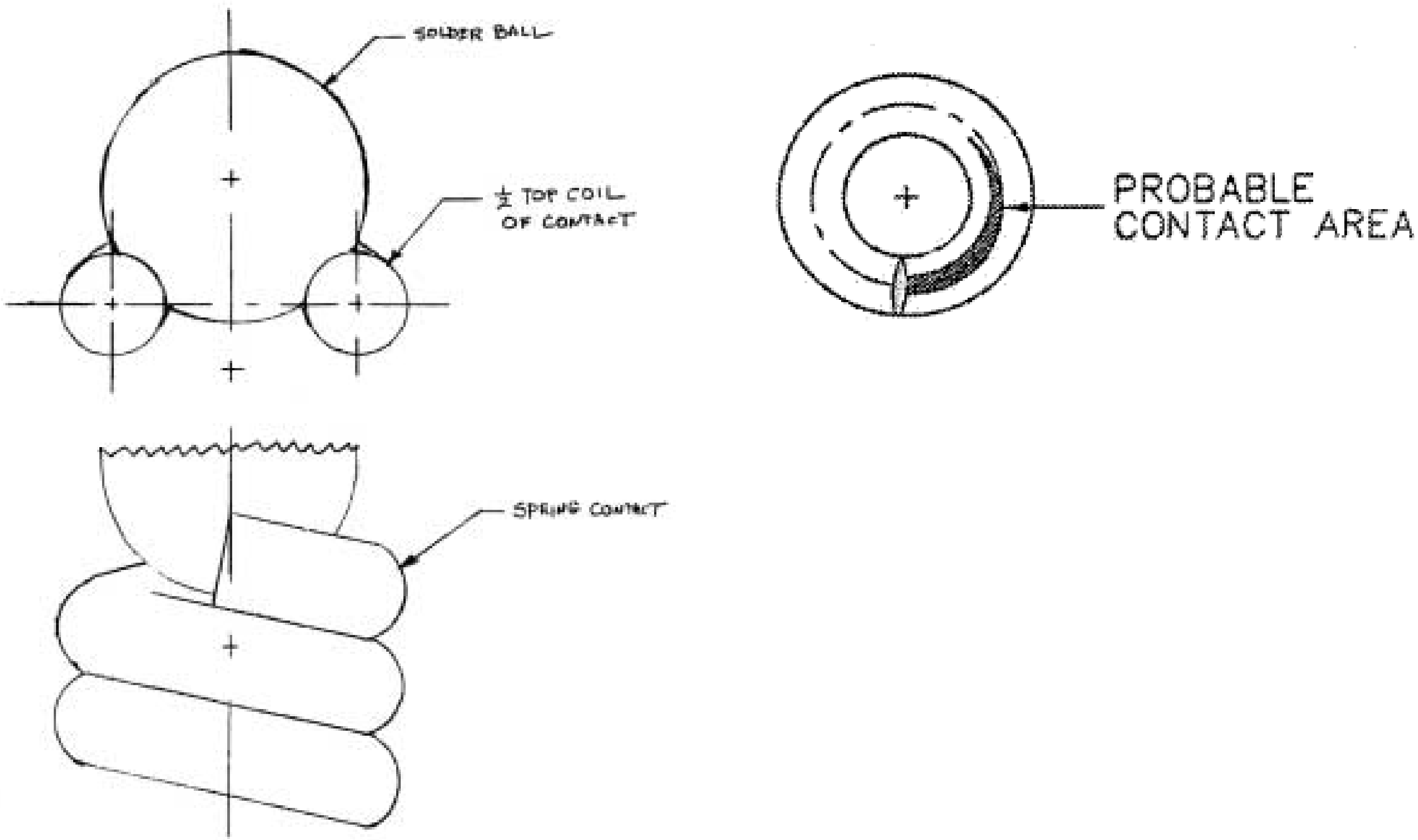
Pitch	**Ball Size**	**Wire Dia. In Contact**	**Contact O.D.**	**Maximum Weight Percent Au, w/o**
0.50mm	.0118 to .0126 in	.0022in	.008in	.06 to .05 w/o
0.65 to 0.80mm	.0126 to .0200 in	.0024in	.012in	.09 to .02 w/o
1.00 to 1.27mm	.0200 to .0300in	.0040in	.016in	.05 to .01 w/o

Assumptions:

- 1/16 of coil surface is in contact with solder ball. Photomicrographs of witness marks show this assumption to be conservative.
- All gold in contact with the solder dissolves in it. This is conservative because there are no reports from industry showing all the gold disappearing.
- Gold is dispersed uniformly throughout volume of solder ball during reflow.

TABLE 2. AVERAGE ELEMENTAL ANALYSES (WEIGHT PERCENT) ON SURFACE OF SOLDER BALLS ON PACKAGE BURNED IN AT 125°C

Sample	Pb	Sn	Au	Cu	Ni
24 Hour Burn-In	31.6	68.5	<.05	<.05	<.05
48 Hour Burn-In	31.4	68.8	<.05	<.05	<.05
168 Hour Burn-In	27.3	72.7	<.05	<.05	<.05



a. Section view showing 1/4 of coil area in contact with ball.

b. Top view showing 1/4 circumference of coil in contact with ball.

Sketch showing how 1/16 of coil surface in contact with solder ball was derived.

Table 5-1 Solder Limts[1] for Tin/Lead Alloys (Sn60-Sn63)

Contaminant	Maximum contaminant Limit (%)[2] Preconditioning (Lead/Wire Tinning)	Assembly Soldering (Pot, Wave, Etc.)
Copper	0.750	0.300
Gold	0.500	0.200
Cadmium	0.010	0.005
Zinc	0.008	0.005
Aluminum	0.008	0.006
Antimony	0.500	0.500
Iron	0.020	0.020
Arsenic	0.030	0.030
Bismuth	0.250	0.250
Silver[3]	0.750	0.100
Nickel	0.025	0.010

Notes:
1. The tin content of the solder bath shall be within ± 1.5% of nominal for the solder specified and tested at the same frequency as testing for copper/gold contamination. The balance of the bath shall be lead or the items listed above.
2. The total copper, gold, cadmium, zinc and aluminum contaminants shall not exceed 0.4% for assembly soldering.
3. Not applicable for Sn62: limits to be 1.75% to 2.25%

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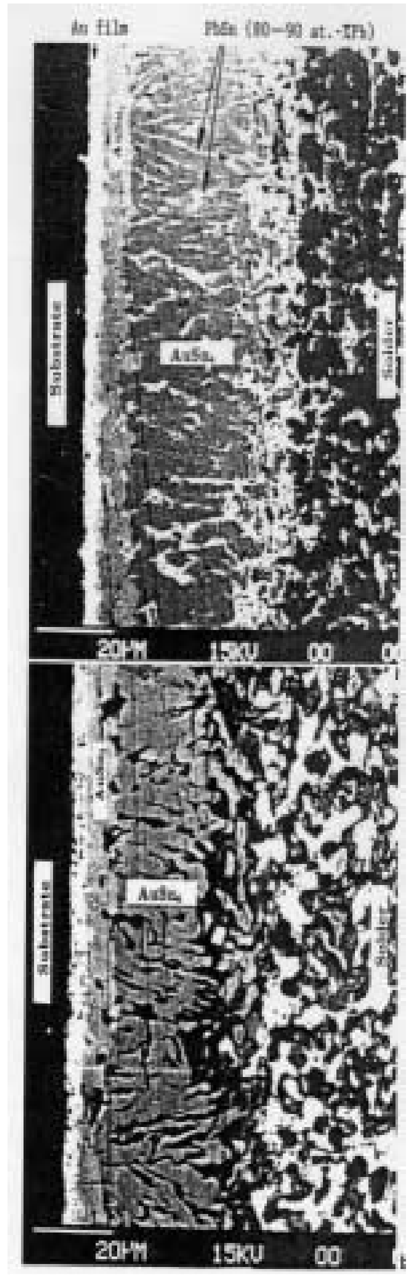
International Corporation

TABLE 3. EFFECTS OF GOLD ON SOLDER PROPERTIES

Concentration Range in Weight Percent, w/o	What Happens	Reference
0-0.3 w/o Au in 63Sn/37Pb	Solubility limit of Au in solder reached and $AuSn_4$ intermetallic forms.	(1)
0.2-0.5 w/o Au in 63Sn/37P	Contamination level at which solder should be renewed	(2),(3),(4)
0.3-2 w/o Au in 63Sn/37Pb	No effect on solder properties	(1)
2-3 w/o Au in 63Sn/37Pb	Spreadability & fluidity of solder reduced	(1)
3 w/o Au in 63Sn/37Pb	Highest acceptable concentration of Au in solder before deleterious effects can occur.	(1)
3-7 w/o Au in 63Sn/37Pb	Shear strength & ductility of solder decrease	(1)
7-10 w/o Au in 63Sn/37Pb	Rapid increase in hardness of solder	(1)



Gold-solder diffusion couple aged for 7 hours at 160ºC*. Figure B.

Mechanically polished section

Mechanically polished followed by electroetching

*El-B. Hannech and C.R. Hall, "Diffusion Controlled Reactions In Au/Pb-Sn Solder System", Materials Science and Technology, Vol 8, No 9, p817, Sept 1992.

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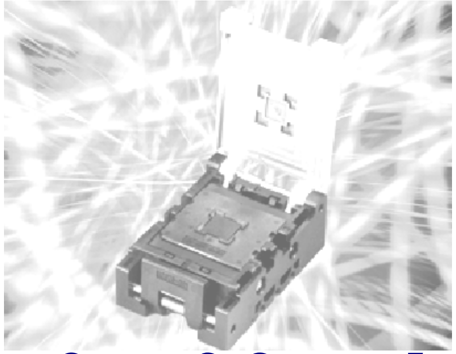
SUMMARY AND CONCLUSIONS

- The quantity of gold diffusing from contacts in burn-in sockets into BGA solder balls was determined by calculation and elemental analysis
- Calculated and analyzed gold content in the solder balls from the contacts was found within industry limits for maximum permitted concentration. These limits are conservative with respect to the affect of gold on solderability and joint embrittlement.
- Witness marks on solder balls after burn-in showed contact area is only the high portion of the contact coil and often showed no presence of reaction with the gold

Challenges of Burn-in Socket Design

for



Fine Pitch DSBGA(CSP) / F BGA (0.5mm)

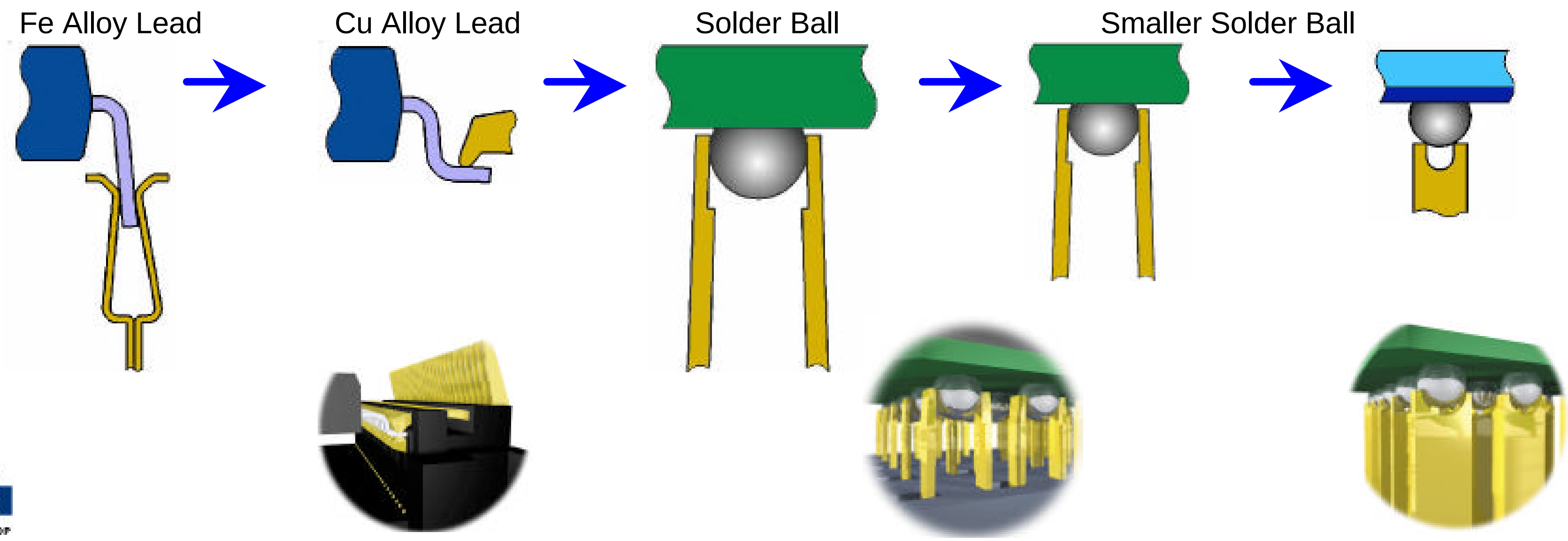
S. ABE and Y. EGAWA

Background of Development

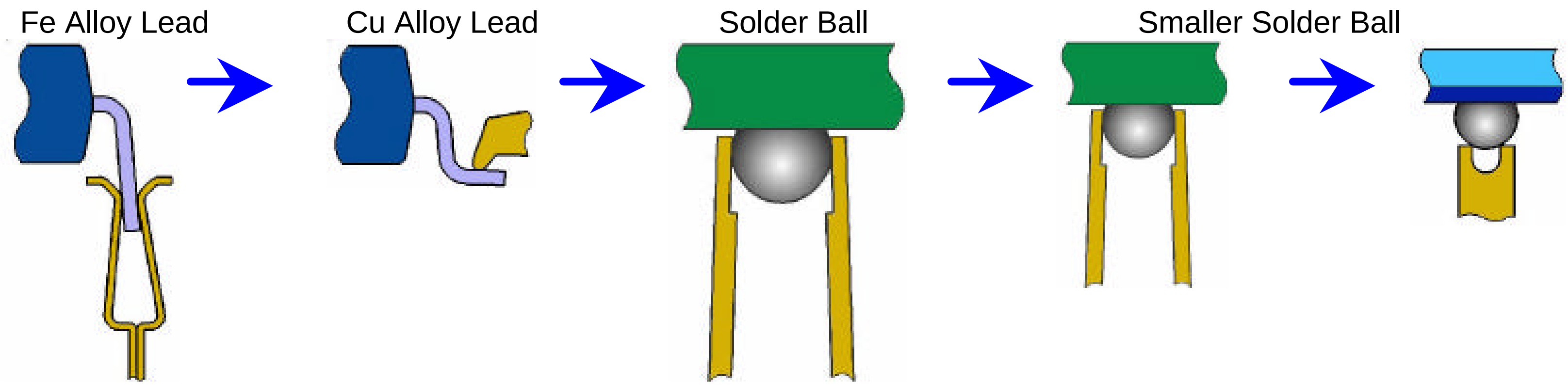
Package Type

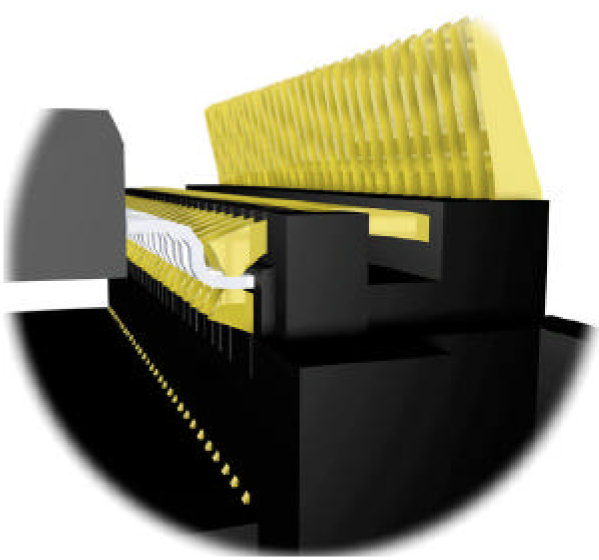
DIP 100, 70 mil P → QFP, SOP 1.27 ~0.5 mm P → BGA 1.27~1.00 mm P → FBGA, DSBGA 0.80~0.65 mm P → FBGA,DSBGA 0.50 mm P

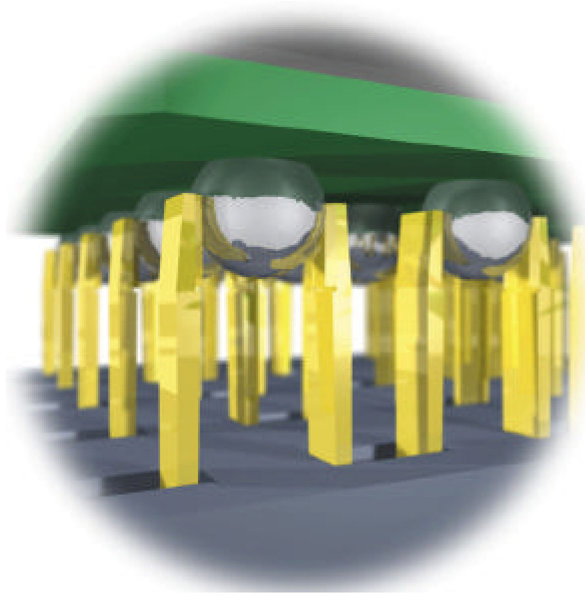
Package Terminal

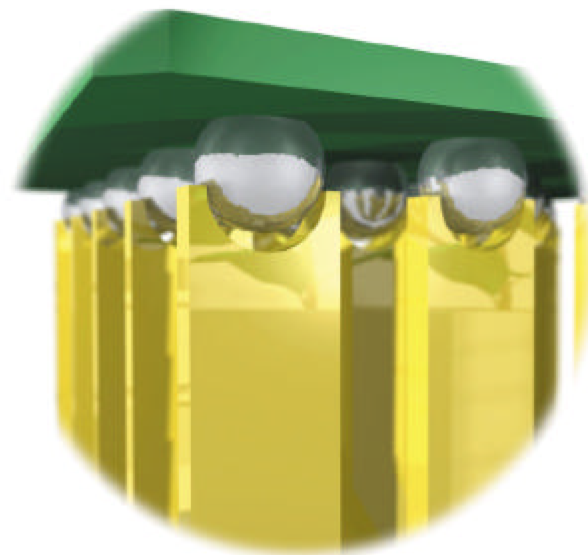


Background of Development

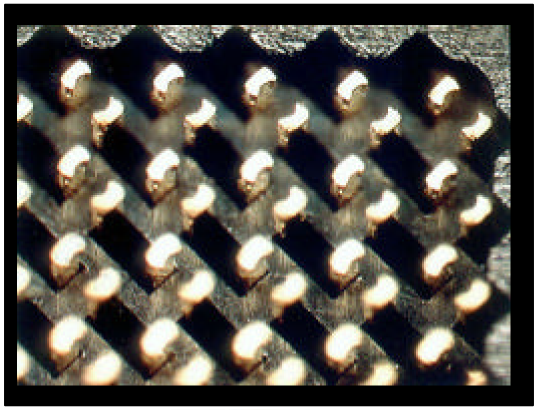


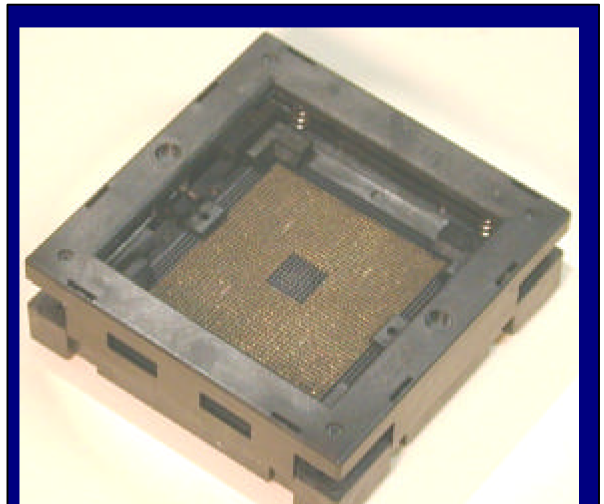




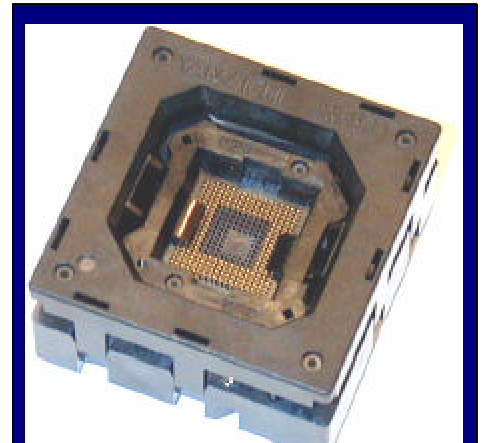


Tweezer Contact Socket

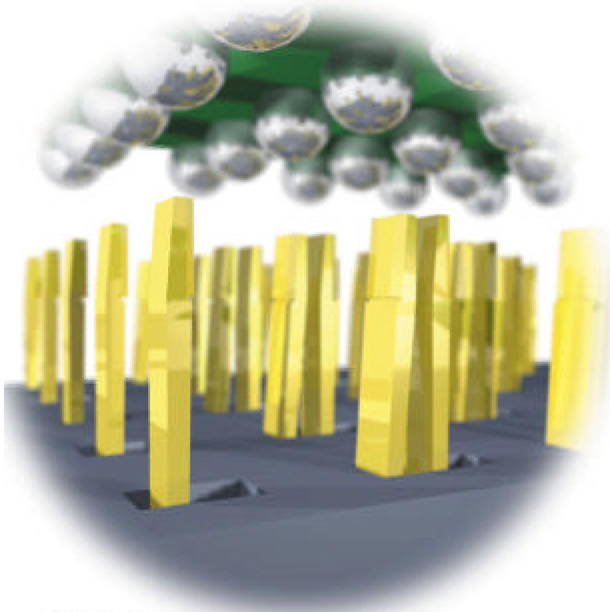




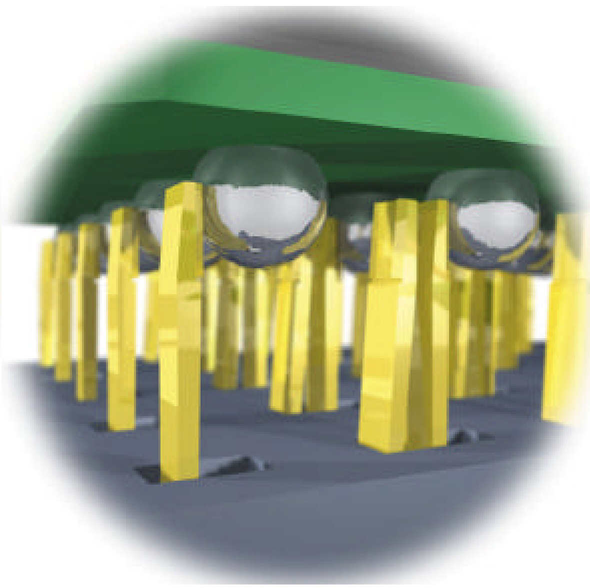
1,600pin / 1mmP



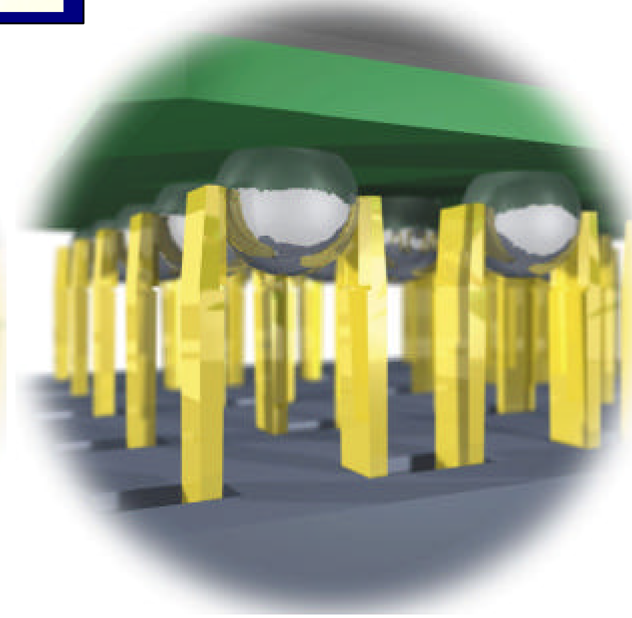
176pin / 0.65mmP



Open Contact

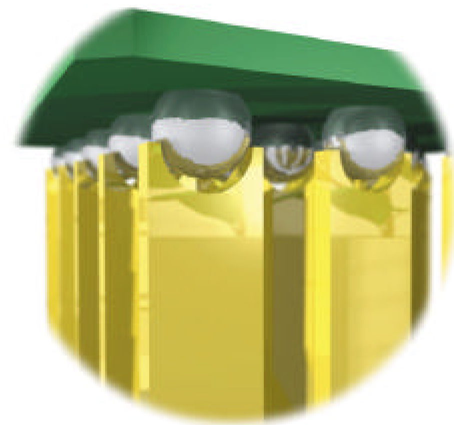


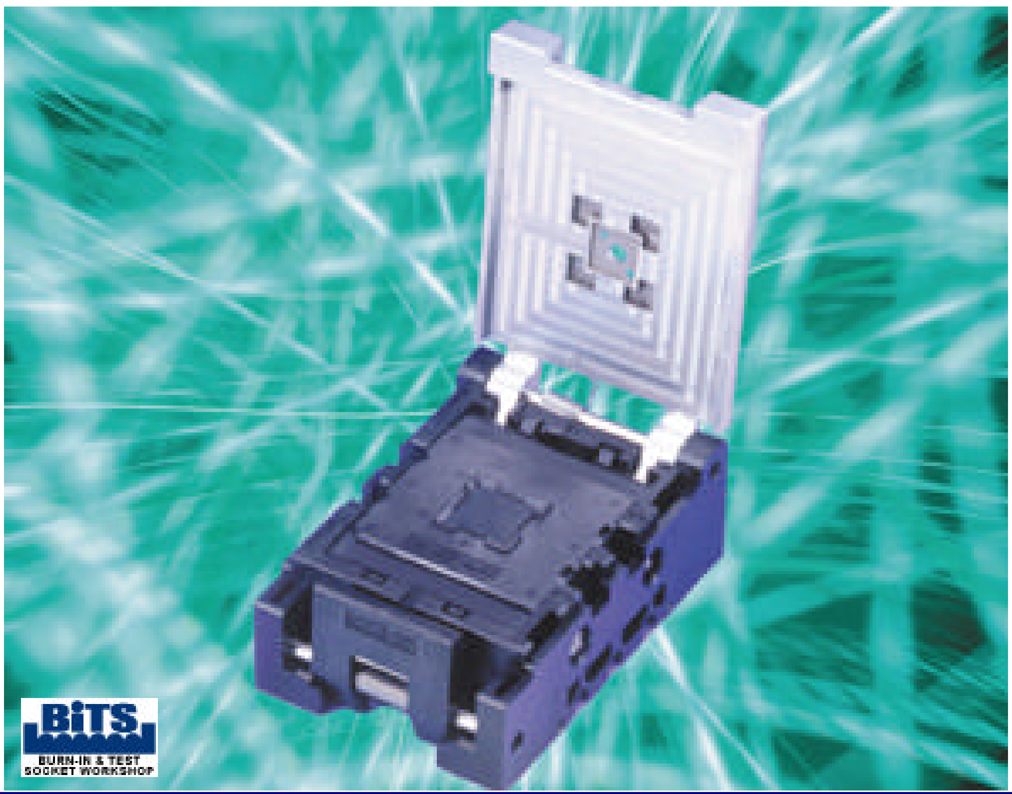
Load Package

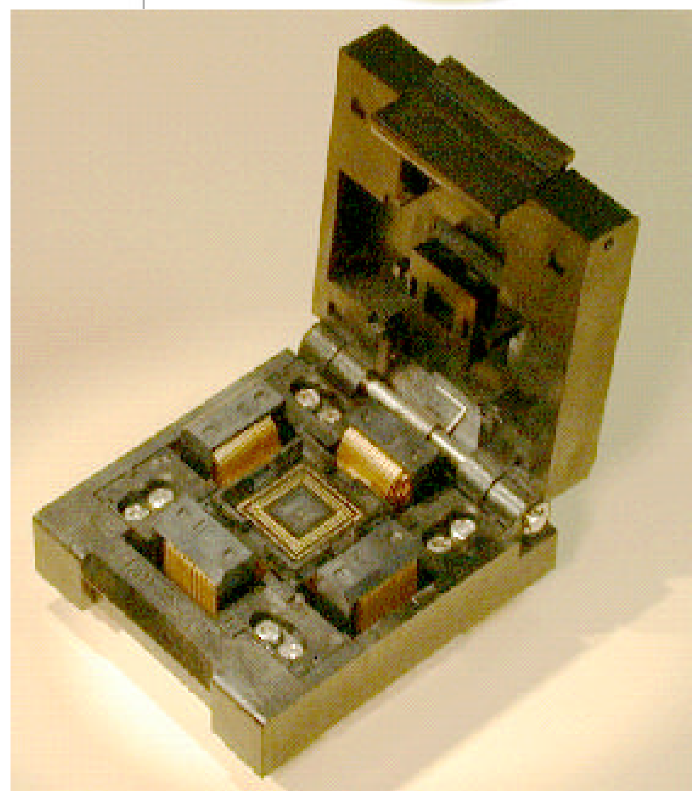


Contact Close

Bow Contact Socket
Stamped Contact Socket



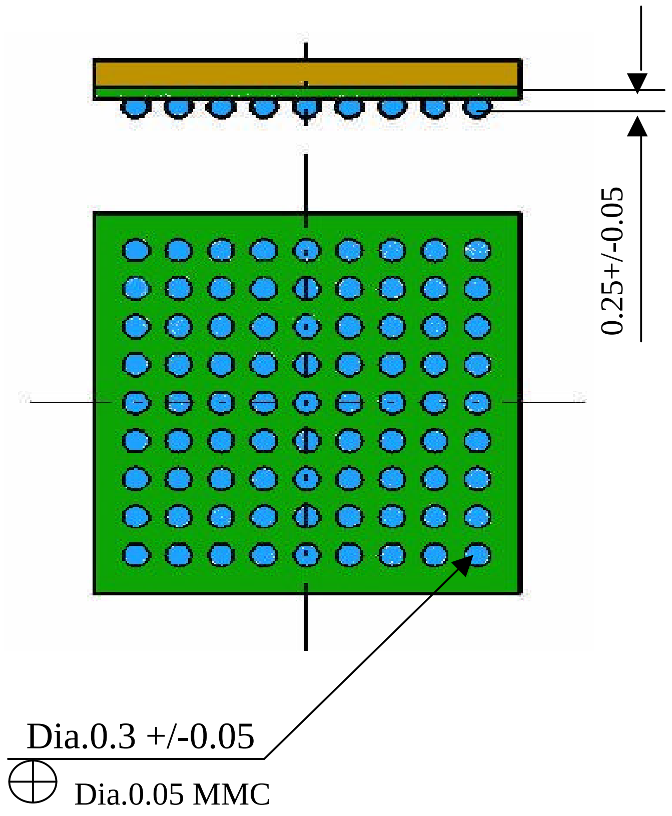


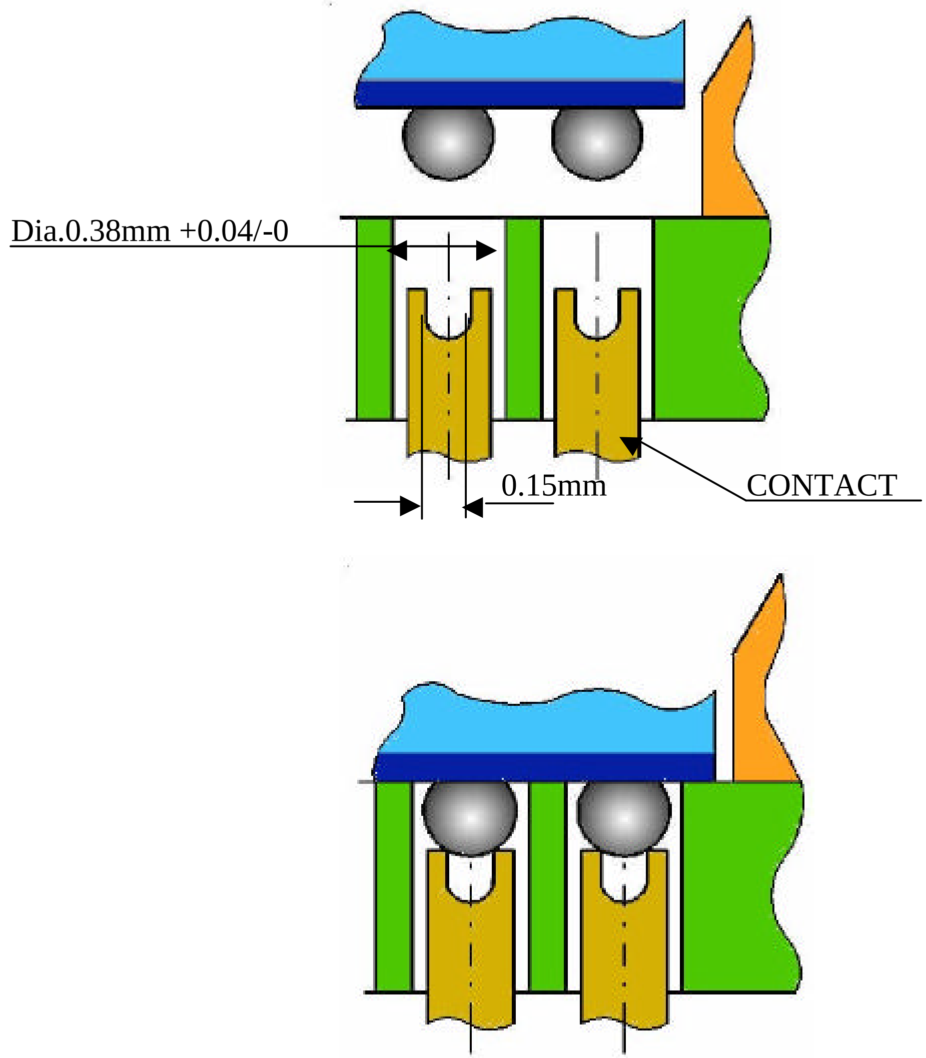


Considerations in the Development of Fine Pitch Burn-In Sockets

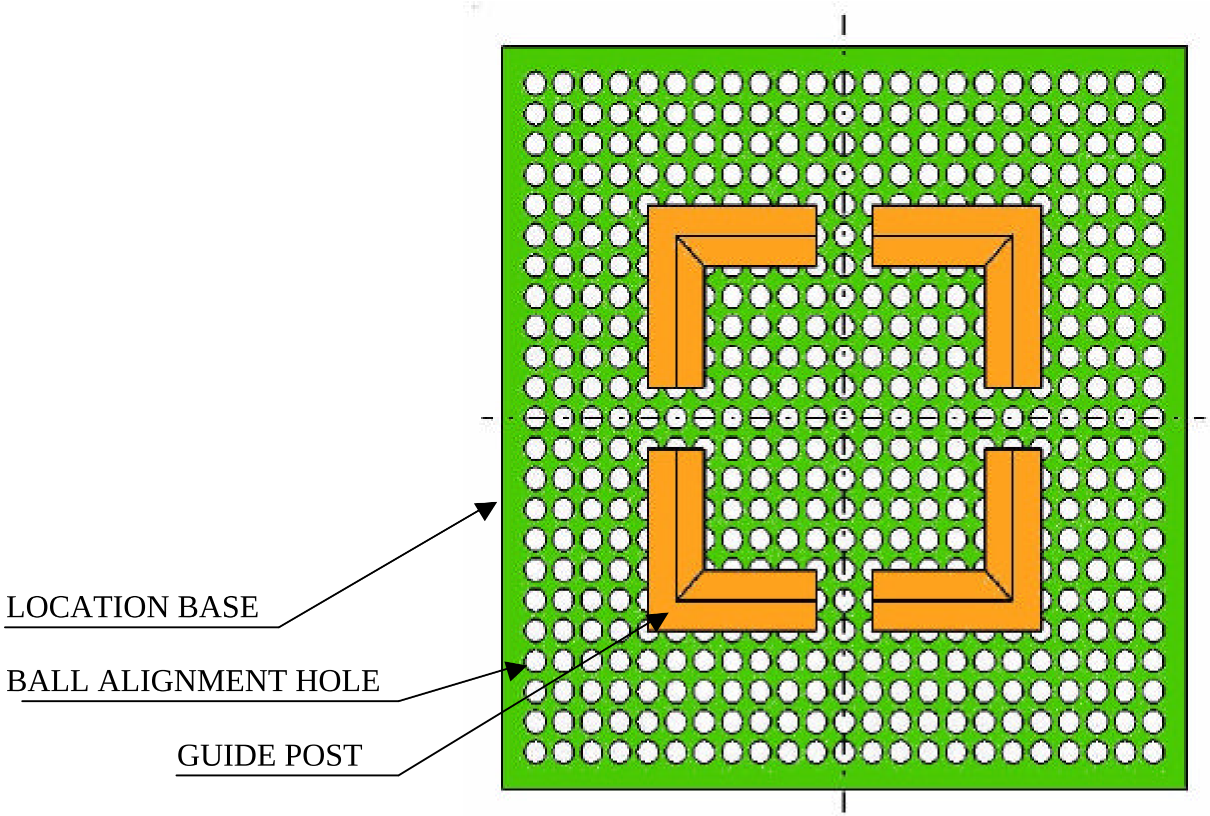
- **Creation of reliable alignment features between the ball and the socket contact.**
- **A contacting method that minimizes solder ball damage, despite various ball sizes and different solder ball alloy compositions.**
- **Stamping and molding techniques that will meet design constraints of very close contact-to-contact pitch.**
- **Considerations made for the printed wiring burn-in board design and socket assembly, such as socket size and fan out of contacts.**

Reliable alignment features between the ball and the socket contact.



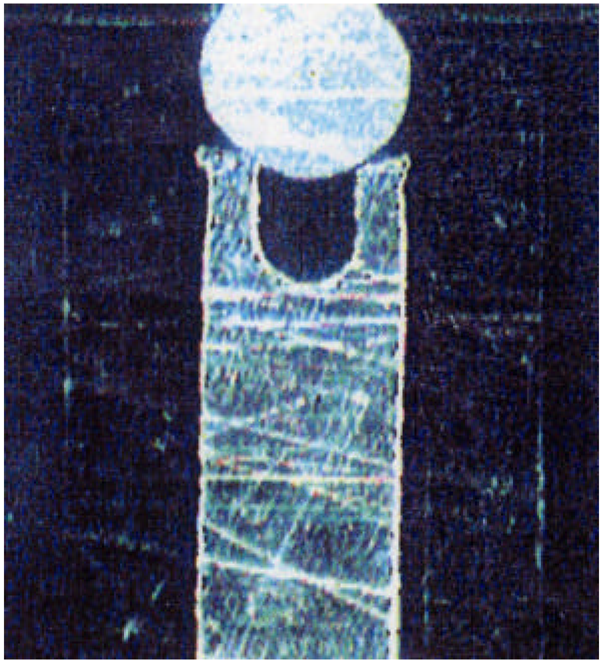


Replaceable guide frames to accommodate different package sizes.



Contacting method

Minimizes solder ball damage,
despite various ball sizes and different solder ball alloy compositions.



Contact force:100mN(10.2gF)/pin

Eutectic solder ball (diameter:0.3mm normal)

150deg2hr

150deg4hr

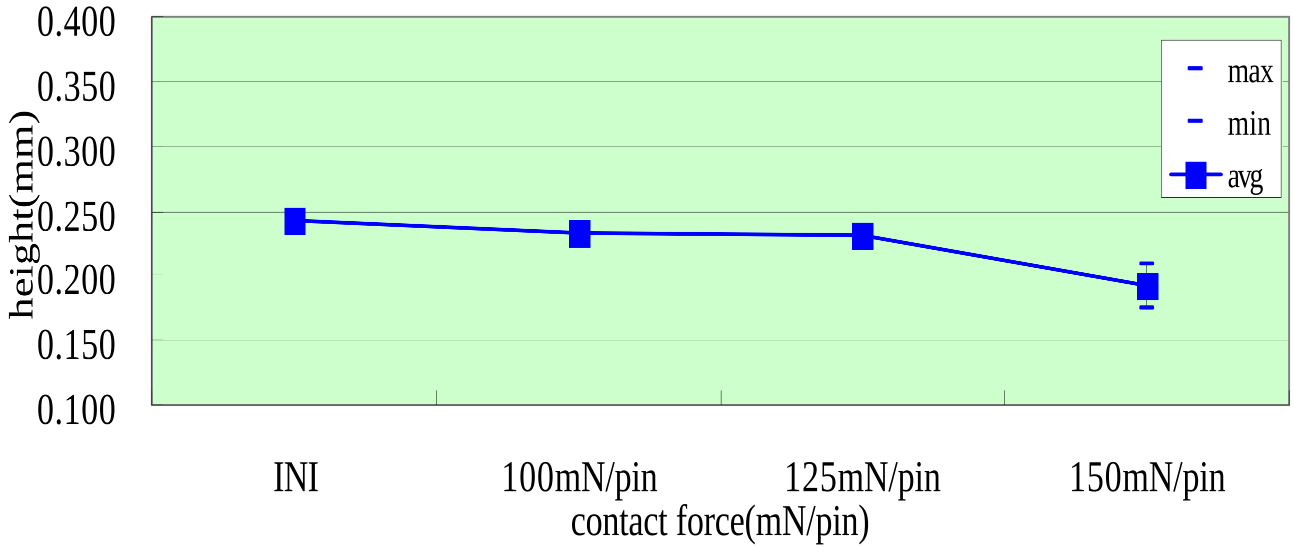
150deg8hr

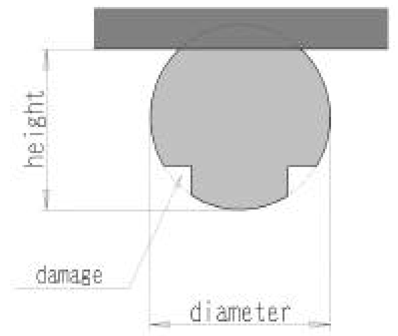
150deg24hr

Contact witness mark (bottom view)

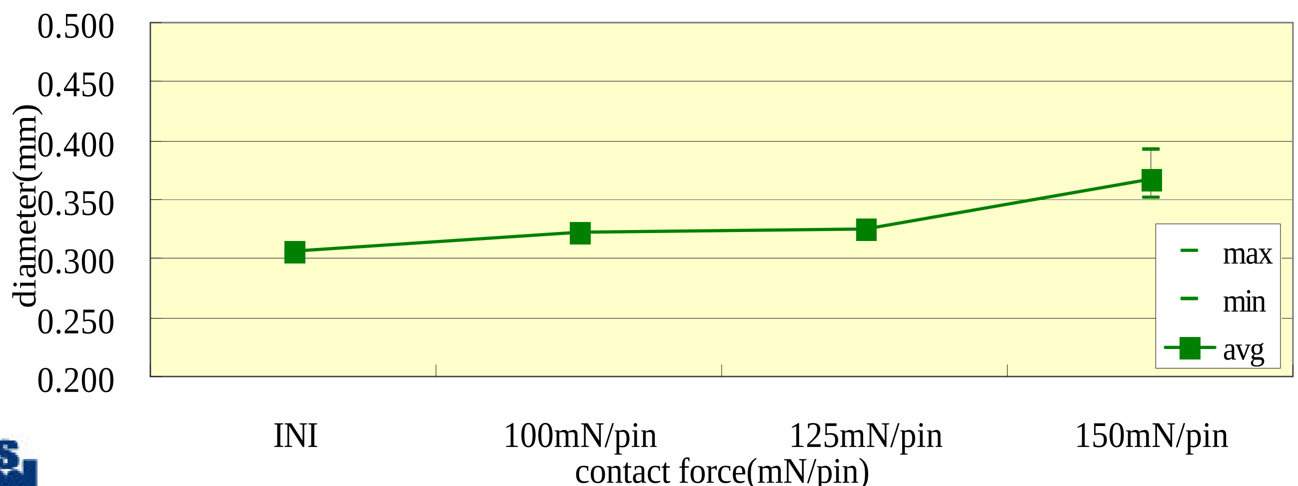
Contact Force vs. Ball Height / Diameter (Eutectic)

Contact Force - Ball Height





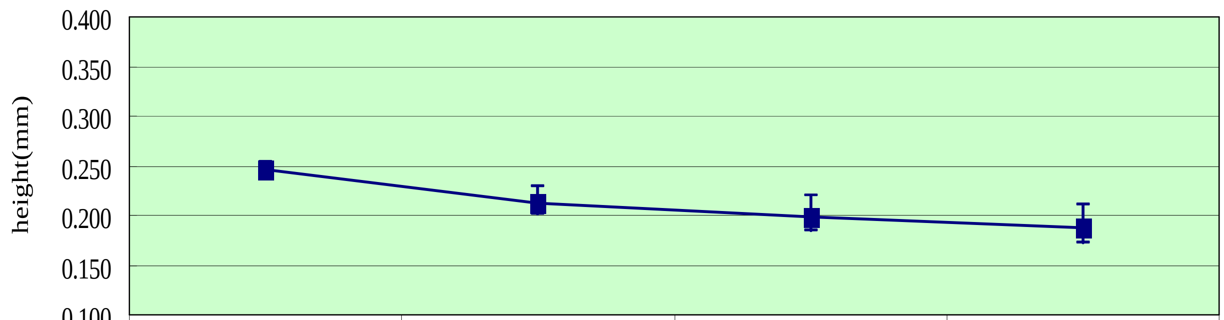
Contact Force - Ball Diameter



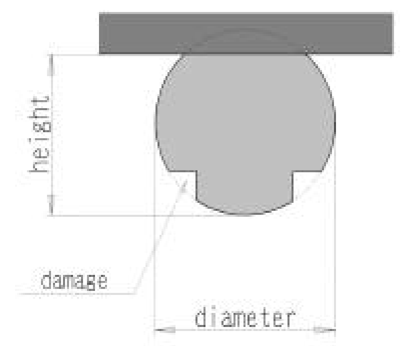
125 deg.C / 8 Hr
Eutectic Solder-ball

Temp. / Operation vs. Ball Height / Diameter (Eutectic)

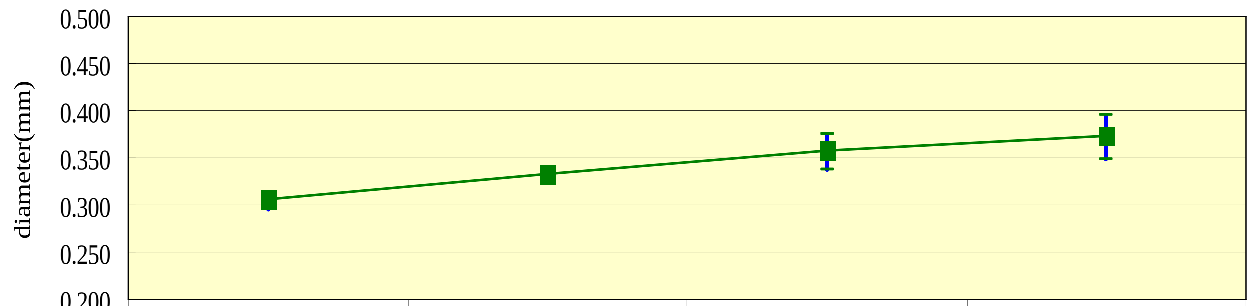
Solder-ball Height (eutectic)



	INI	eutectic solder 8hr	eutectic solder 16hr	eutectic solder 24hr
MAX	0.254	0.230	0.220	0.211
MIN	0.237	0.202	0.184	0.173
AVG	0.246	0.213	0.198	0.188



Solder-balls Diameter (eutectic)

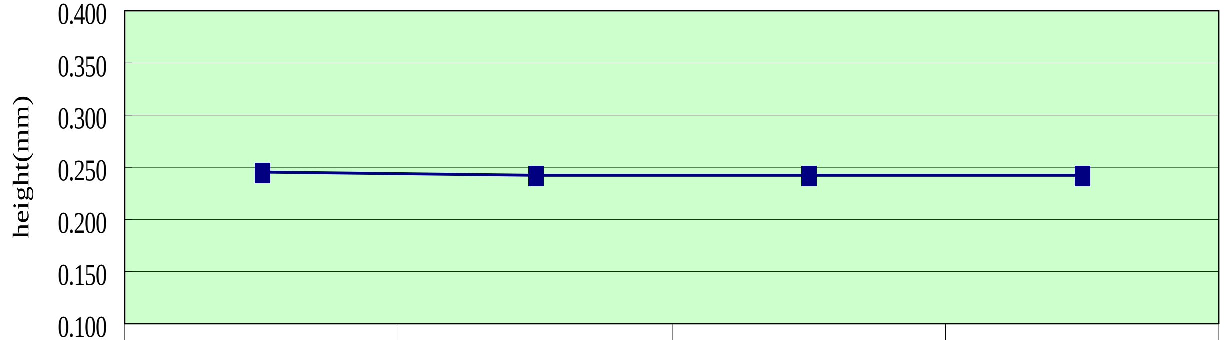


	INI	eutectic solder 8hr	eutectic solder 16hr	eutectic solder 24hr
MAX	0.313	0.339	0.375	0.396
MIN	0.296	0.323	0.337	0.348
AVG	0.306	0.333	0.358	0.374

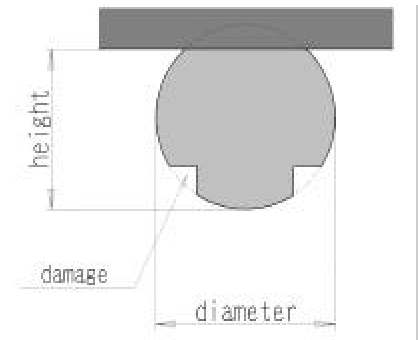
Contact Force 100mN/pin
140 deg.C / 8, 16, 24 Hr
100 times operation ea.
Eutectic Solder-ball

Temp. / Operation vs. Ball Height / Diameter (Hi-Melt)

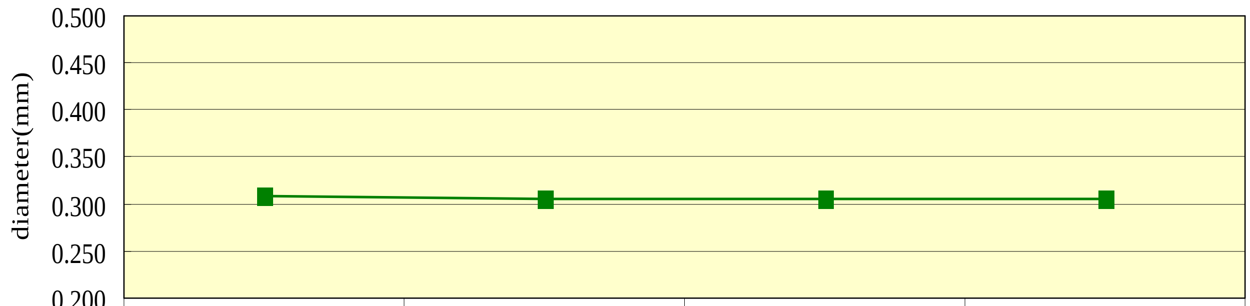
Solder-ball Height (hi-melt)



	INI	hi-melt solder 8hr	hi-melt solder 16hr	hi-melt solder 24hr
MAX	0.248	0.244	0.244	0.242
MIN	0.241	0.240	0.240	0.241
AVG	0.245	0.242	0.242	0.242



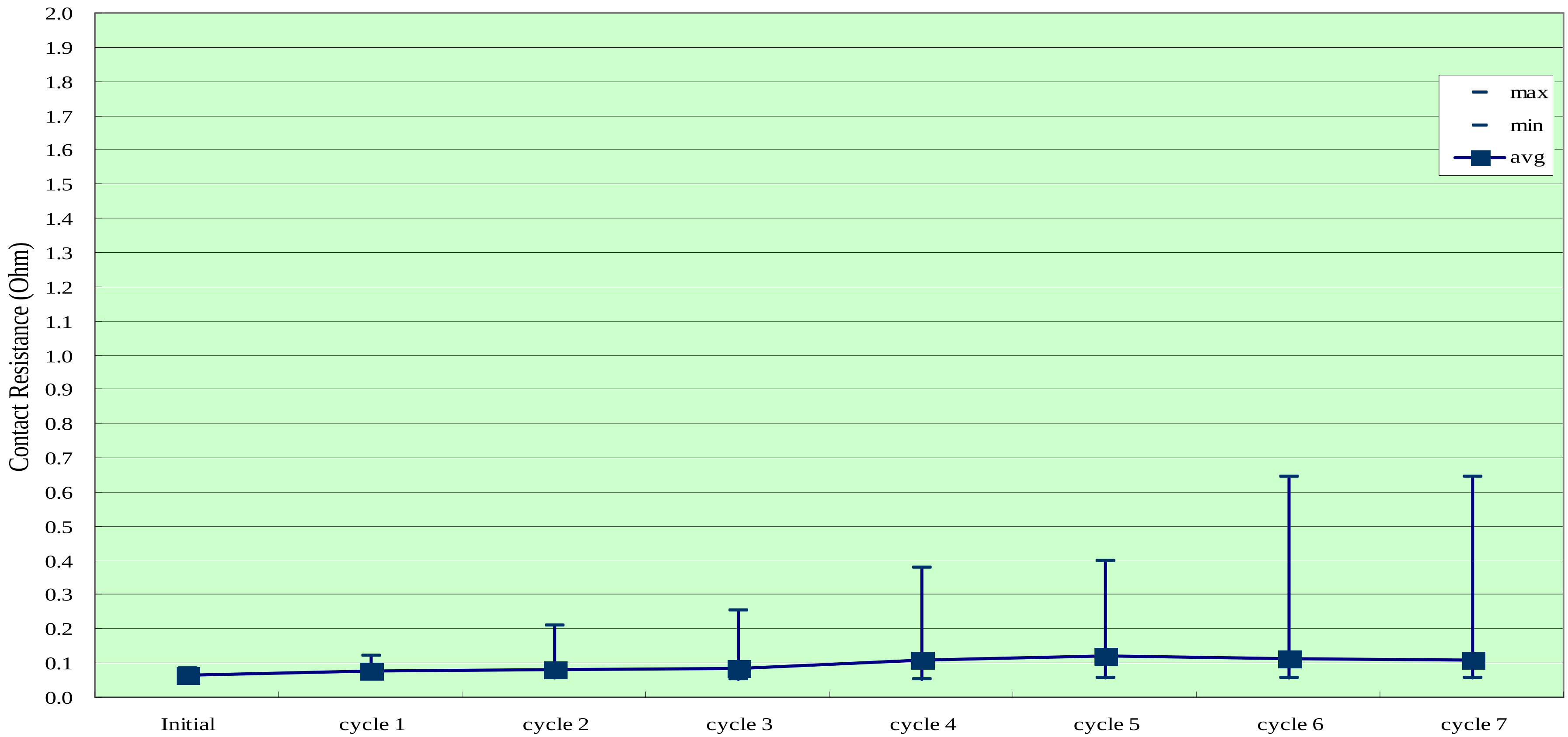
Solder-ball Diameter (hi-melt)



	INI	hi-melt solder 8hr	hi-melt solder 16hr	hi-melt solder 24hr
MAX	0.311	0.310	0.311	0.311
MIN	0.305	0.301	0.302	0.304
AVG	0.308	0.305	0.306	0.306

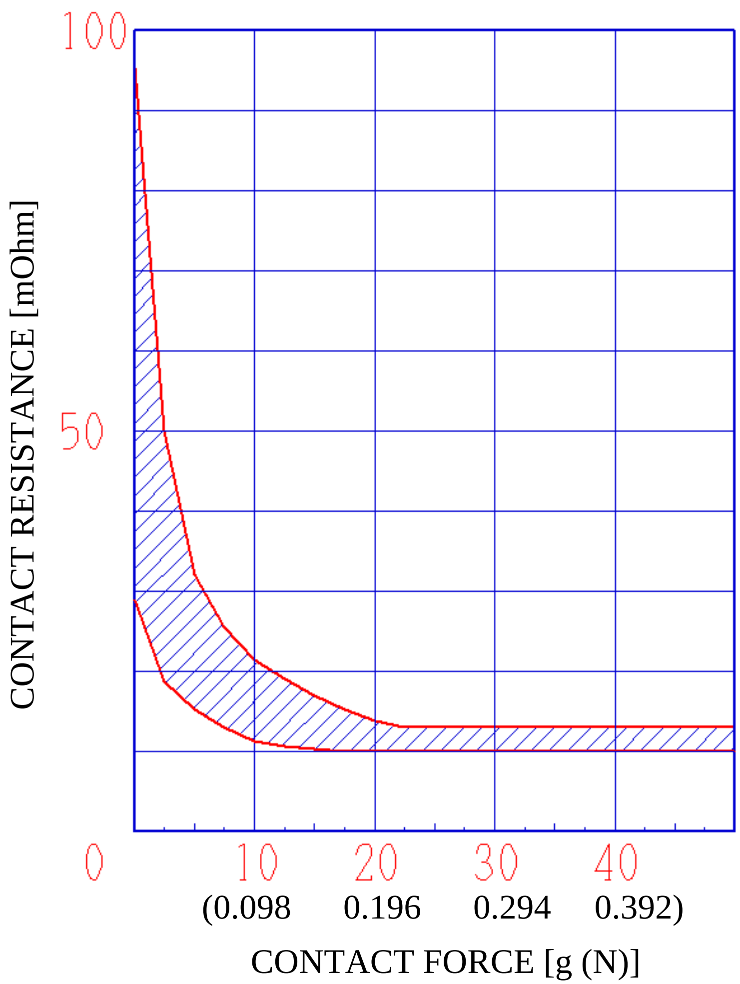
Contact Force 100mN/pin
140 deg.C / 8, 16, 24 Hr
100 times operation ea.
Eutectic Solder-ball

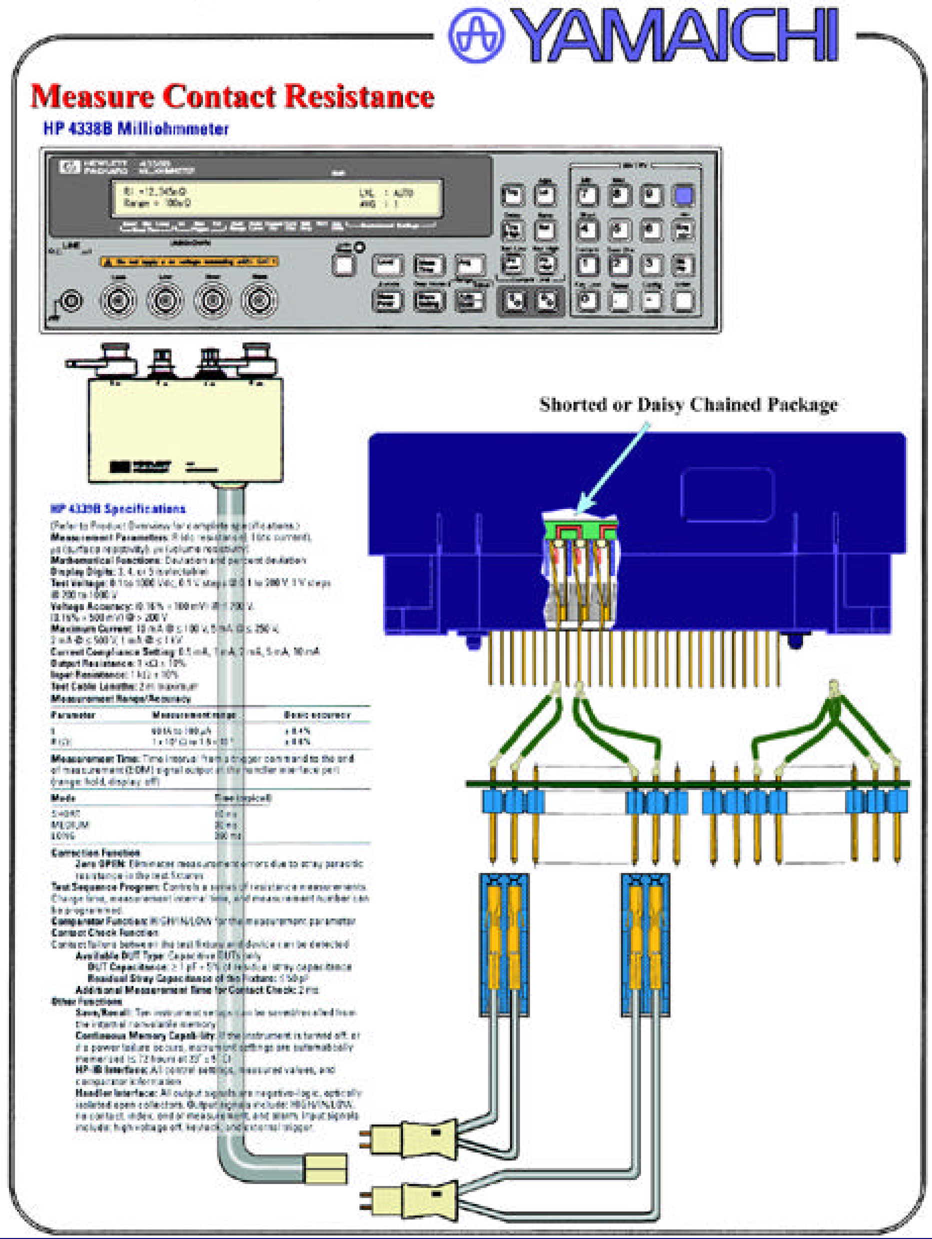
Temp. / Operation vs. Contact Resistance (Eutectic)



Note: contact tip to contact tip resistance
contact force : 100mN/pin
1 cycle: 150 deg.C 8 Hr
100times Operation
Eutectic Solder-ball

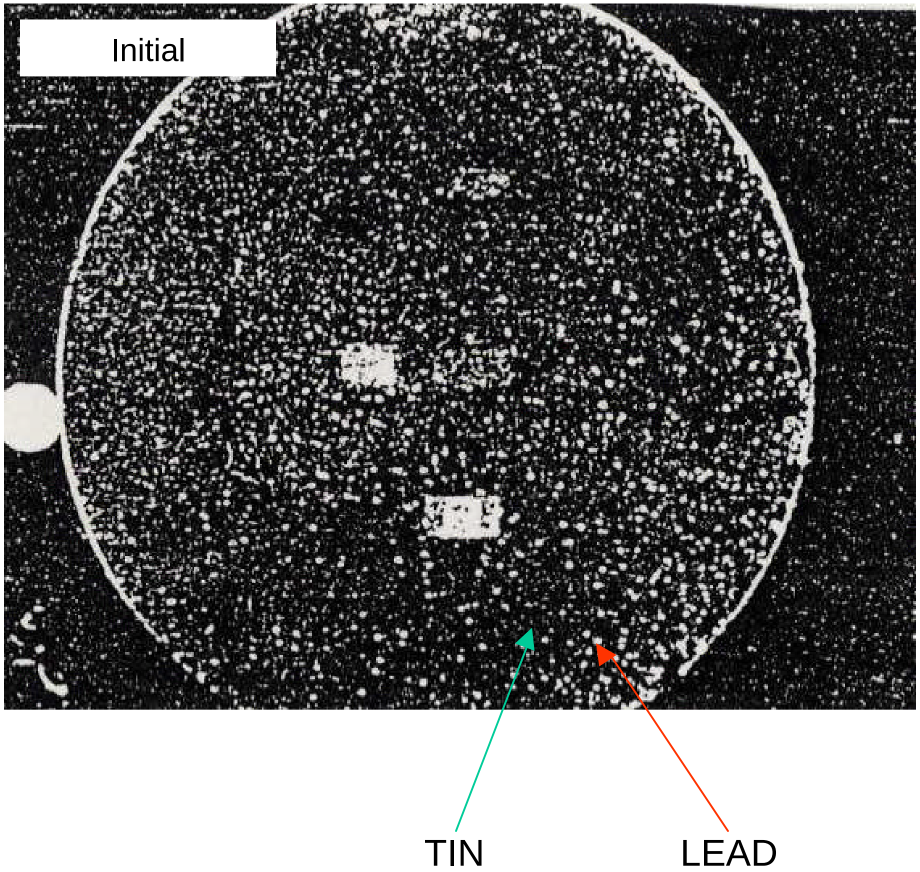
Contact Force vs. Contact Resistance (Eutectic)

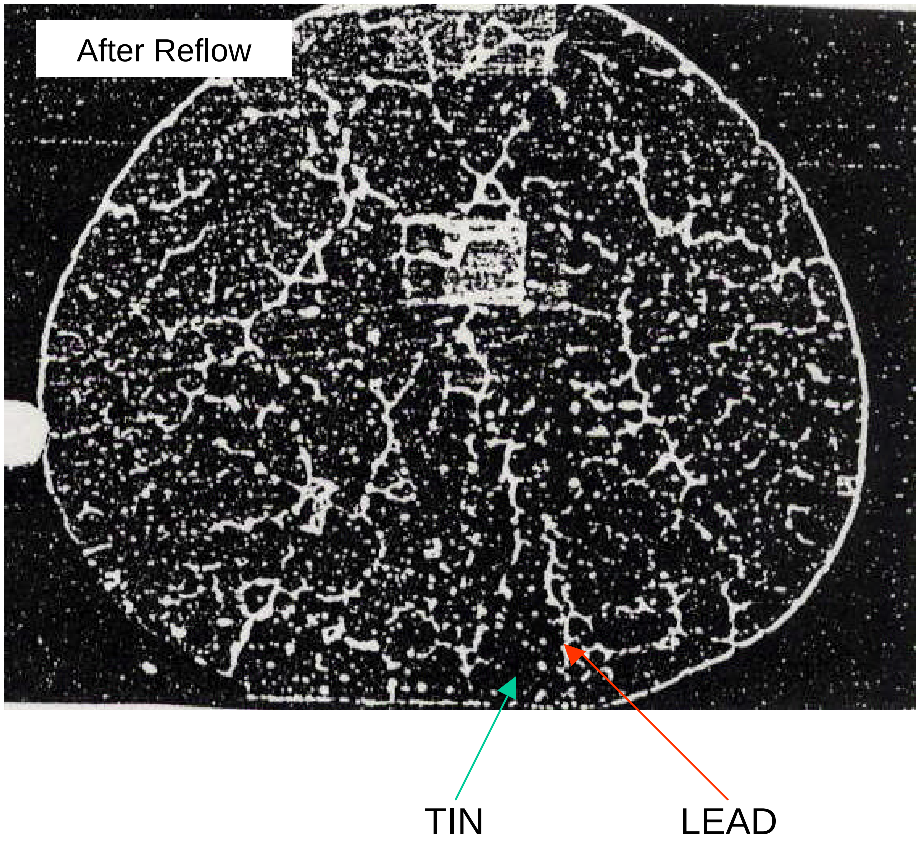




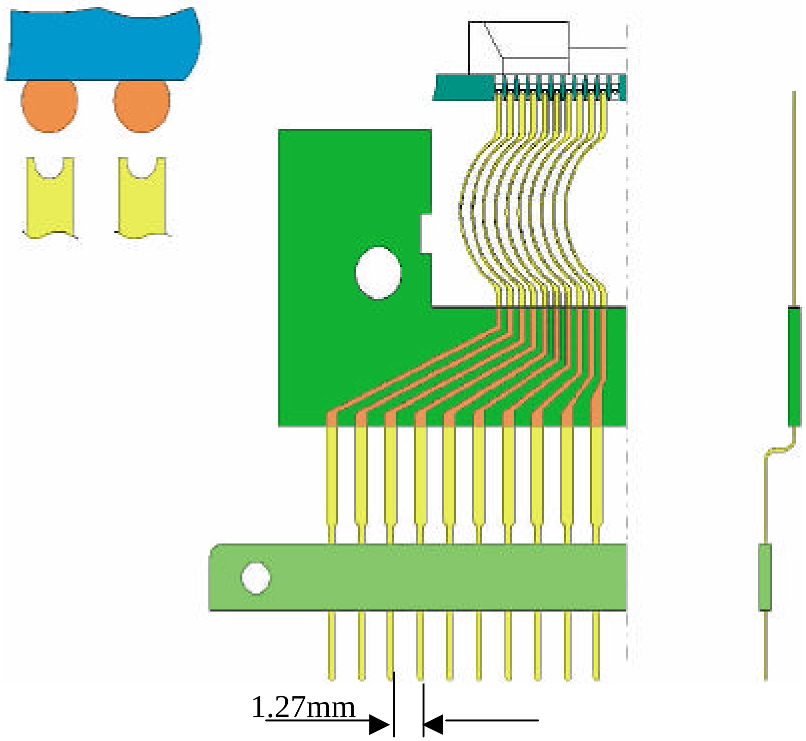
Section of Solder Ball

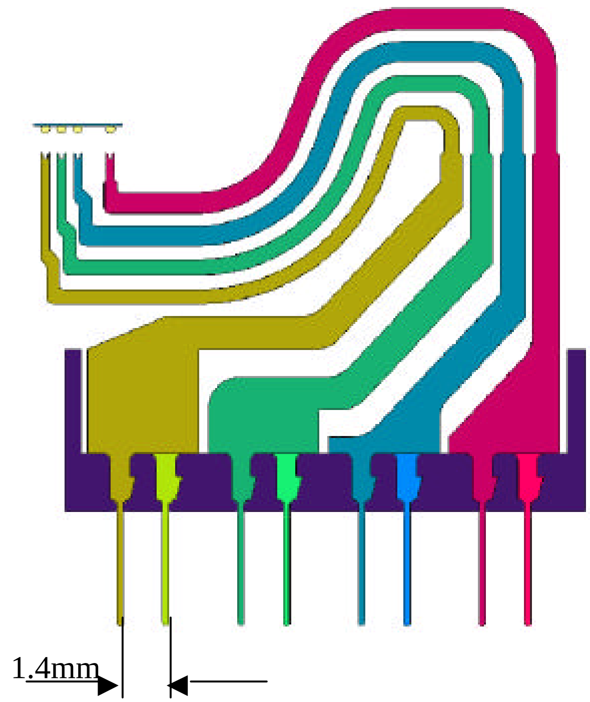
SEM





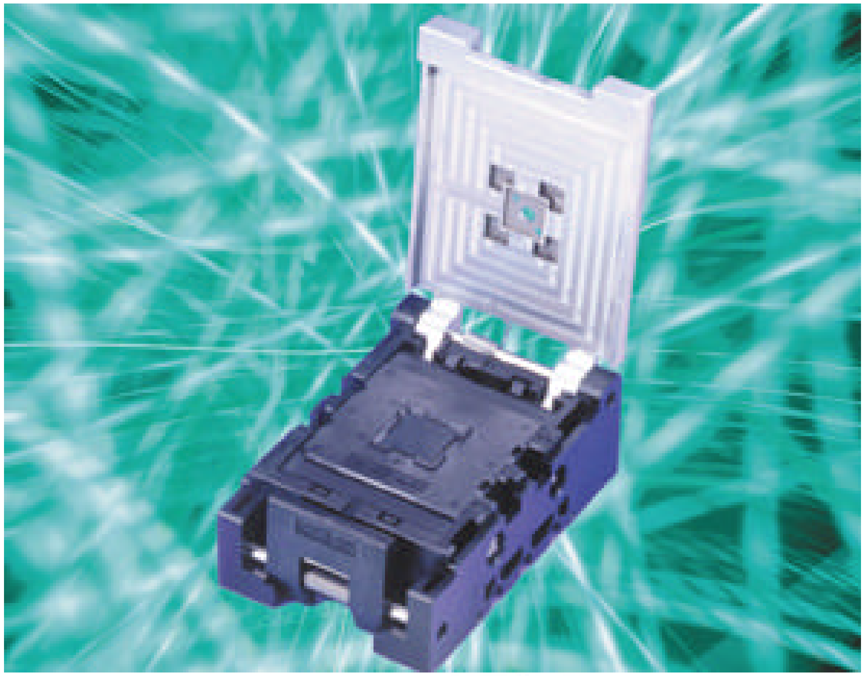
Stamping and molding techniques that will meet design constraints of very close contact-to-contact pitch.

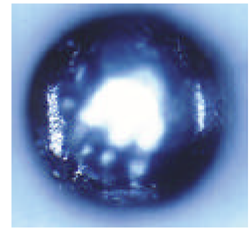


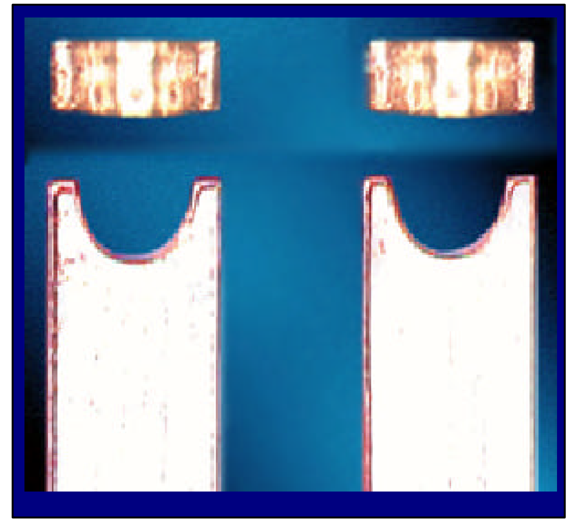


Considerations made for the printed wiring burn-in board design and socket assembly, such as socket size and fan out of contacts.

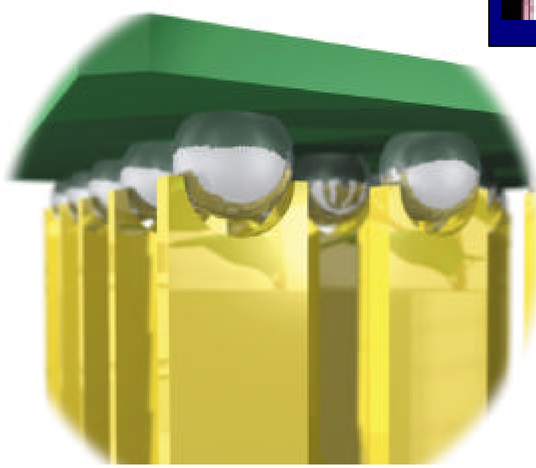
Bow Contact Clam Shell Socket 0.5mm Pitch





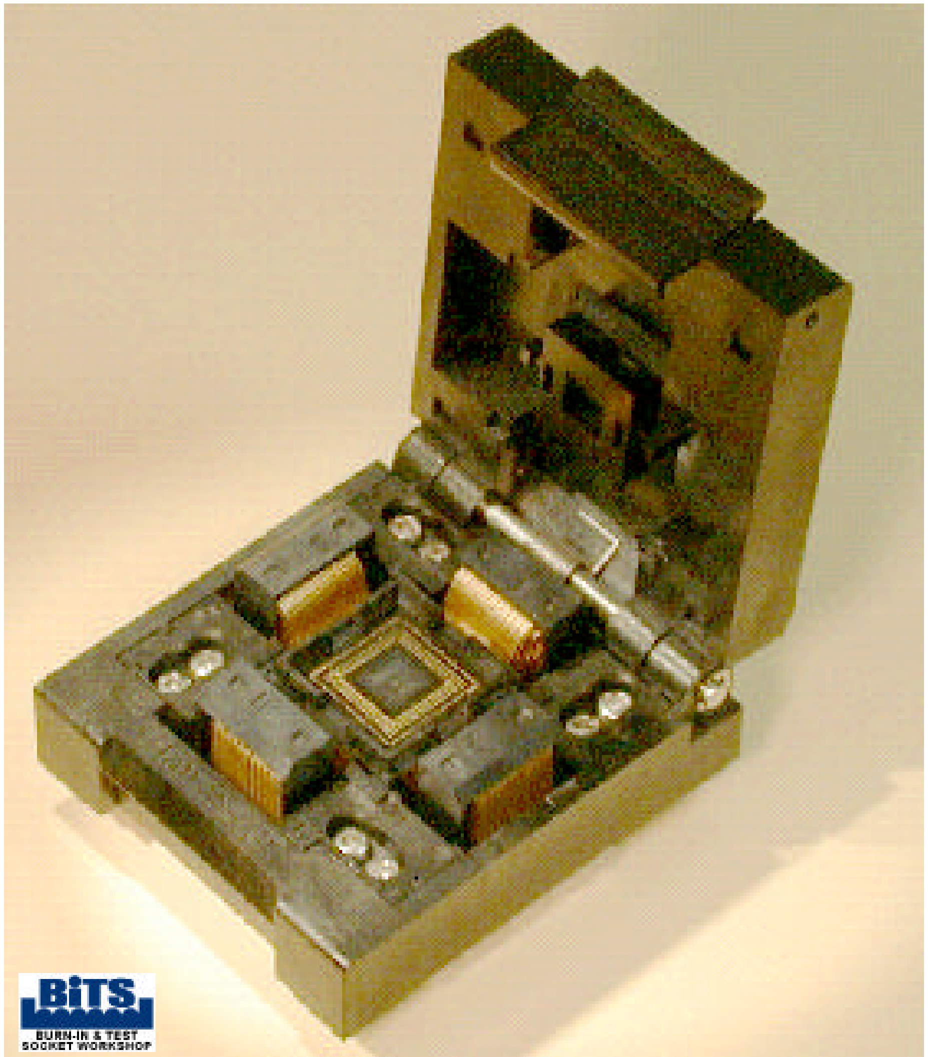


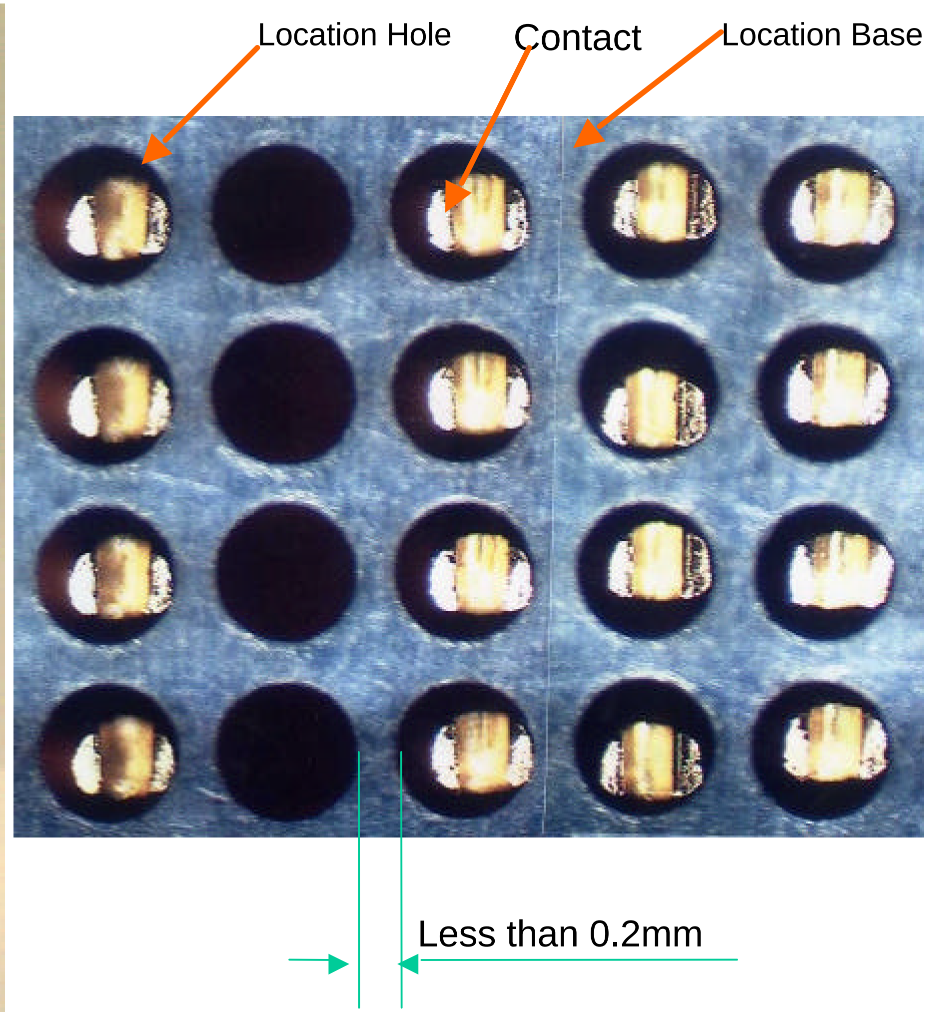
Open Lid for Package Loading



Close Lid to Connect

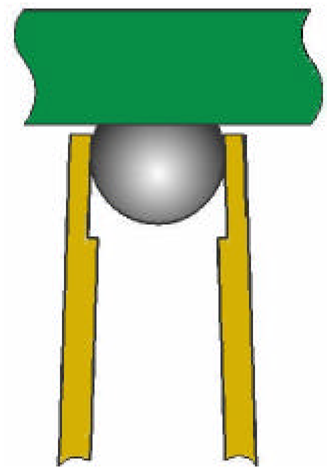
Stamped Contact Clam Shell Socket 0.5mm Pitch



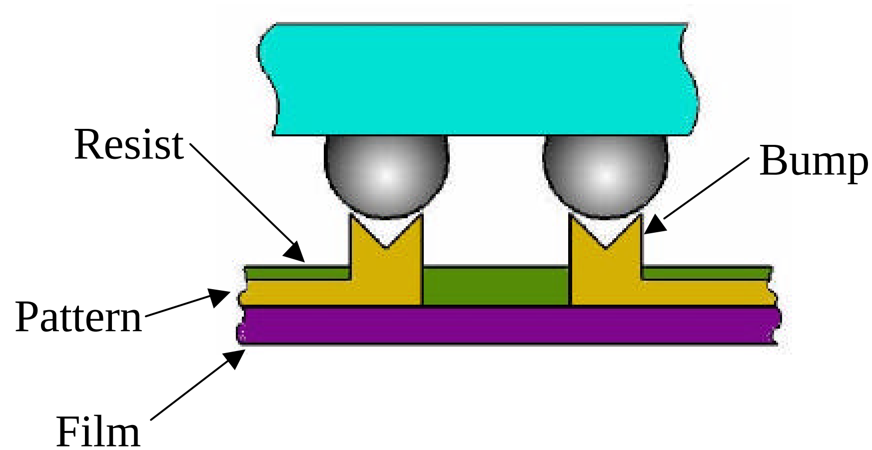


Future Fine Pitch Socket Technology

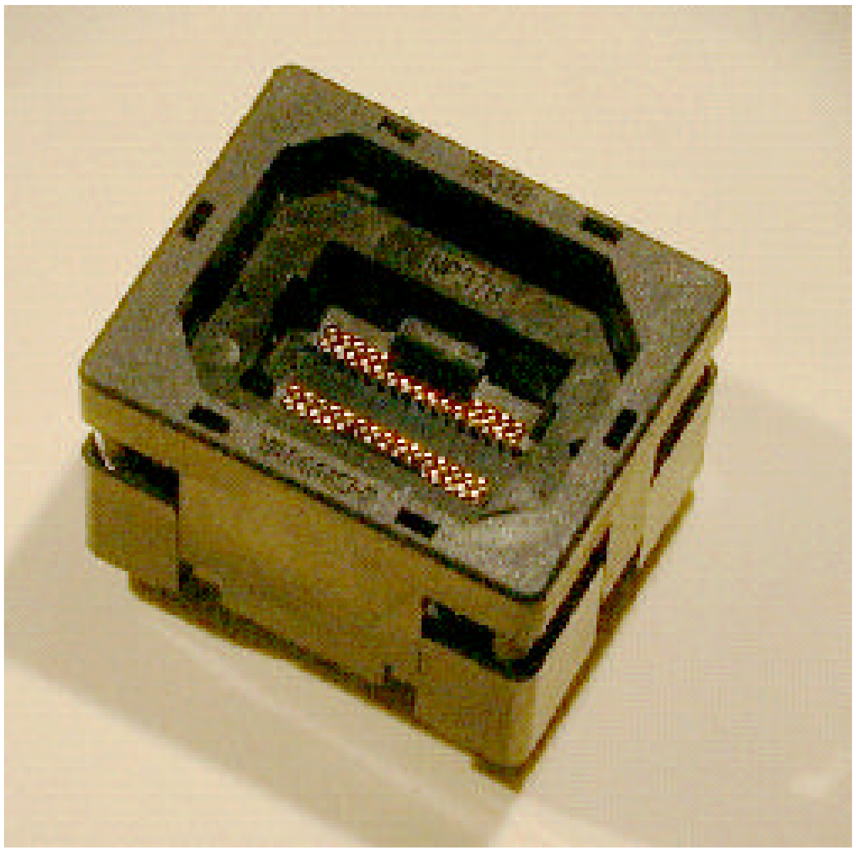
Tweezer Type Contact
(Alternative for 0.5 mm pitch CSP)



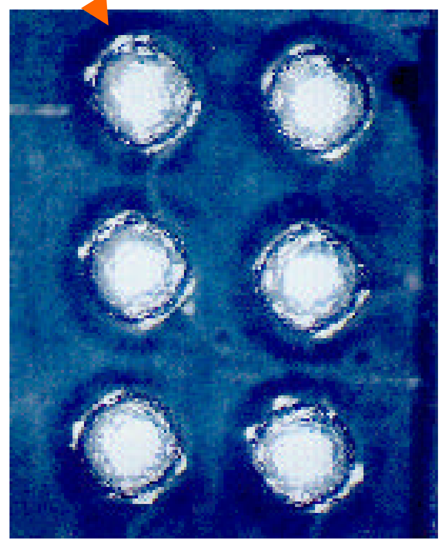
Contact Sheet Technology
(for Flip Chip Application)



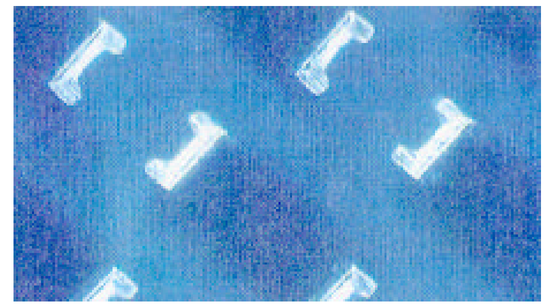
Open Top Tweezer type Contact Socket 0.5mm P



Contact Mark



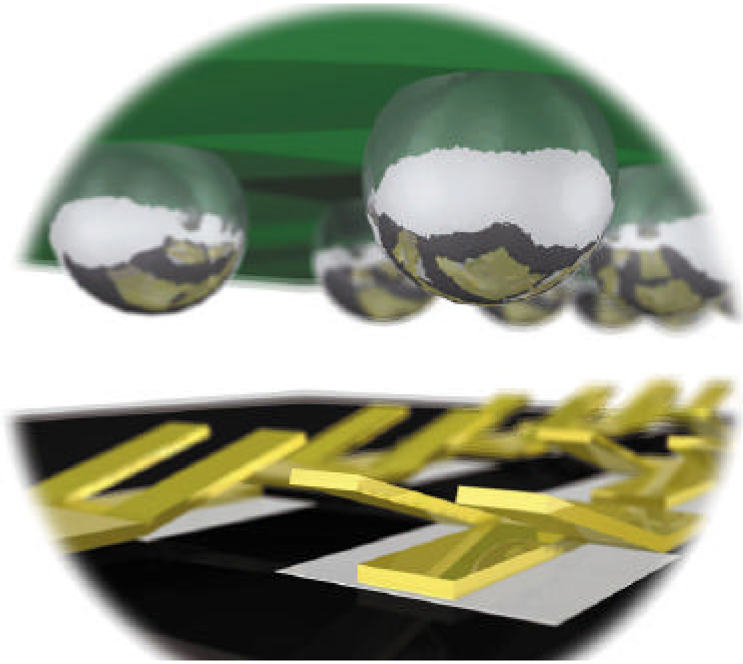
Contact



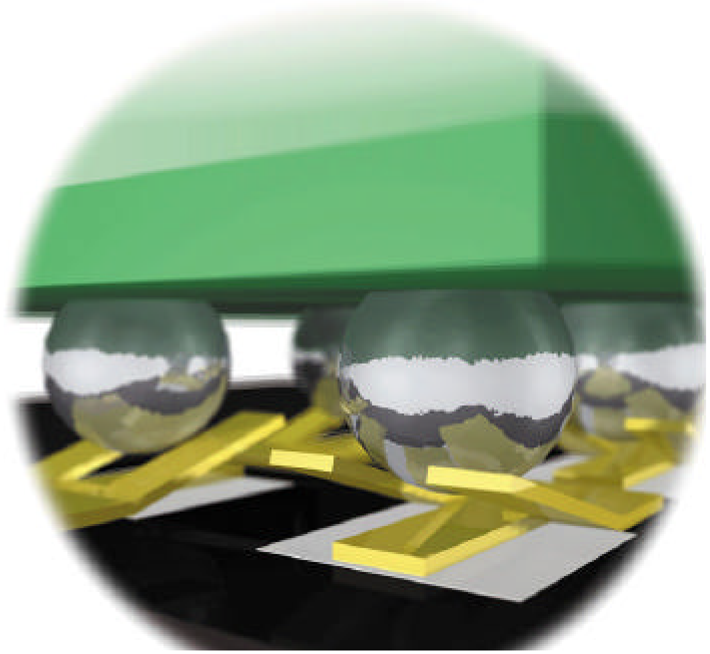
Top View

Side View

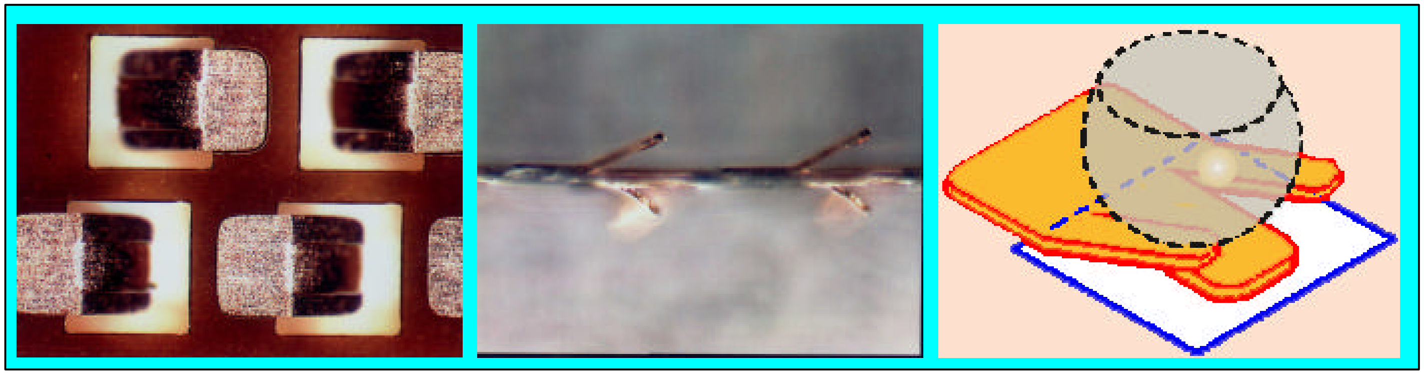
Contact Sheet type Socket 0.5mm P



Open Lid for Package Loading



Close Lid to Connect

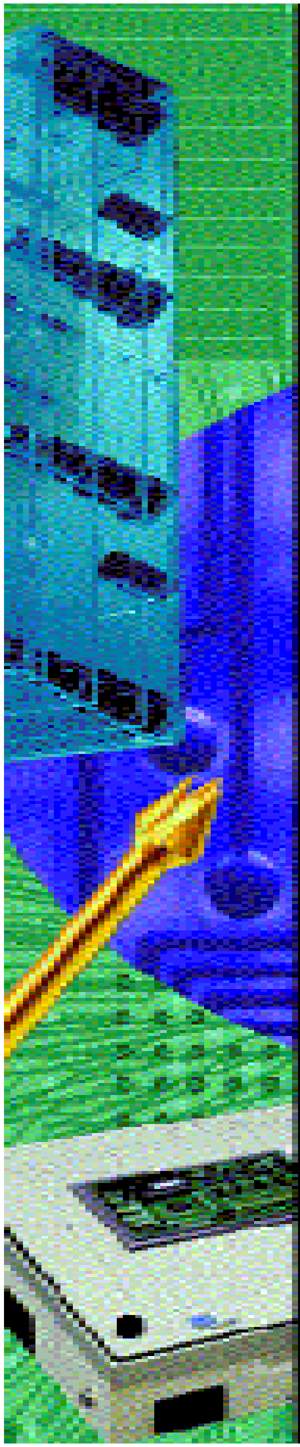


Conclusion

During the developmental stage of FBGA / CSP burn-in sockets, a number of obstacles were raised.

However, cost and manufacturing capability to meet high volume demand for this continuously narrowing pitch trend is still an issue that needs to be addressed.

The challenge was addressed and we came up with several innovative approaches and solutions.



ECT

EVERETT CHARLES TECHNOLOGIES

Testing the Limits

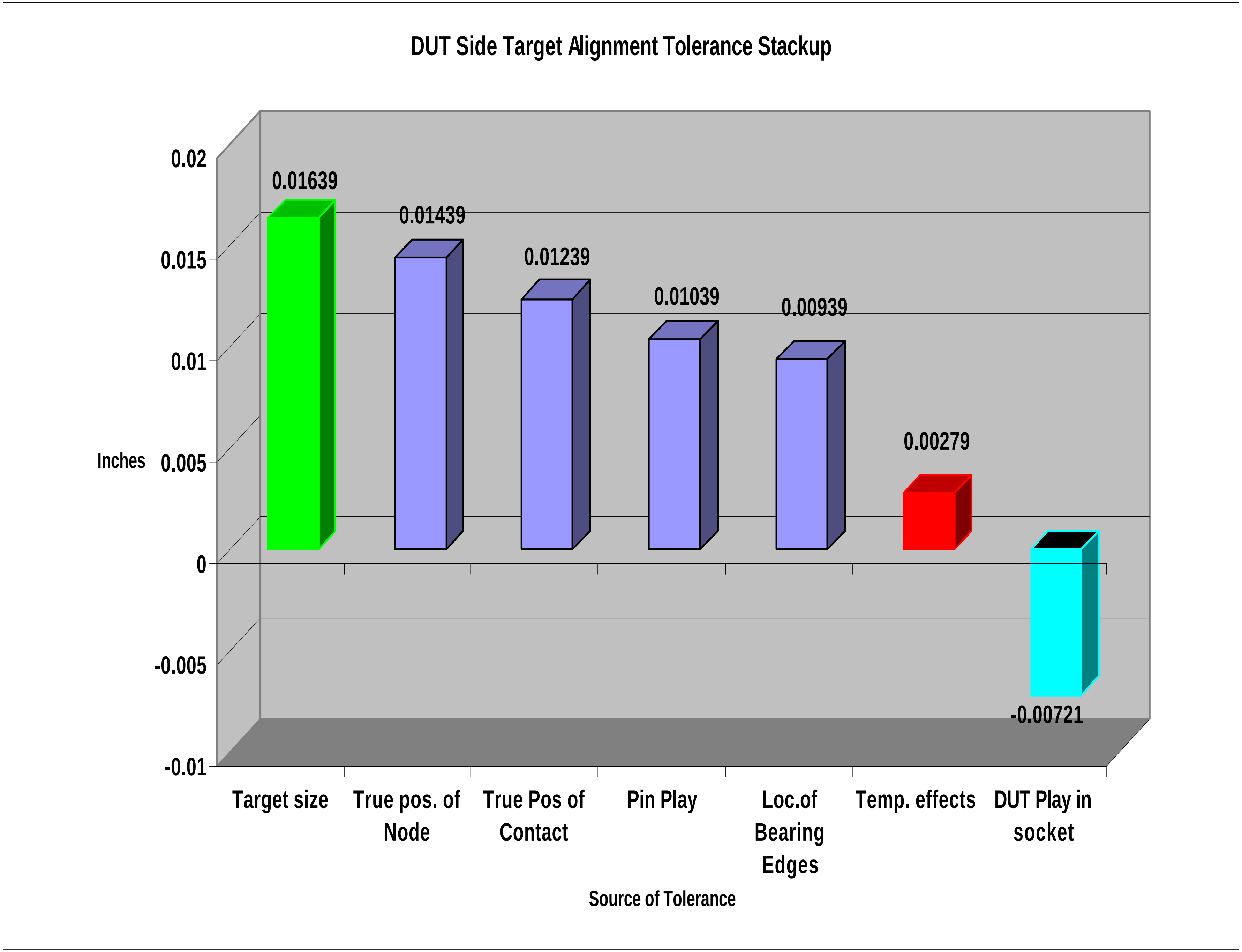
A Closed Loop Geometric Tolerance Socket Design Process for Area Array IC Packages

By: GORDON A. VINTHER

1/29/2000

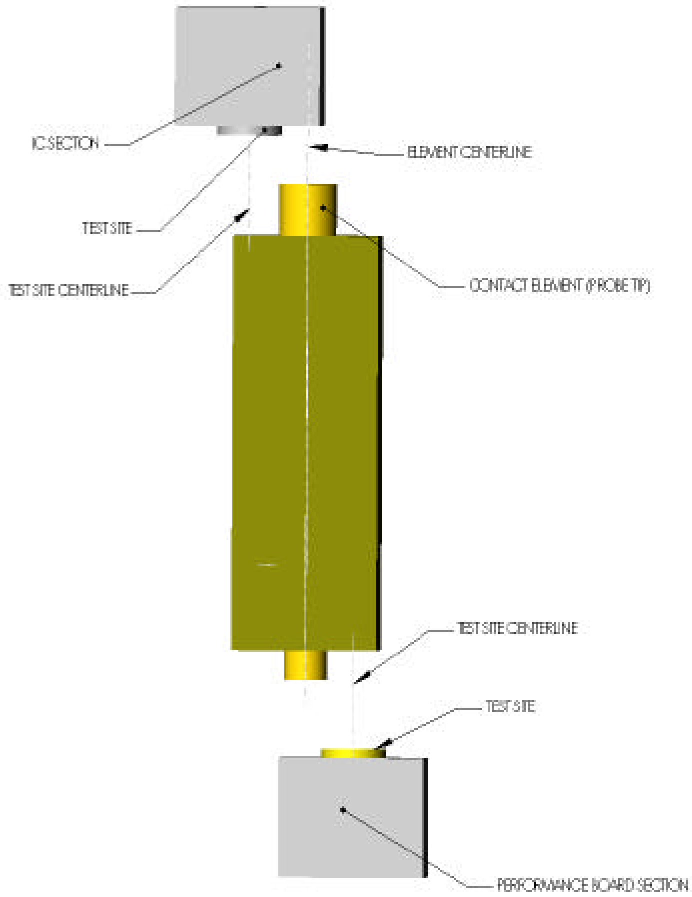
A Closed Loop Geometric Tolerance Socket Design Process for Area Array IC Packages

- New area array IC's with higher point counts and tighter pitch require systematic design methodology
- Various IC footprints including BGA, LGA have different alignment characteristics that must be individually addressed
- Each variable in system must be clearly defined, understood and quantified for accurate alignment


DUT Side Target Alignment Tolerance Stackup
0.02
0.015
0.01
0.005
0
-0.005
-0.01
Inches
0.01639
0.01439
0.01239
0.01039
0.00939
0.00279
-0.00721
Target size
True pos. of Node
True Pos of Contact
Pin Play
Loc.of Bearing Edges
Temp. effects
DUT Play in socket
Source of Tolerance

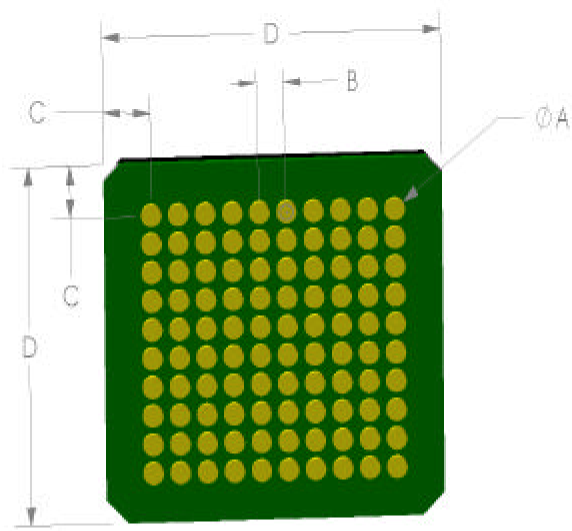
Performance Board to DUT alignment calculation

- Worst case is IC test target to one side and Performance board test target to opposite side
- Limit of contact is when distance between centerlines of test target and contact element exceeds the sum of radii of the two all variation included



DUT variables
that affect alignment of a test socket

- Test target size “A”
- Test target to test target tolerance “B”
- Test target to DUT edge “C”
- DUT perimeter “D”
- Coplanarity of test target

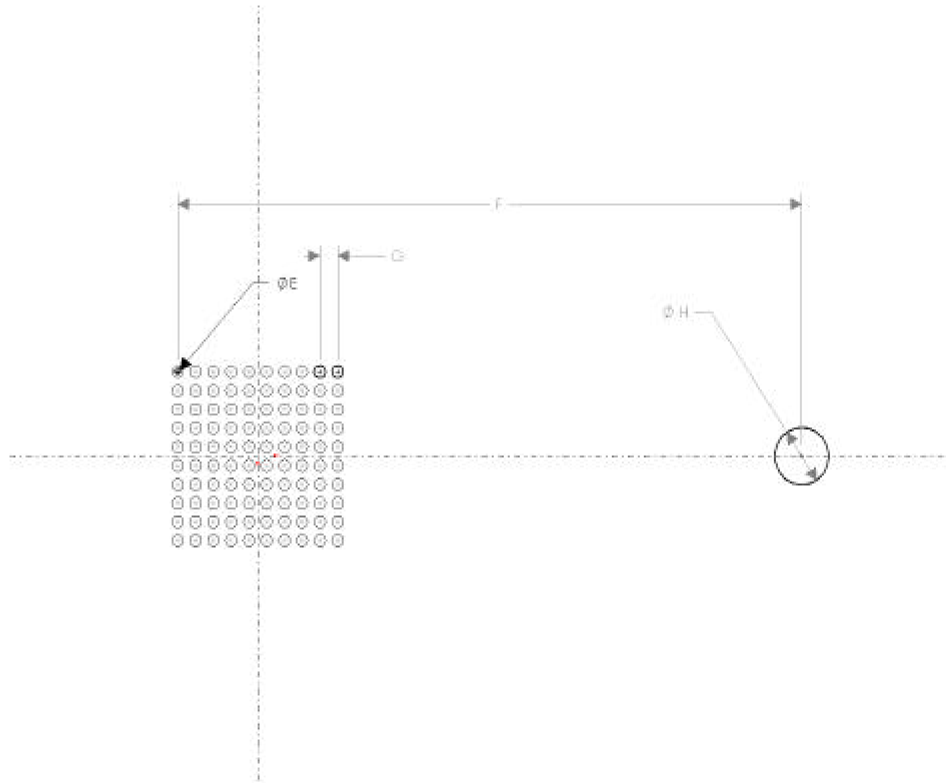


DUT analysis portion of analysis spreadsheet

DUT Variability	MAXIMUM	MINIMUM
DUT side hole Size in Socket	0.023	0.0215
DUT Side Plunger diameter	0.02	0.019
DUT Land/Ball off center (True Position) "B/C"	0.004	0
DUT Perimeter tolerance X-Axis "D"	1.38	1.375
DUT Perimeter tolerance Y-Axis (if diff)		
Socket Cavity for DUT X-Axis	1.385	1.382
Socket Cavity for DUT Y-Axis (if diff)		
DUT Land/Ball size "A"	0.037	0.025
DUT Side Hole Shift (True Position)	0.004	0
DUT Side Pin Slop	0.002	0.00075
Socket Bearing Edges Location (true position)	0.001	0
Base Thickness	0.086	0.084
Base C-Bore Depth	0.074	0.073
Base C-Bore Diameter	0.035	0.034
End body diameter of plunger (Flange Dia)	0.03	0.029
45 degree chamfer size on flange	0.003	0.002
Extension Length due to drill point	0.0048069	0.004206024
Plunger tip length	0.041	0.039
Dist. Plunger tip sticks out with HIB pad flush with bottom	0.0358069	0.030206024

Performance board variables that affect alignment of a test socket

- Pad or land size and shape “E”
- Pad true position with respect to tooling “F” or Pad to pad true position “G”
- Tooling hole size “H”
- Pad to pad coplanarity



Performance board alignment analysis portion of spreadsheet

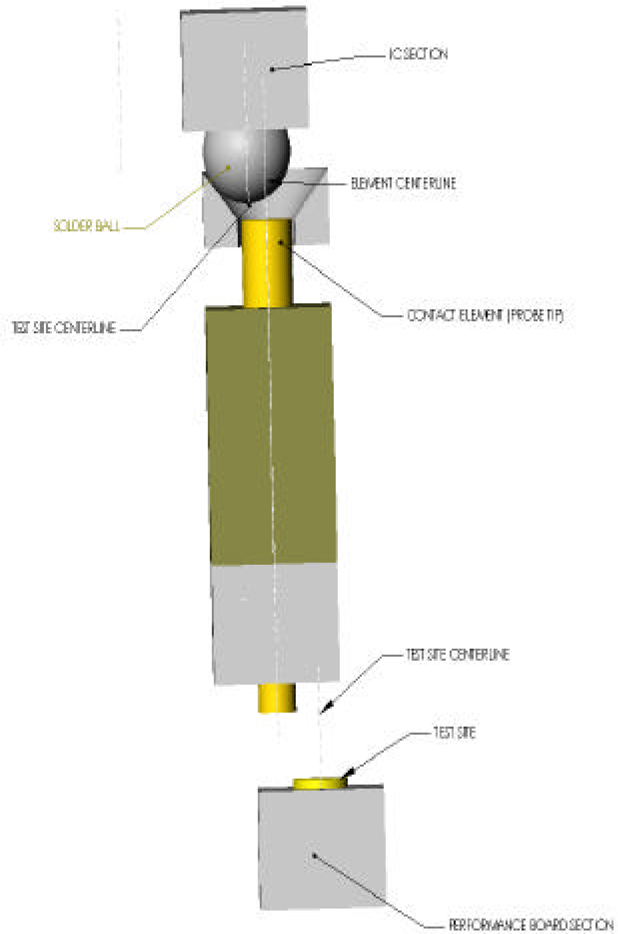
HIB Variability		
HIB Side Hole Size in Socket	0.019	0.017
Barrel (Terminal) Contact Diameter	0.0155	0.0145
HIB Side Hole Shift (true position)	0.004	0
HIB Pad Shift (True Position) "F" or "G"	0.004	0
HIB Pad Size "E"	0.028	0.026
HIB Side Pin Slop	0.00225	0.00075
Retainer C-Bore Depth	0.03	0.029
Retainer C-Bore Diameter	0.034	0.033
Retainer thickness	0.041	0.039
End body diameter of terminal	0.03	0.0295
45 degree chamfer size on flange	0.003	0.002
Extension Length due to drill point	0.0023189	0.001545934
Terminal tip length	0.026	0.024
Dist. Terminal tip can stick out retainer bottom (reach)	0.0193189	0.014

Other factors affecting socket system

System Data	MAXIMUM	MINIMUM
Interposer thickness	0.026	0.024
total stack hieght of contactor x-section	0.153	0.147
45 degree counterbore in interposer dia	0.049	0.047
Distance ball seats within interposer (within C-Bore)	0.0193223	0.015837049
Probe Free Length	0.168	0.16
Preload on HIB (terminal flush with retainer (inches)	0.012794	-0.00080688
Preload on HIB (terminal flush with retainer (ounces)	0.6785361	
Compression on DUT (no probe reach for HIB pad)	0.0242347	0.01368986
Solder mask thickness	0.005	0
Amount ball goes subflush to 108deg crown tip	0.0068945	0.006353213
Full compression of Probe (inches)	**0.1340309**	**0.14405747**
Note: Probe should not be compressed more than .136"		
Socket Base Material used	Torlon 4203	
Material Coefficent of thermal expansion in.in/degree F	0.000017	
Socket operating Temperatures	212	0
Growth due to temp. change per linear inch	0.002414	0.00119
Distance between tooling pis on socket	1.925	1.925
Total Growth of socketing system	0.0023235	0.001145375
Note: Thermal expansion calcs based on socket being		
manufactured at 70 degrees F (ambient temperature)		

BGA alignment

- With BGA, DUT perimeter to test site tolerance is eliminated because DUT is registered to test site not DUT perimeter



Final synopsis of data

HIB Side Analysis		
Engagement Less socket play	0.0198546	0.011926525
Tooling pin diameter	0.094	0.09375
Tooling hole diameter in HIB "H"	**0.098**	**0.094**
Socket Play on HIB (tooling pin slop)	0.00425	0
Engagement with cylinder tip	0.0198546	0.007676525
Plunger to HIB pad engagement with single point tip	**0.0121046**	**0.000426525**
Note: Must be greater than .00 to hit with B tip		
DUT Side Analysis		
Engagement of two cyclinders less DUT play in socket	0.0266046	0.013676525
Dut play in socket cavity	0.01	0.002
Cavity location tolerance (true position)	0.0007	0.0000
Engagement with DUT play in Socket (no interposer)	**0.0245**	**0.0056**
Engagement with Interposer design socket	**0.0255**	**0.0106**
Note: Must be greater than .00 to make contact		

Other tolerancing factors which can magnify registration issues