A Case Study Lead-free Thick Film Conductors with Lead-containing and Lead-free Solders

차장 **유 연 수**
(헤라우스 오리엔탈 하이텍)

A Case Study of Lead –free Thick Film Conductors with Lead-containing and Lead-free Solders

By

Peter Bokalo, Samson Shahbazi, Colleen Matier

Heraeus Inc. Circuit Material Division
24 Union Hill Road
West Conshohocken, PA 19428
Phone: 610-825-6050
Fax: 610-825-7061
Web: www.4cmd.com

Abstract

The electronic market thrust for many hybrid circuit manufacturers is changing because commercial market segments such as telecommunications, automotive and consumer electronics have increased the demand world wide for environmentally friendly thick film products. This, in turn, places a stronger emphasis on the material suppliers within the circuit fabrication industry to provide toxin free products with equal or higher performance than traditional technology.

A new group of silver based thick film conductors, which are totally free of such toxins as cadmium, nickel and lead have been developed to meet new environmental requirements.
Traditional thick film products and newly developed toxin free compositions will be compared and data will be presented. To evaluate their performance, both groups of conductors were tested for solder acceptance, leach resistance and aged adhesion with standard lead-containing solder and higher temperature lead-free solder.

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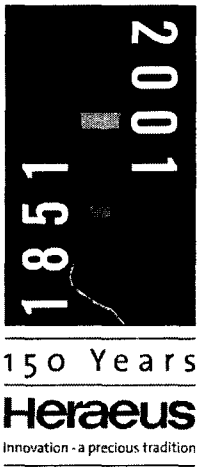

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By Peter Bokalo

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Outline

1. **Silver Based Conductor Description**
2. **Materials and Solders Selections**
3. **Processes and Tests Descriptions**
4. **Test Results**
5. **Summary**

Materials and Equipment

1.0 Materials

1.1 Substrate : 1"x1"x0.025" , 96% alumina
1.2 Screens : 8 x 10 frame, 325 mesh, 0.5 mil emulsion
1.3 Thick Film : Ag, Ag/Pt, Ag/Pd, Ag/Pt/Pd Conductors
1.4 Solders : Sn/Ag & Sn/Pb/Ag

2.0 Equipment

2.1 Printer : MPM Model TF100
2.2 Dryer : Box Oven Blue M
2.3 Furnace : Fast Fire BTU

3.0 Test Equipment

3.1 AutomaticSolder Dipper : Robotic Process Systems
3.2 Pull Tester : Zwick Material Tester
3.3 Storage Oven : Box Oven Blue M

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Solder Selection and Process

1 - Solder : Sn62/Pb36/Ag2
The Most Widely Used Solder in Thick Film Industry,
Temperature used in this Study 230°C.

1.1 - Processed : With RMA Flux
Solder Acceptance = 230°C for 5 seconds
Solder Leach Resistance = 230°C for 5&10 seconds.

2 - Solder : Sn96.5/Ag3.5
The Most Recommended Lead-free Solder for T.F. Ckts.
Temperature used in this Study 260°C.

2.1 - Processed : With RMA Flux
Solder Acceptance = 260°C for 5 seconds
Solder Leach Resistance = 260°C for 5&10 seconds.

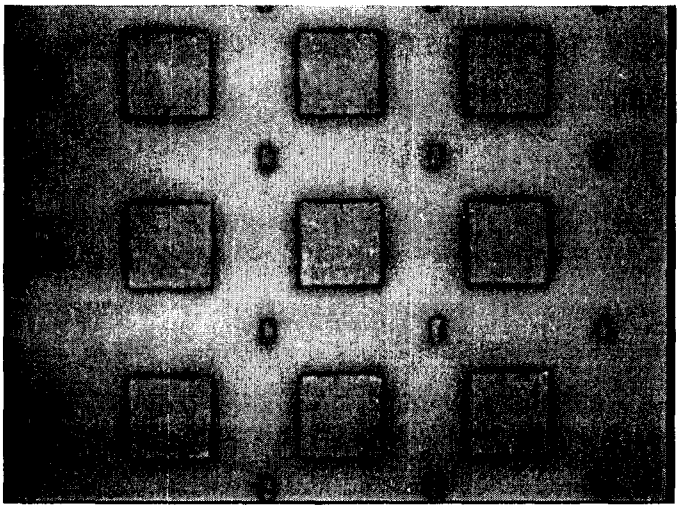
Thick Film Materials used in this Study

Environmentally Friendly Products
(Cadmium,Nickel and Lead Free)

1.1 - 100% Silver
1.2 - Silver /Platinum (99:1)
1.3 - Silver /Platinum/Palladium (Low Pt/Pd)
1.4 - Silver /Palladium (6:1)
1.5 - Silver /Platinum/Palladium (HighPt/Pd)

The Comparison Conductors (Containing Lead) in this Study Have the Similar Ratio of Pt and Pd to Ag as the Above Materials.

Environmentally Friendly Conductors



Printed Conductor Test Pads on Alumina Substrate

Printing and Firing Process

1. **- All Conductors were Printed with 325 Mesh, 0.5 Mils Emulsion.**
2. **- The Screen Pinting Parameters were Adjusted to Achieve Fired Conductor Thickness to Specifications.**
3. **- All Conductors were Dryed at 150°C for 10 Minutes.**
4. **- All Conductrors were Fired in Fast Fire, Belt Furnace at 850°C, for 10 min. at Peak Temperature, 36 min. Cycle.**
5. **- Test Samples were Re-fired at 850°C Three Times to Simulate Circuit Fabrication Process.**

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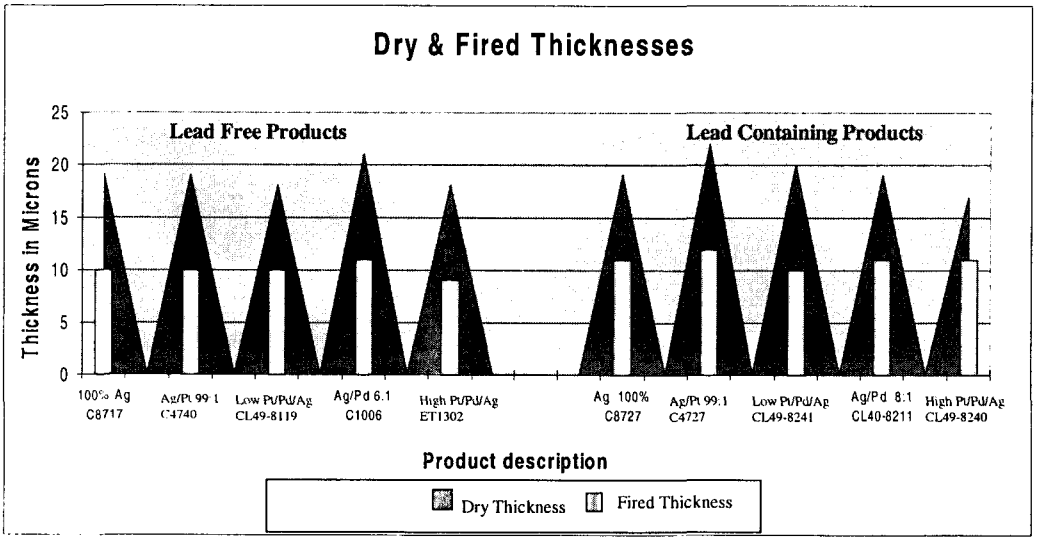
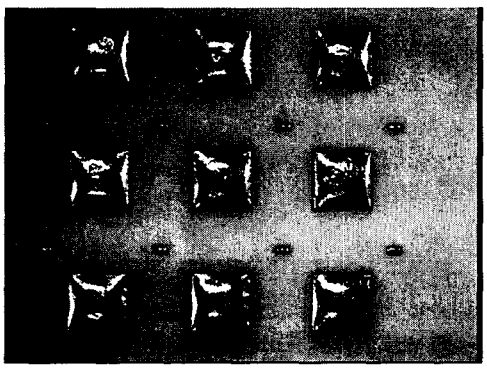


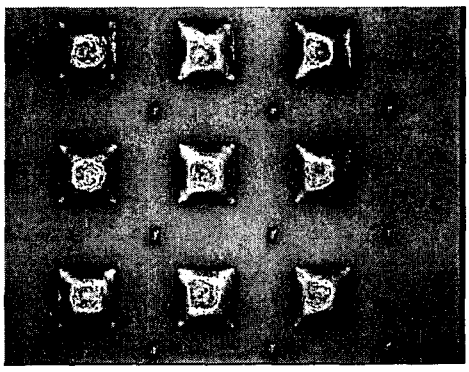
Solder and Test Process

1. - **All Substrates were Soldered with Automatic Solder System.**
2. - **Wire Leads were Attached per Heraeus Procedure.**
3. - **Zwick Pull/Peel Tester was Used for Adhesion Test.**
4. - **Initial Pull Test was Performed 24 Hours After Attaching Wire Leads.**
5. - **Storage Temperature was 150ºC in a Box Oven from 48Hrs. to 250 Hours.**

Solder Acceptance Test

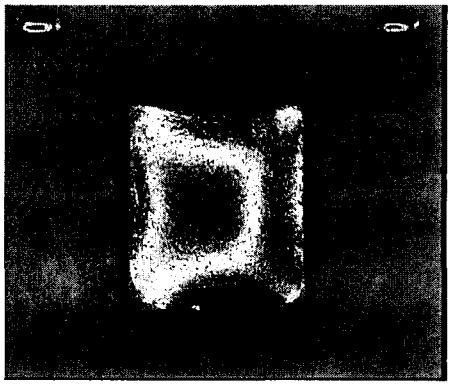


Pads Soldered with Sn62/Pb36/Ag2

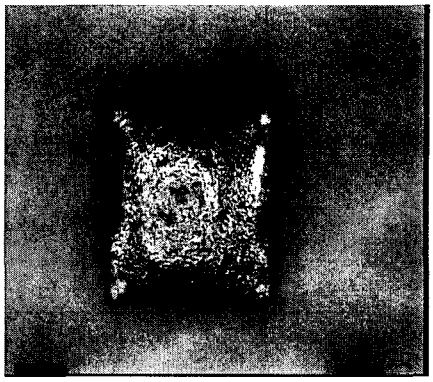


Pads Soldered with Sn96.5/Ag3.5

Solder Surface

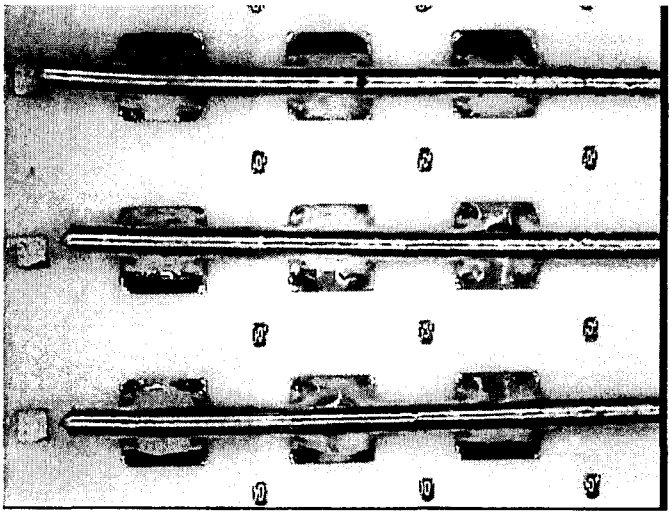


62Sn/36Pb/2Ag solder



96.5Sn/3.5Ag solder

Solder Pads 2mm x 2mm (80 X 80 Mils)



Attached Wire Leads for Pull Test

Solder Acceptance & Leach Resistance

Lead Containing Conductors			Solder Acceptance		Leach Resistance Solder Dip	
	Part #	Description	Sn62	Sn96.5	Sn62	Sn96.5
1	C8717	100% Ag	100%	>95%	2X	1X
2	C4740	Ag/Pt 99:1	>95%	95%	2X	1X
3	CL49-8119	Low Pt/Pd/Ag	>90%	90%	2X	1X
4	C1006	Ag/Pd 6:1	>95%	95%	3X	3X
5	ET1302D	High Pt/Pd/Ag	>90%	90%	4X	3X
Lead Free Conductors						
6	C8727	Ag 100%	100%	>90%	2X	1X
7	C4727	Ag/Pt 99:1	100%	95%	3X	2X
8	CL49-8241	Low Pt/Pd/Ag	>95%	90%	3X	2X
9	CL40-8211	Ag/Pd 8:1	>95%	>95%	3X	2X
10	CL49-8240	High Pt/Pd/Ag	100%	>95%	4X	3X

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Leach Resistance

Lead Containing Conductors			Thickness		Initial Resistivity					
	Part #	Description	Dry	Fired	After1 X dip	2 x dip	3 x dip	4 x dip	5 x dip	6 x dip
1	C8717	100% Ag	19	10	0.501	X	X			
2	C4740	Ag/Pt 99:1	19	10	0.652	X	X	X		
3	CL49-8119	Low Pt/Pd/Ag	18	10	0.698	X				
4	C1006	Ag/Pd 6:1	21	11	1.188	X	X	X		
5	ET1302D	High Pt/Pd/Ag	18	9	1.124	X	X			
Lead Free Conductors										
6	C8727	Ag 100%	19	11	0.358	X				
7	C4727	Ag/Pt 99:1	22	12	0.531	X	X	X	X	
8	CL49-8241	Low Pt/Pd/Ag	20	10	0.735	X	X	X	X	X
9	CL40-8211	Ag/Pd 8:1	19	11	1.194	X	X	X		
10	CL49-8240	High Pt/Pd/Ag	17	11	1.011	X	X	X		

Note: Leach Resistance is Based on Doubling the Resistivity of 20 mils wide X 2000 mils long Conductor Trace

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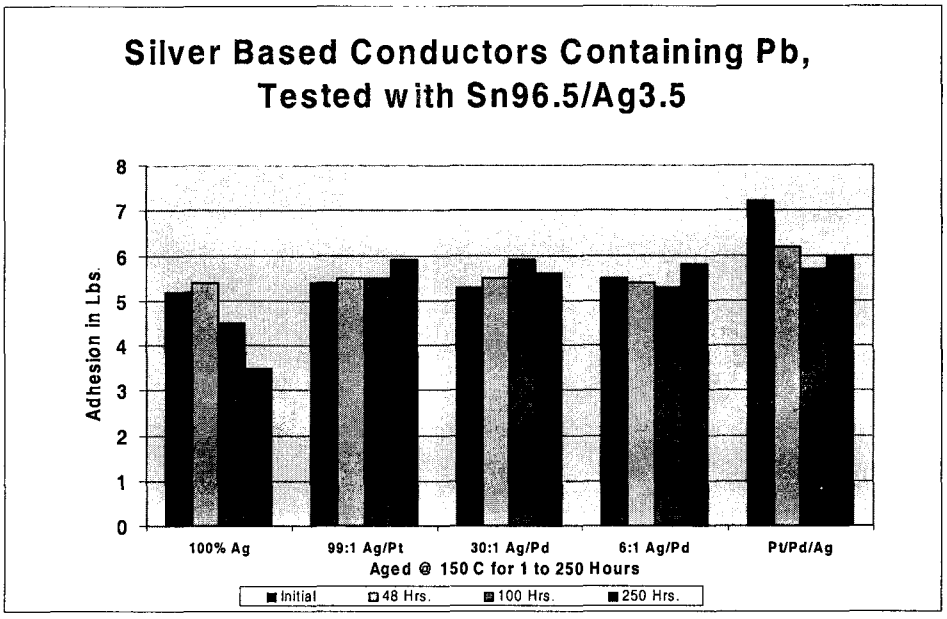

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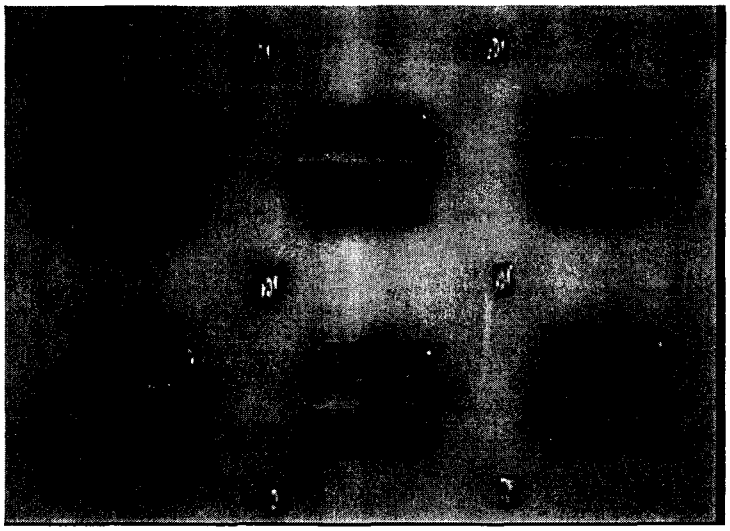
Adhesion Pull Test



Failure Mode on Initial Pull Test

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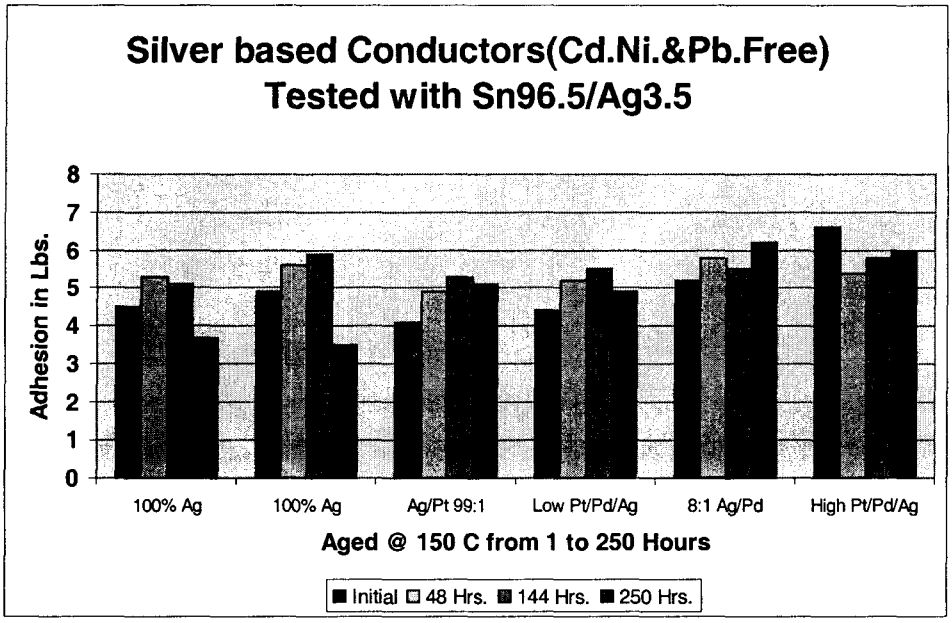

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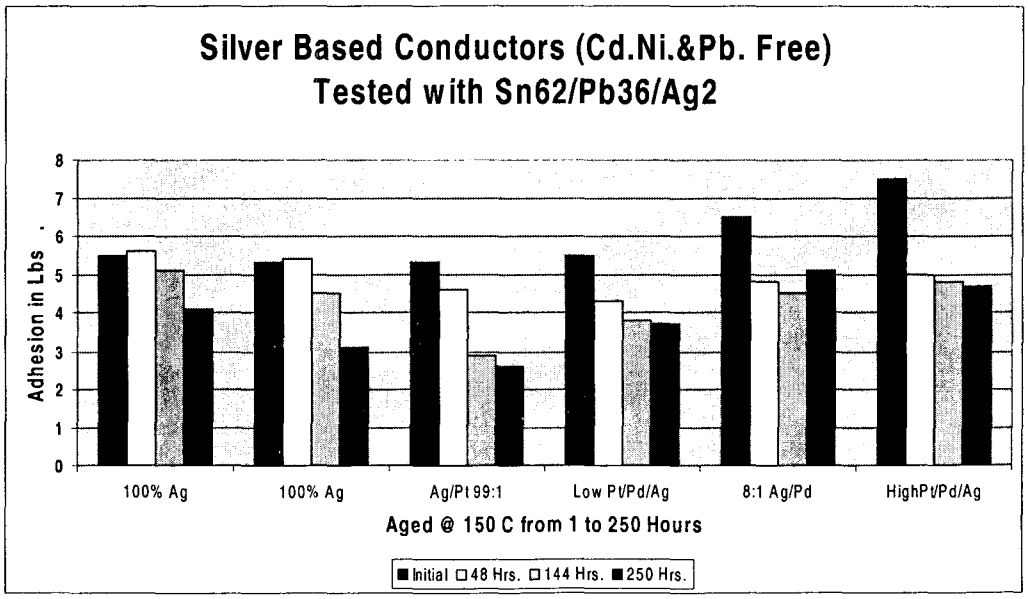

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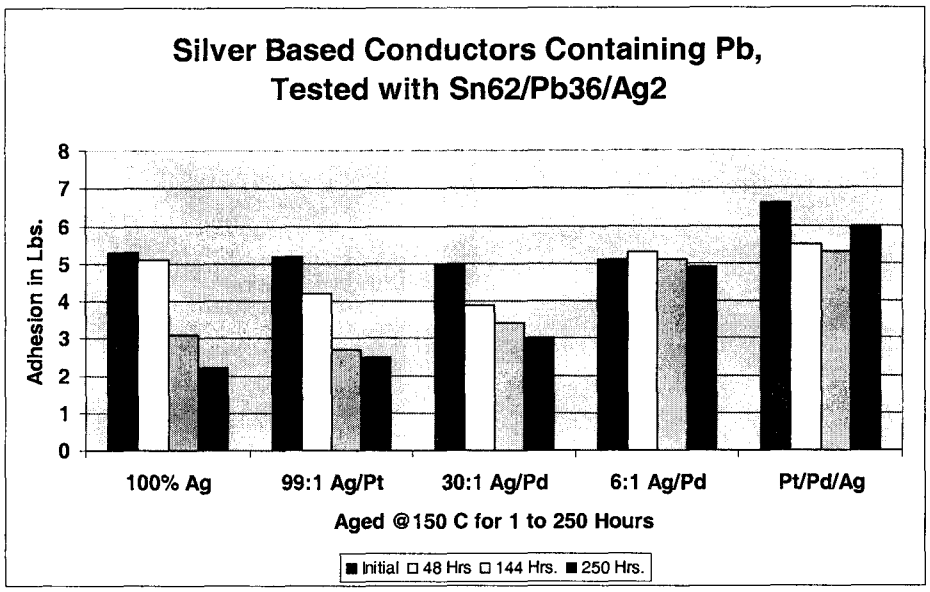

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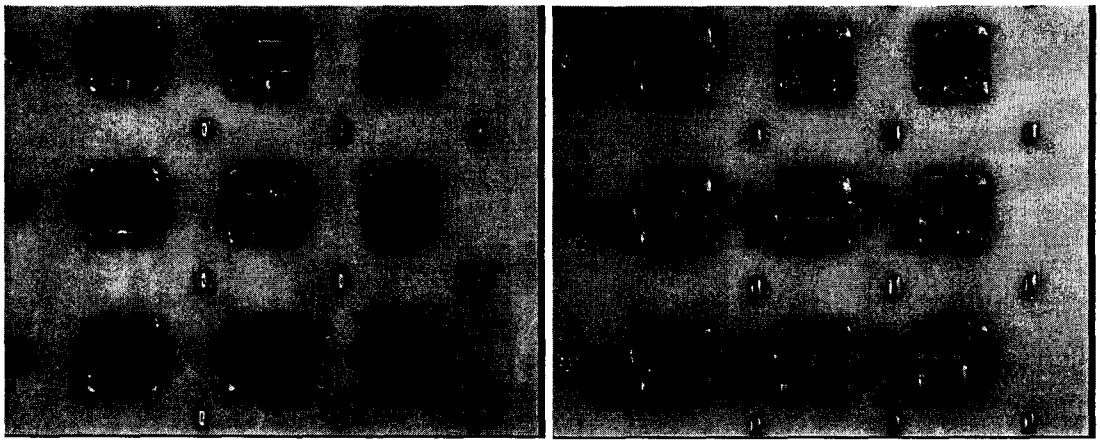
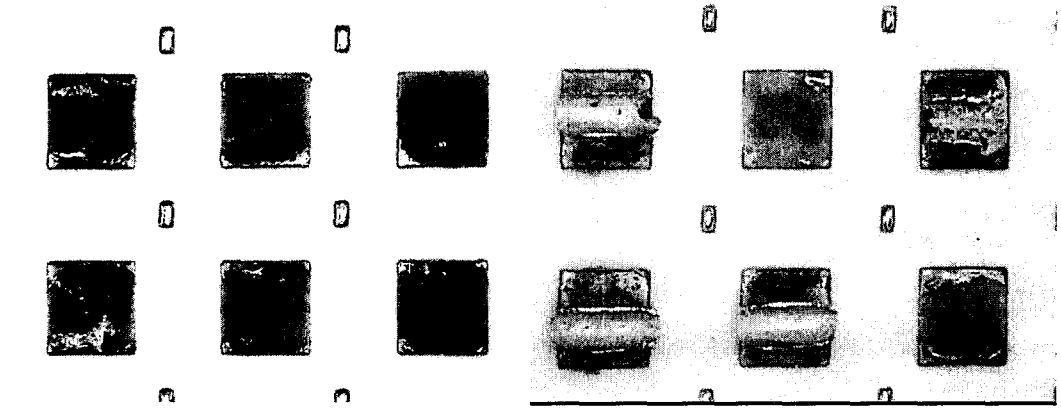
Test Pads Failure Mode



Failure Mode after 144 Hr. with Sn62

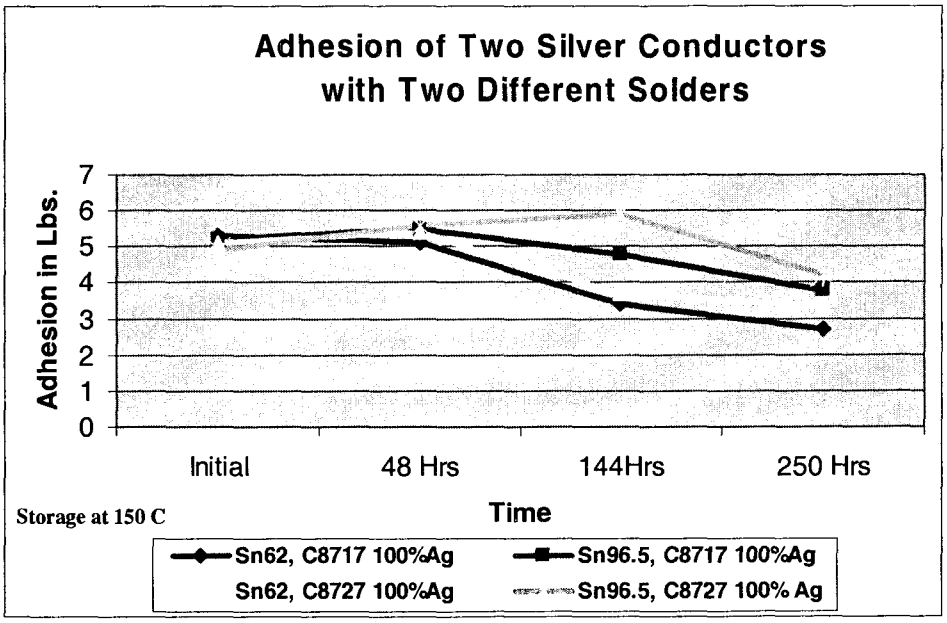
Failure Mode after144 Hr. with Sn96.5

Test Pads Failure Mode



Solder Pads after 250 Hours with Sn62

Solder Pads after 250 Hours with Sn96.5



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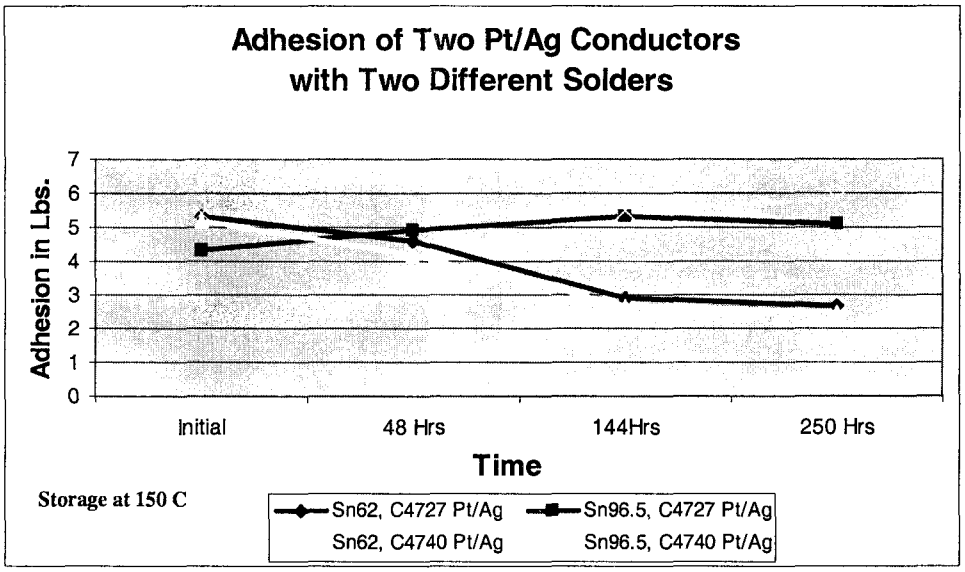

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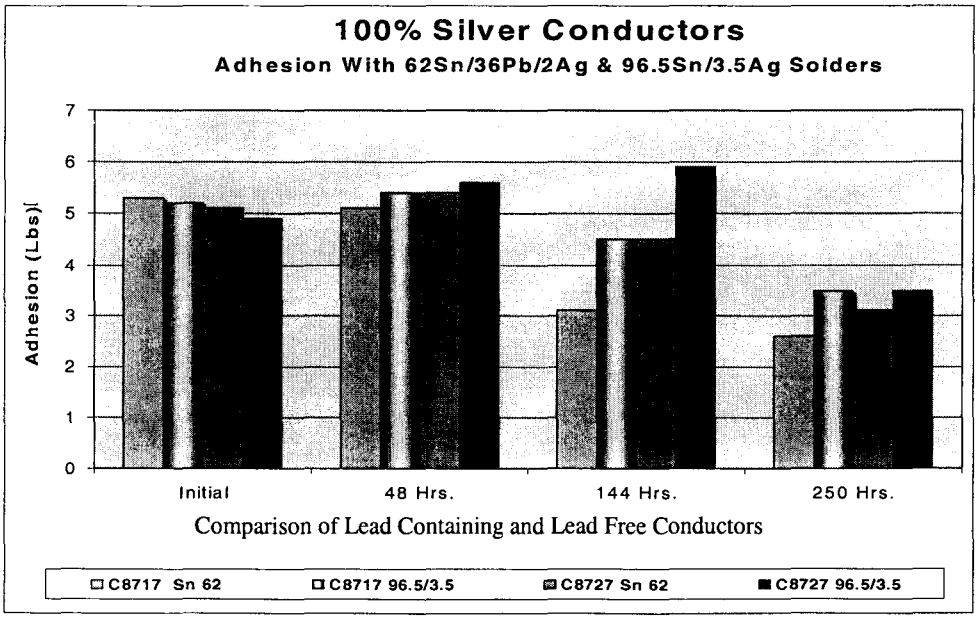

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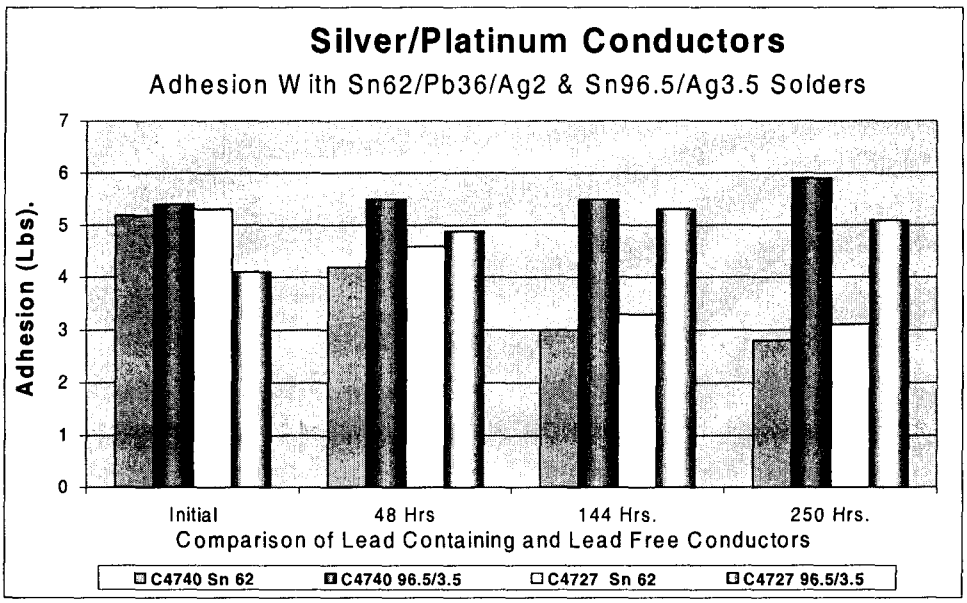

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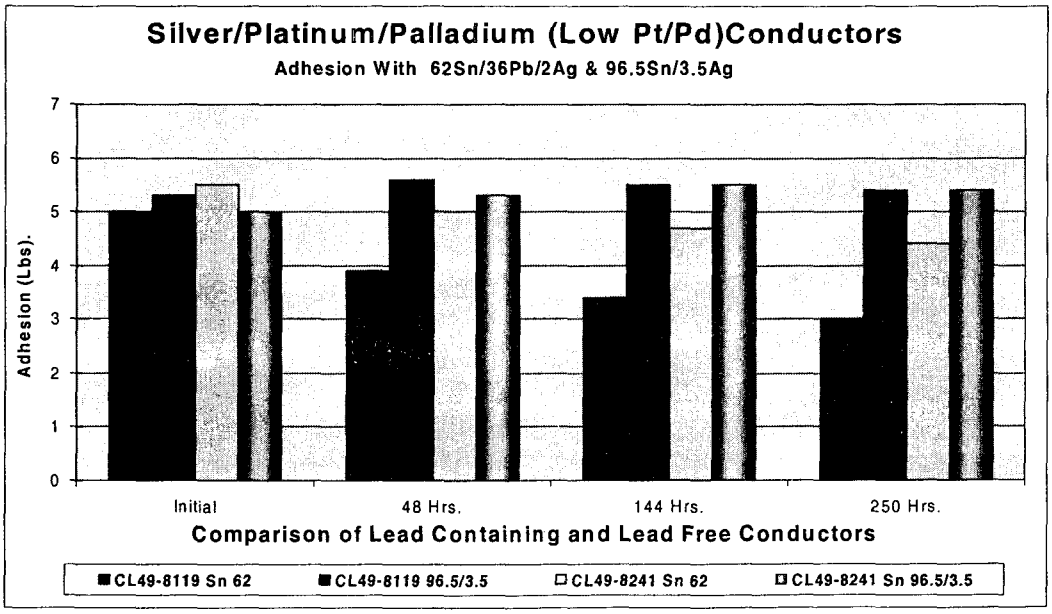

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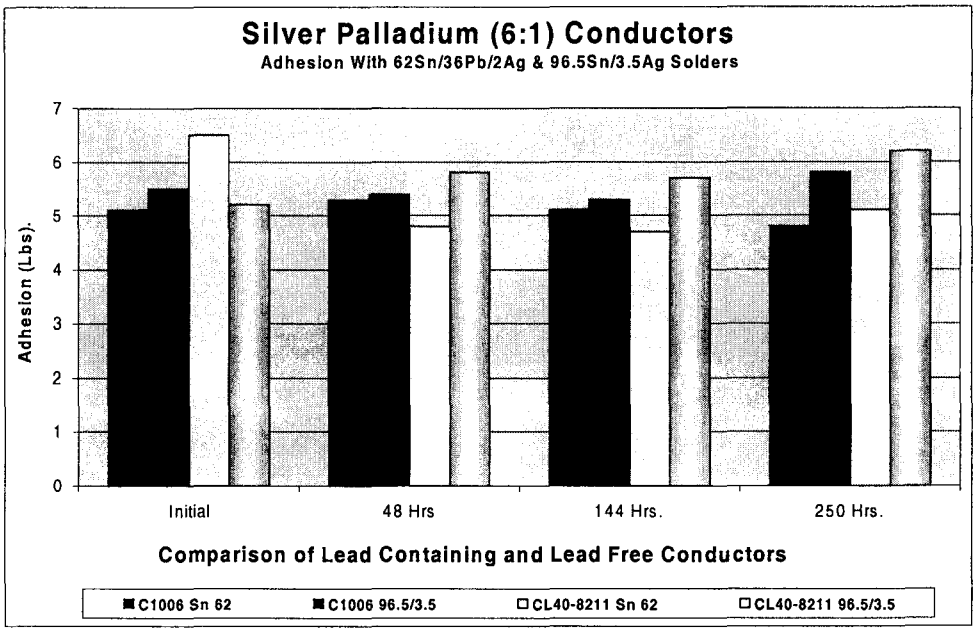

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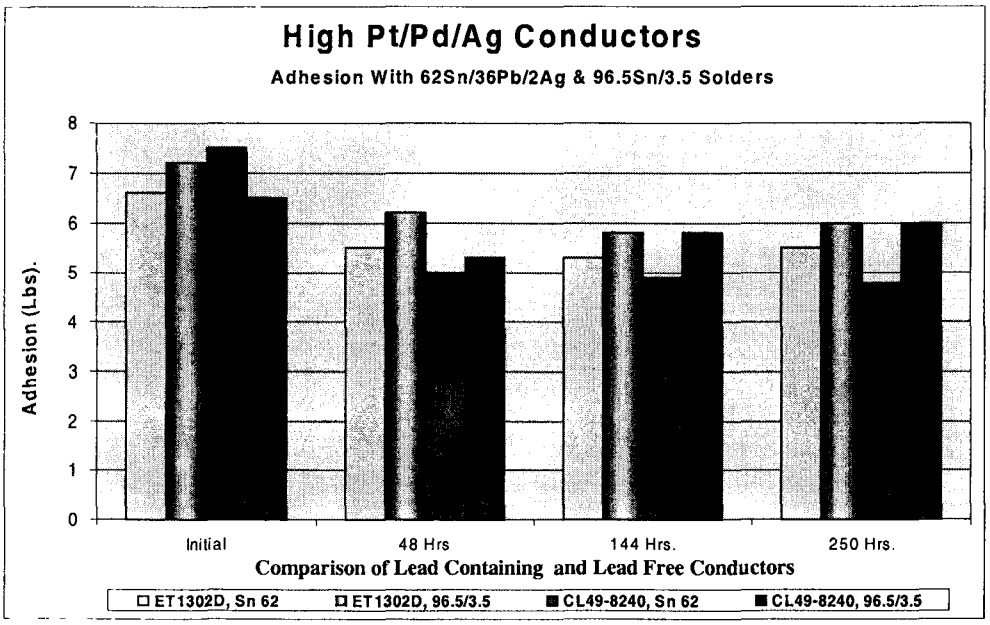

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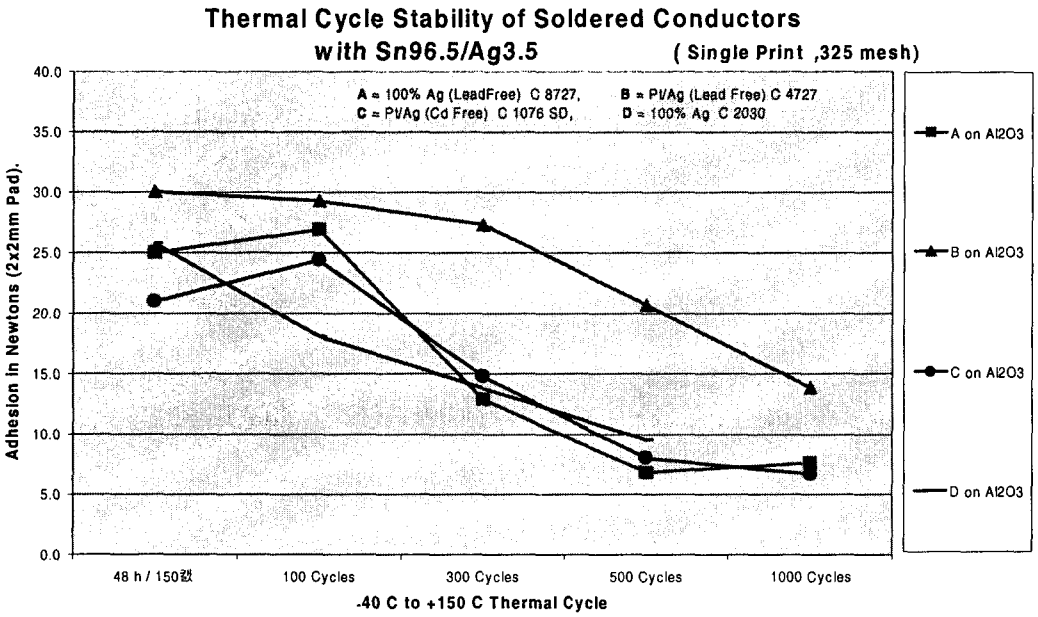

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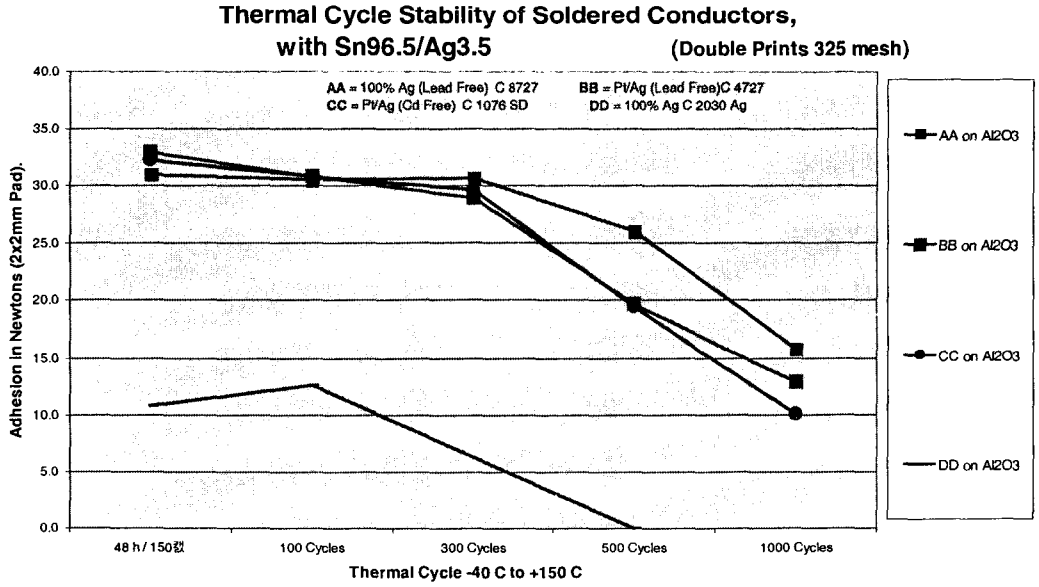
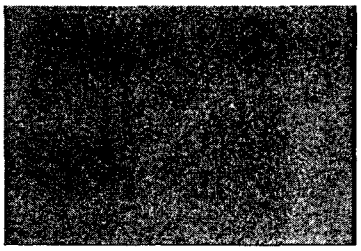
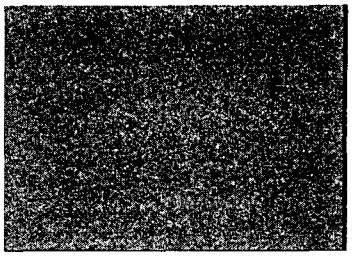


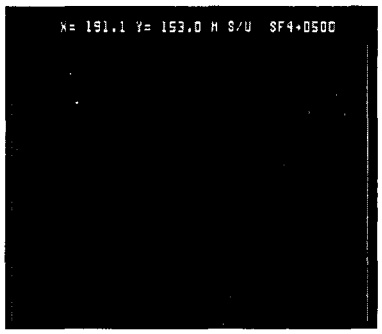


Conductor Surface



Back Light Density

Conventional Conductor



Cd. Ni. & Pb. Free Conductor

Summary

- **The Recently Developed Lead-free Conductors are Very Dense**
- **Fast Screen Printing and Fine Line Capability**
- **Perform Equally or Better with Low and High Temperature Solders**
- **Very Good Solder Acceptance and Aged Adhesion with Sn96.5/Ag3.5**
- **Fully Environmentally Friendly Conductors with Lead Free Solders**
- **Future Development : Lead Free Dielectrics and Resistors**