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Properties of Bulk Sintered Silver As a Function of Porosity

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EXECUTIVE SUMMARY

This report summarizes a study where various properties of bulk-sintered silver were investigated over a range of porosity. This work was conducted within the National Transportation Research Center's Power Device Packaging project that is part of the DOE Vehicle Technologies Advanced Power Electronics and Electric Motors Program. Sintered silver, as an interconnect material in power electronics, inherently has porosity in its produced structure because of the way it is made. Therefore, interest existed in this study to examine if that porosity affected electrical properties, thermal properties, and mechanical properties because any dependencies could affect the intended function (e.g., thermal transfer, mechanical stress relief, etc.) or reliability of that interconnect layer and alter how its performance is modeled.

Disks of bulk-sintered silver were fabricated using different starting silver pastes and different sintering conditions to promote different amounts of porosity. Test coupons were harvested out of the disks to measure electrical resistivity and electrical conductivity, thermal conductivity, coefficient of thermal expansion, elastic modulus, Poisson's ratio, and yield stress.

The authors fully recognize that the microstructure of processed bulk silver coupons may indeed not be identical to the microstructure produced in thin (20-50 microns) layers of sintered silver. However, measuring these same properties with such a thin actual structure is very difficult, requires very specialized specimen preparation and unique testing instrumentation, is expensive, and has experimental shortfalls of its own, so the authors concluded that the herein measured responses using processed bulk sintered silver coupons would be sufficient to determine acceptable values of those properties.

Almost all the investigated properties of bulk sintered silver changed with porosity content within a range of 3-38% porosity. Electrical resistivity, electrical conductivity, thermal conductivity, elastic modulus, Poisson's ratio, and yield stress all depended on the porosity content in bulk-sintered silver. The only investigated property that was independent of porosity in that range was coefficient of thermal expansion.

1. INTRODUCTION

Silver sintering for interconnection of die to substrates and substrates to heat sinks in power electronic components is an attractive joining alternative to soldering because silver sintered joints have a higher temperature capability, higher thermal conductivity, and are more mechanically resilient. They have been studied for over 10 years [e.g., 1-6], and while their development continues to address a myriad of pending issues, sintered silver joints are starting to be used in some commercial power electronic modules such as the SKiM and SKiiP modules made by Semikron (Nuremberg, Germany).

Sintered silver joints contain porosity. The sintering process, a solid-state diffusional process, typically involves pressure-assistance; however, fully dense sintered silver interconnects do not result. Up to a few tens of percent of porosity seem typical and have been reported [2-3]. Additionally, lower applied pressures for sintering are continually being sought, so resulting porosity content in these sintered joints are likely to be higher yet. For example, Göbl [4] estimated porosity to range between 5-20% when the pressure used in sintering was varied. It is logical to conclude that the porosity for "no-pressure" sintering could be higher yet than 20%.

Interest existed to examine if the amount of porosity affected electrical properties, thermal properties, and mechanical properties because any dependencies could affect the intended function (e.g., thermal transfer, mechanical stress relief, etc.) or reliability of that interconnect layer and alter how its performance is modeled.

Lastly, the authors fully recognize that the microstructure of processed bulk silver coupons may indeed not be identical to the microstructure produced in thin (20-50 microns) layers of sintered silver. Measuring these same properties with such a thin actual structure is non-trivial, requires very specialized specimen preparation and unique and non-standardized testing instrumentation and test methods [7], and has experimental shortfalls of its own [2]. The authors concluded that the herein measured responses using processed bulk sintered silver coupons would be sufficient to determine acceptable values of those properties.

2. EXPERIMENTAL PROCEDURE

A description of the silver pastes, their consolidation into disk billets, and descriptions of the methods used to measure electrical, thermal, and mechanical properties are presented.

2.1. Fabrication of Bulk Silver

2.1.1. Description of Silver Pastes

Four different silver pastes were acquired and used to make bulk sintered silver coupons.[1] They are listed in Table I. Three of the pastes are manufactured by Heraeus and the fourth by DuPont. The two "LTS" Heraeus pastes were developed specifically for sintering.

Table I. List of silver pastes used to fabricate bulk coupons.

Brand Name	Manufacturer
C 1075 S	W. C. Heraeus GmbH, Hanau, Germany
LF131	DuPont, Research Triangle Park, NC USA
LTS 016	W. C. Heraeus GmbH, Hanau, Germany
LTS 043	W. C. Heraeus GmbH, Hanau, Germany

Mass loss as a function of temperature was studied in all four pastes using thermogravimetric analysis (TGA), and endothermic or exothermic responses were examined using differential scanning calorimetry (DSC). Their results are illustrated in Figs. 1-8.

[1] Reference herein to any specific commercial company, product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring, and shall not be used for advertising or product endorsement purposes.

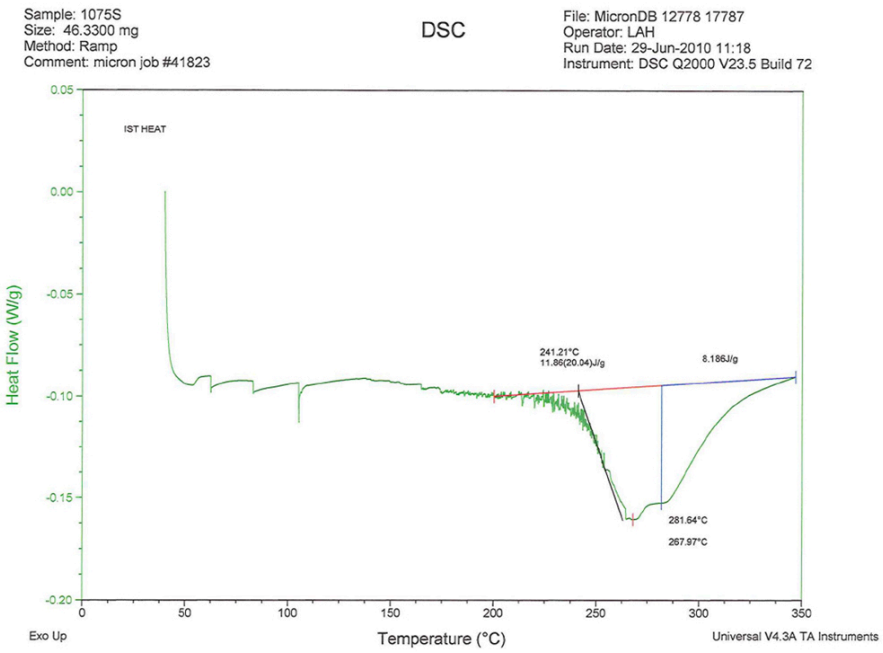

Figure 1. Differential scanning calorimetry (DSC) of C1075S silver paste.

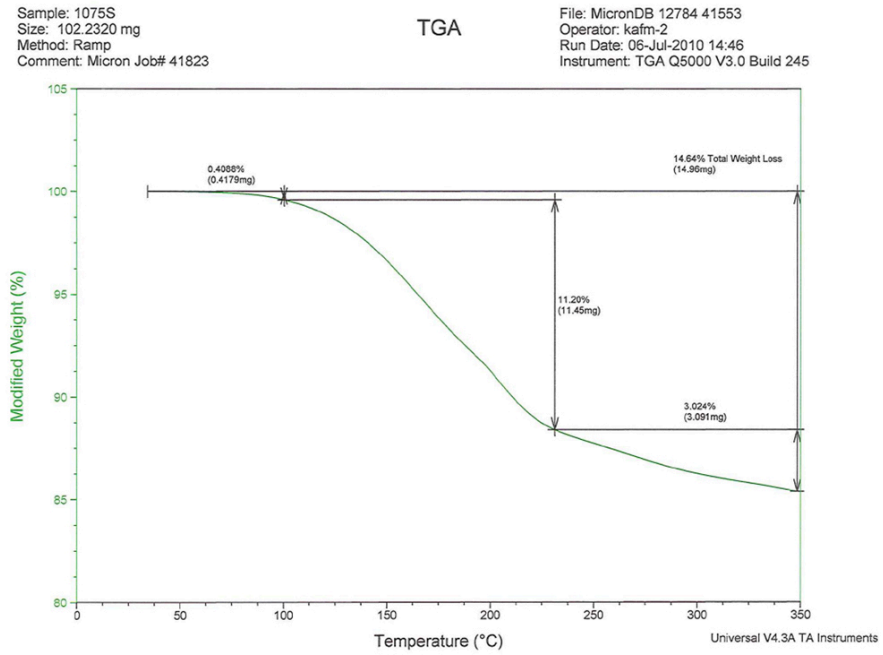

Figure 2. Thermogravimetric analysis (TGA) of C1075S silver paste.

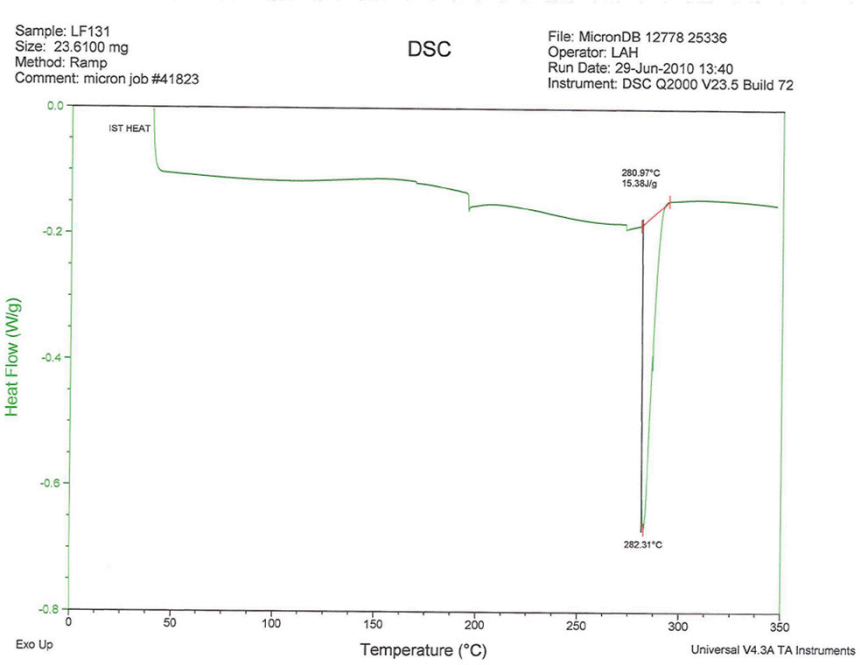

Figure 3. Differential scanning calorimetry (DSC) of LF131 silver paste.

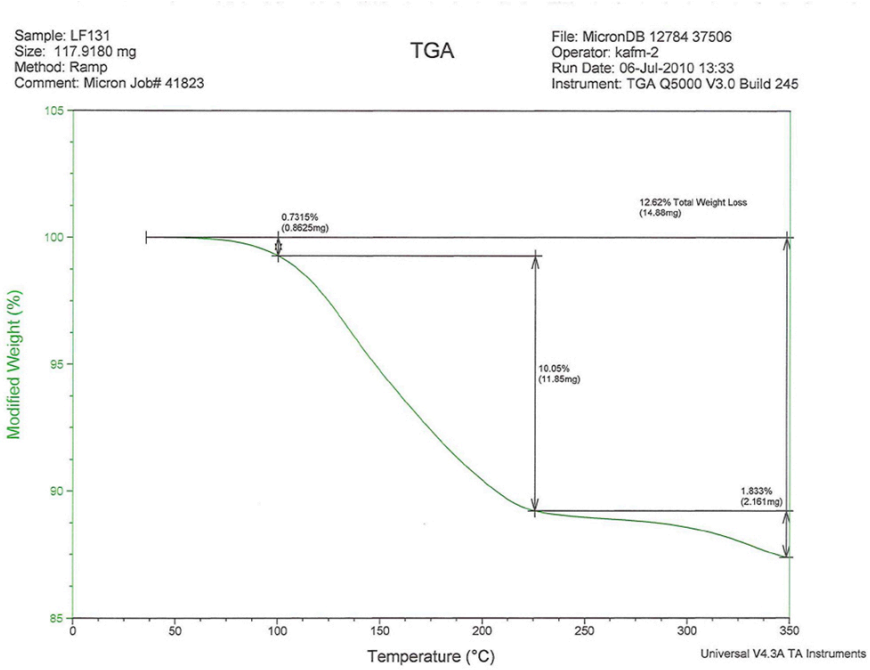

Figure 4. Thermogravimetric analysis (TGA) of LF131 silver paste.

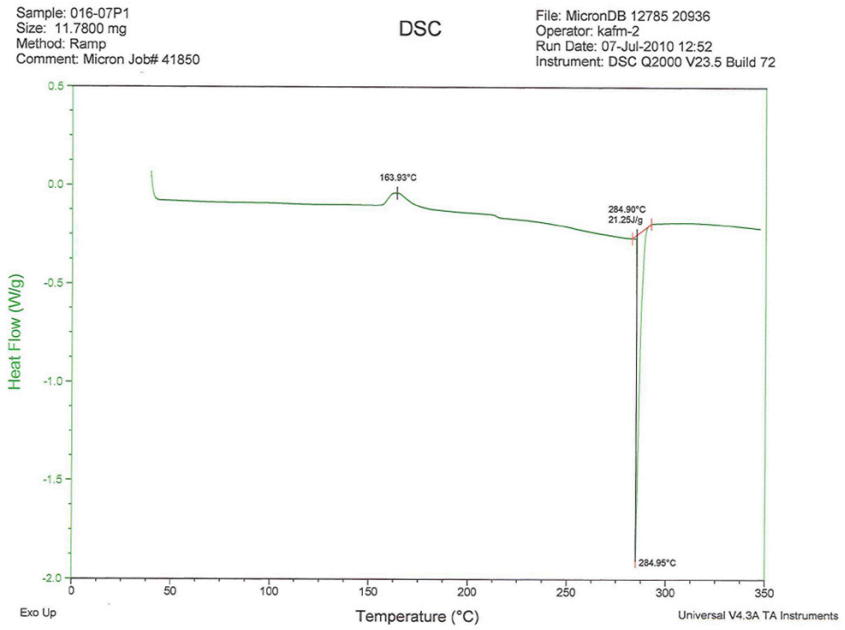

Figure 5. Differential scanning calorimetry (DSC) of LTS016 silver paste.

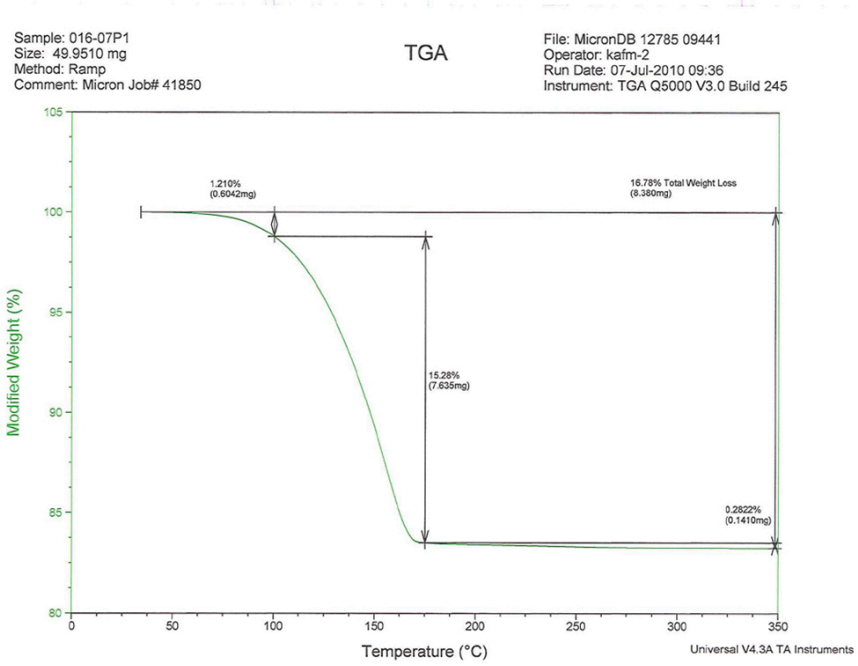

Figure 6. Thermogravimetric analysis (TGA) of LTS016 silver paste.

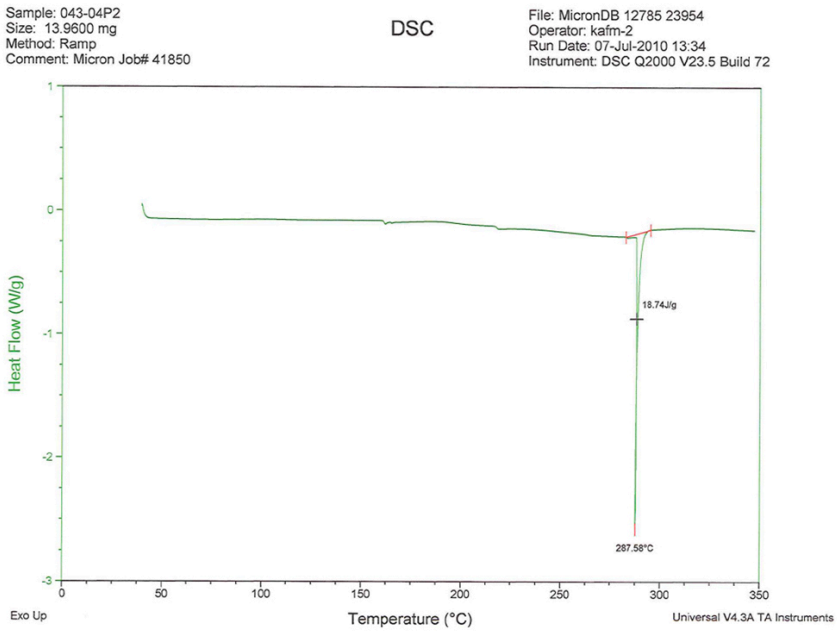

Figure 7. Differential scanning calorimetry (DSC) of LTS043 silver paste.

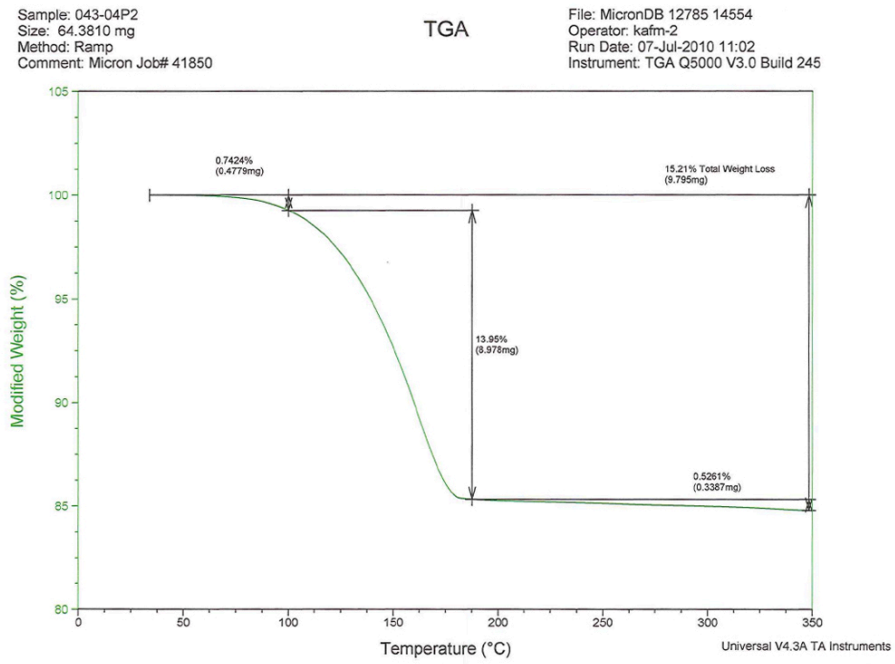

Figure 8. Thermogravimetric analysis (TGA) of LTS043 silver paste.

2.1.2. Processing of Coupons

Bulk silver specimens were fabricated with pressure-assistance using a custom-made fixture utilizing a clamp-on, conductive-heater (Watlow, St. Louis, MO). Pastes were dried in ambient air, ground with a mortar and pestle, and sieved through a 100-mesh screen. The resulting dried silver powder is shown in Fig. 9. An amount of dried powder was weighed to produce a disk with thickness of ~ 4-5 mm. Its charging into the mold/heater is also shown in Fig. 9.

The assembled heating system is shown in Fig. 10. The location where the powder was compressed was centered vertically and subjected to an isothermal temperature during sintering. Two thermocouples for the clamp-on heater were located at the top and controlled heating and over-temperature protection, and an independent (third) thermocouple was positioned close to the work volume and actual temperature control was based on this thermocouple. The relatively massive (thick-walled) stainless steel tubular mold promoted an isothermal temperature during the sintering process. This system heated up and reached temperature equilibrium in approximately 5 minutes. Application of pressure commenced once that equilibrium was reached. Sintering temperature, stress, time-under stress, and apparent bulk density are listed in Table II.

Examples of produced disks are shown in Fig. 11. Specimens for property measurements were harvested out of these disks.

Figure 9. Dried silver powder (left) and it being poured into the mold (right).

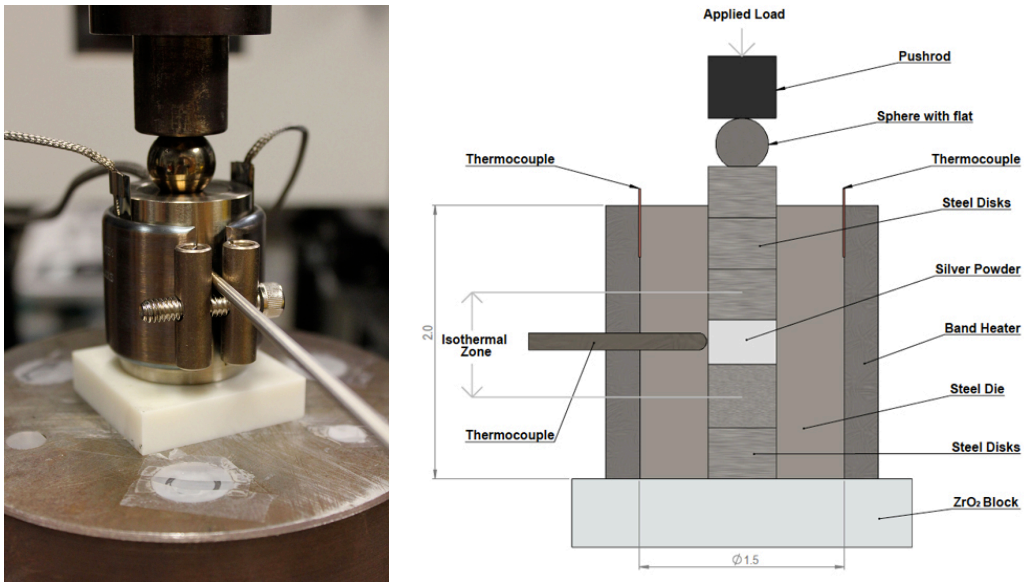

Figure 10. Assembled heating system (left) ready for pressure-assisted sintering and a schematic drawing of its structure (right).

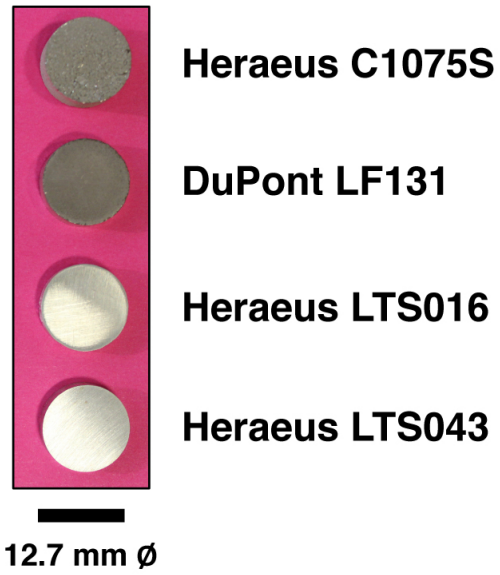

Figure 11. Examples of processed bulk silver coupons.

2.2. Property Measurements

The intention of fabricating the bulk specimens was to enable the harvesting of sufficiently sized test coupons so electrical, thermal, and mechanical properties could be measured. Focused ion beam (FIB) milling (Hitachi FB-2000A, Hitachi, Ltd., Tokyo, Japan) and follow-on scanning electron microscopy (SEM) of the microstructures were performed on one test coupon from each of the four pastes listed in Table II.

2.2.1. Electrical Resistivity and Conductivity

Electrical resistivity was measured using an electric resistance measuring system (ULVAC ZEM-3, Methuen, MA). A small bar sample of 2 x 2 x 10 mm long was used. Measurements were made over a temperature range of -50-200°C. Two R type thermocouples were used as temperature and voltage probes. Current vs. voltage curves were obtained before each measurement to ensure good electrical contact. Electrical conductivity was calculated by inversing the electrical resistivity measurements.

2.2.2. Thermal Conductivity

A laser flash diffusivity measuring system (TA Instrument, New Castle, DE) was used for thermal diffusivity measurements. The TA/Anter X-platform has a two-sample holder and xenon flash lamp. Measurements were made over a temperature range of -50C to 200°C. The samples were 12.7 mm in diameter and 1-2 mm thick. The ASTM standard 1461 was followed in data collection and analysis. The thermal diffusivity is calculated using the Clark & Taylor method. Thermal conductivity (κ) of the material was calculated according to $\kappa = \alpha \bullet \rho \bullet Cp$ where α is thermal diffusivity, ρ is density, and Cp is heat capacity. Density was measured in all samples and Cp was assumed to be 240 J/kg•K for all temperatures.

2.2.3. Coefficient of Thermal Expansion

Coefficient of thermal expansion was measured using a dual-rod dilatometer (Dilatronic 1, Theta Industries, Port Washington, NY) using a sapphire standard in all tests. 2 x 2 x 10 mm specimens were used and measurements were taken from room temperature to 250°C.

2.2.4. Elastic Modulus and Poisson's Ratio

Elastic modulus and Poisson's ratio were measured using a resonant ultrasound spectroscope (Magneflux, Albuquerque, NM). A 2 x 2 x 10 mm specimen was used and measurements were only made at room temperature.

2.2.5. Yield Stress

Yield stress was estimated using an electromechanical test frame (Model 5867, Instron, Canton, MA). Two prismatic bars with nominal dimensions of 3 x 3 x 4.5 mm were prepared. The 4.5 mm dimension was compressively loaded and the force associated with the onset of non-linearity was identified using graphical analysis for each test. That force was divided by the 3 x 3 mm cross-section to calculate the engineering yield stress. Only room temperature testing was performed.

3. RESULTS AND DISCUSSION

3.1. Densities and Microstructures

The sintering conditions and produced densities are listed in Table II. A range of 62 to 97% of theoretical full density were produced.

Table II. Processing conditions and produced silver bulk densities.

Silver Paste	**Sintering Conditions** T = sintering temperature S = uniaxial compressive stress t = time under stress	**Produced Apparent Bulk Density (g/cm^3)**	**Produced % of Full Density†**
C 1075 S	T = 250°C, S = 50 MPa, t = 10 min	6.46	62.1
LF131	T = 350°C, S = 50 MPa, t = 10 min T = 350°C, S = 50 MPa, t = 10 min	8.41 8.42	80.9 81.0
LTS 016	T = 350°C, S = 50 MPa, t = 25 min	10.07	96.8
LTS 043	T = 350°C, S = 50 MPa, t = 25 min T = 350°C, S = 50 MPa, t = 25 min	9.66 10.03	92.9 96.4

† Theoretical density of silver = 10.4 g/cm^3.

Dual beam focused ion beam (FIB) milling (Hitachi FB-2000A, Tokyo, Japan) was performed on one test coupon from each of the four pastes listed in Table II. An illustration of the FIB milling layout is shown in Fig. 12 with the resulting images for the four porosity ranges shown in Fig. 13. The drawn boxes in Fig. 13 are regions where the porosity is representative of the bulk. The region between each box and the specimen's surface is not representative of the bulk porosity because their dense structure was a consequence of the (consolidating) surface grinding used to produce the overall test coupons. The amounts and changes of evident porosity among them is consistent with the measured apparent bulk density of each.

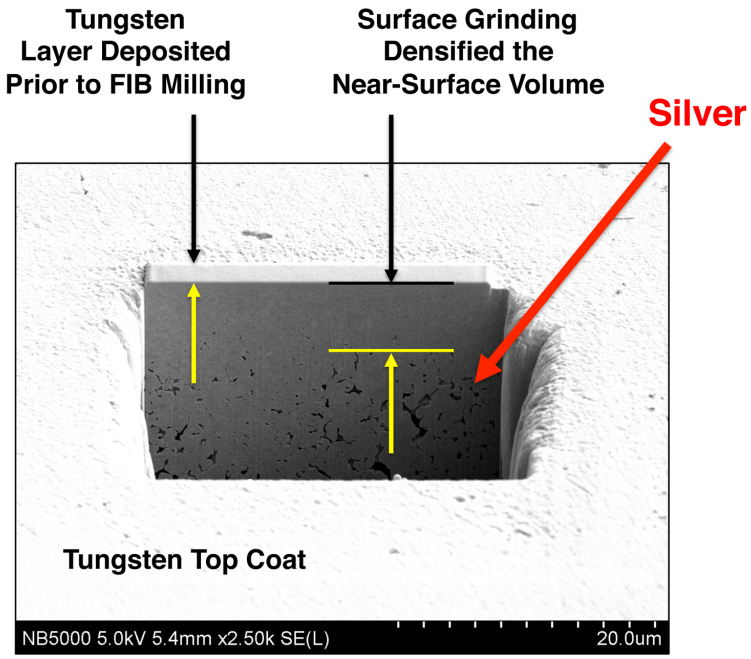

Figure 12. Example of a focused ion beam (FIB) milled trench.

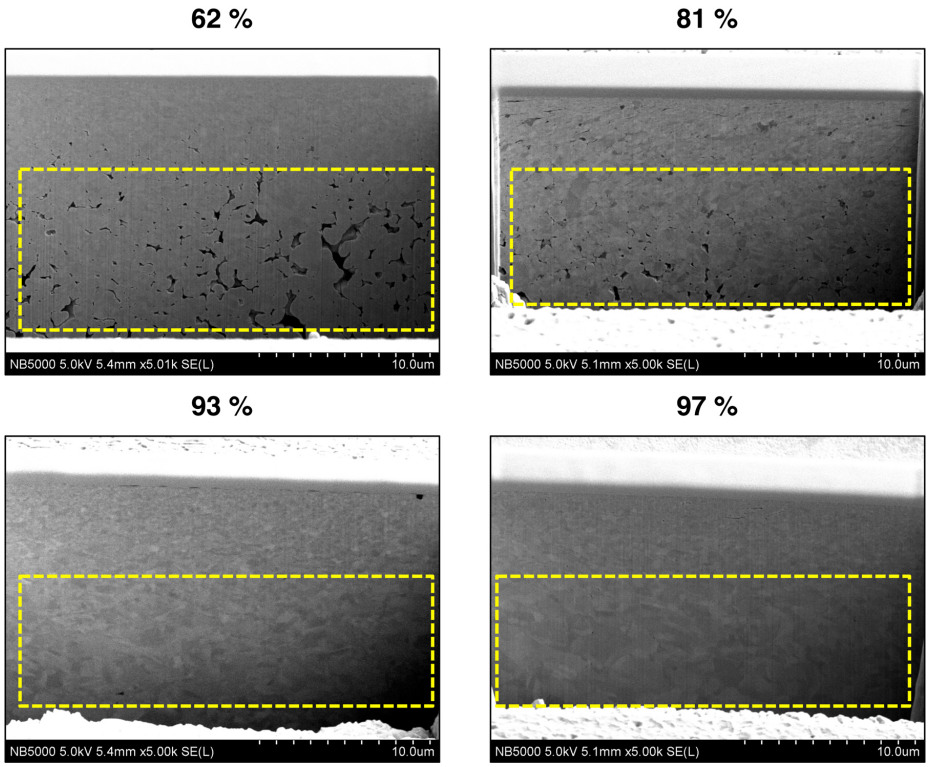

Figure 13. Structures formed by FIB milling as a function of porosity.

3.2. Property Measurements

The resulting property measurements as a function of porosity follow.

3.2.1. Electrical Resistivity and Conductivity

Electrical resistivity as a function of porosity and temperature is shown in Fig. 14. Electrical resistivities quadrupled from when density decreased from 97% to 62% and increased with temperature. At room temperature electrical resistivity was ~ 2 μΩ•cm for 93-97% dense silver, ~ 4 μΩ•cm for 81% dense silver, and ~ 8 μΩ•cm for 62% dense silver.

Electrical conductivity as a function of porosity and temperature is shown in Fig. 15. Given reciprocity exists between electrical resistivity and conductivity, electrical conductivities decreased by approximately one-fourth when density decreased from 97% down to 62% and they decreased with temperature. At room temperature electrical conductivity was 40-50 MS/m for 93-97% dense silver, ~ 25 MS/m for 81% dense silver, and ~ 10 MS/m for 62% dense silver.

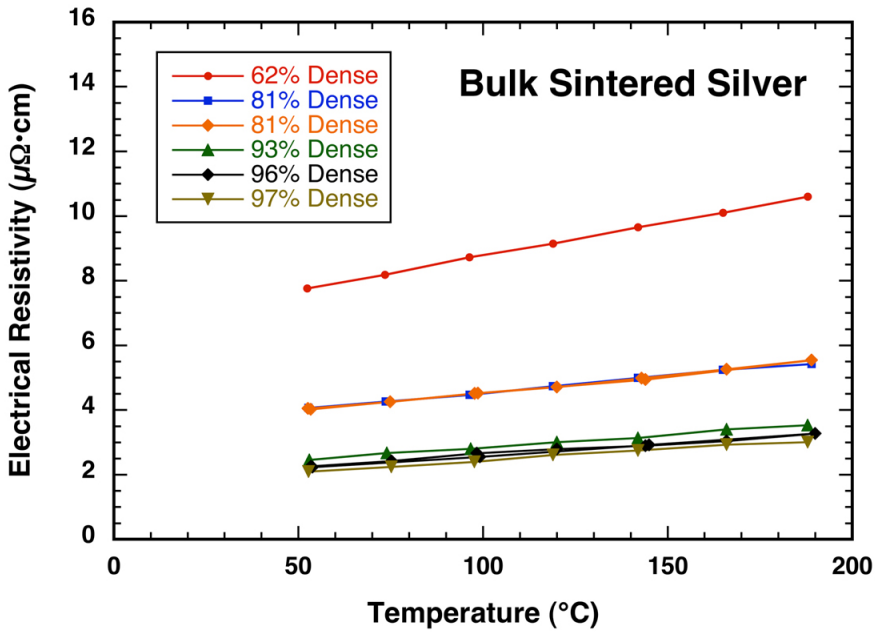

Figure 14. Electrical resistivity (ρ) as a function of porosity and temperature.

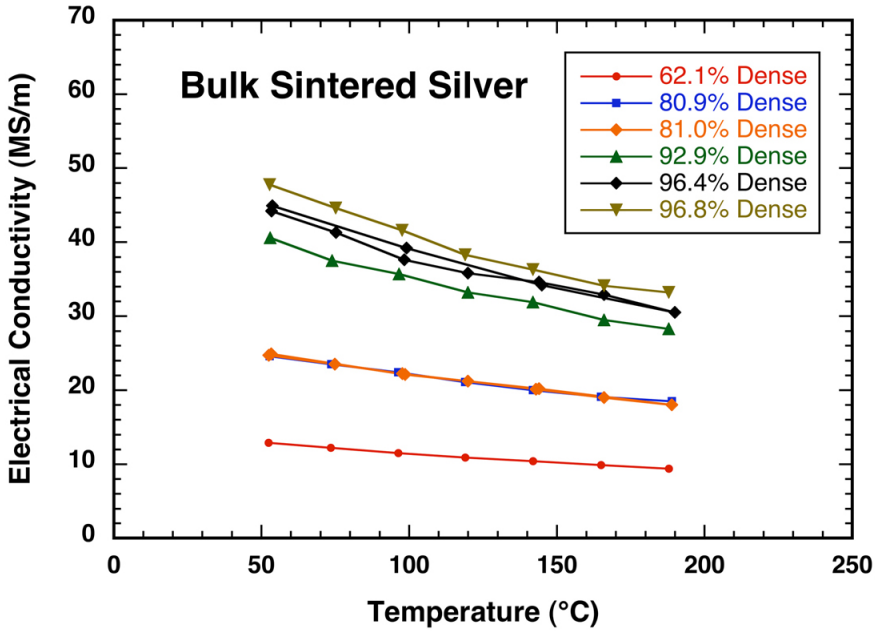

Figure 15. Electrical conductivity (σ) as a function of porosity and temperature.

3.2.2. Thermal Conductivity

Thermal conductivity as a function of porosity and temperature is shown in Fig. 16. Thermal conductivity decreased by approximately 80% when the density decreased from 97% to 62%. Thermal conductivities were temperature independent between -50 and 200°C for any given porosity level. At room temperature thermal conductivity was ~ 375 W/mK for 96% dense silver, ~ 350 W/mK for 93% dense silver, ~ 175 W/mK for 81% dense silver, and ~ 75 W/mK for 62% dense silver.

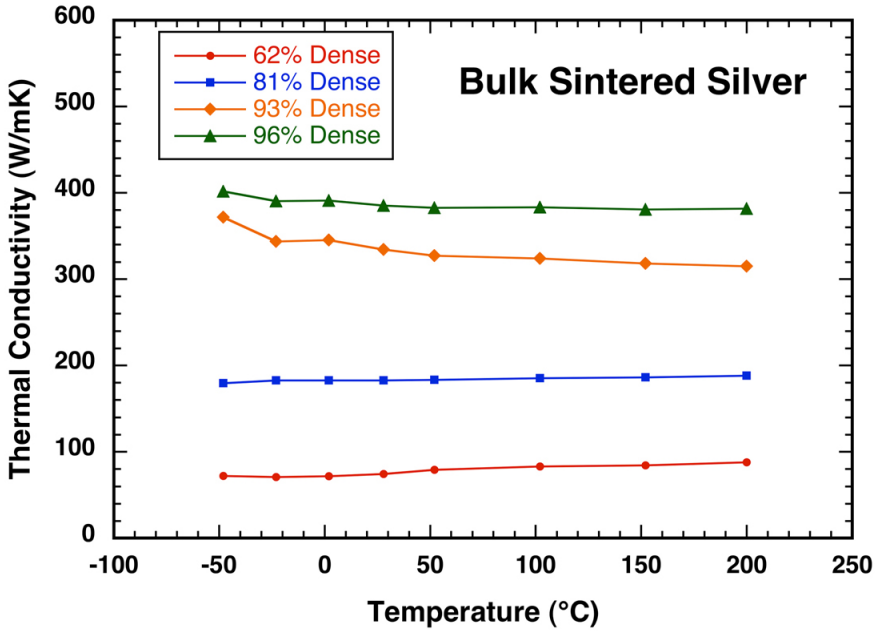

Figure 16. Thermal conductivity (κ) as a function of porosity and temperature.

3.2.3. Coefficient of Thermal Expansion

Coefficient of thermal expansion as a function of porosity is shown in Fig. 17. The average CTE up to 250°C was independent of porosity and was approximately 20 x 10^{-6}/°C. CTE was the only measured property in this study that was independent of porosity.

3.2.4. Elastic Modulus and Poisson's Ratio

Elastic modulus as a function of porosity is shown in Fig. 18. Elastic modulus decreased by approximately 80% when the density decreased from 97% to 62%. Elastic modulus was 72 GPa for 96-97% dense silver, 58 GPa for 93% dense silver, 40 GPa for 81% dense silver, and 14 GPa for 62% dense silver.

Poisson's ratio as a function of porosity is shown in Fig. 19. Poisson's ratio decreased by approximately 45% when the density decreased from 97% to 62%. Poisson's ratio was ~ 0.37 for 96-97% dense silver, ~ 0.28 for 81% dense silver and 0.20 for 62% dense silver.

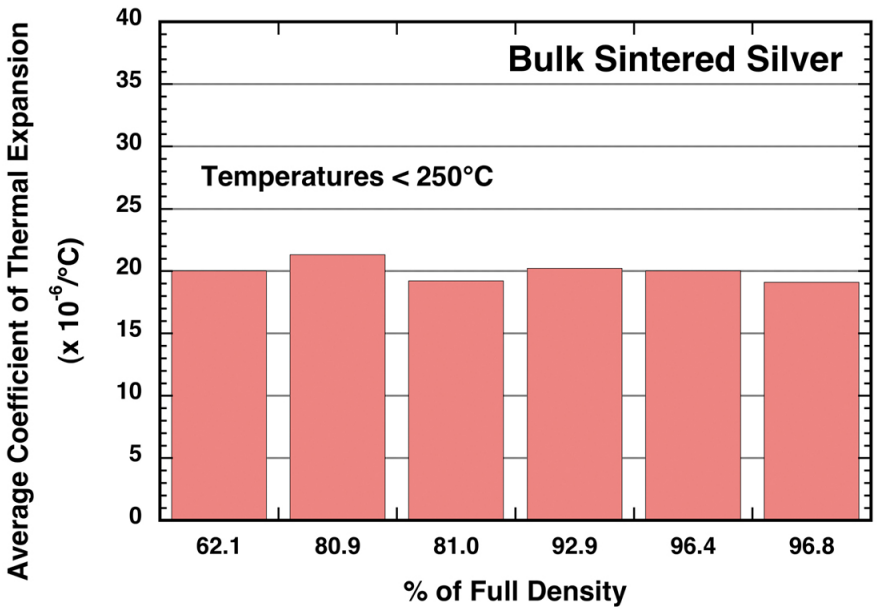

Figure 17. Coefficient of thermal expansion (CTE) as a function of porosity.

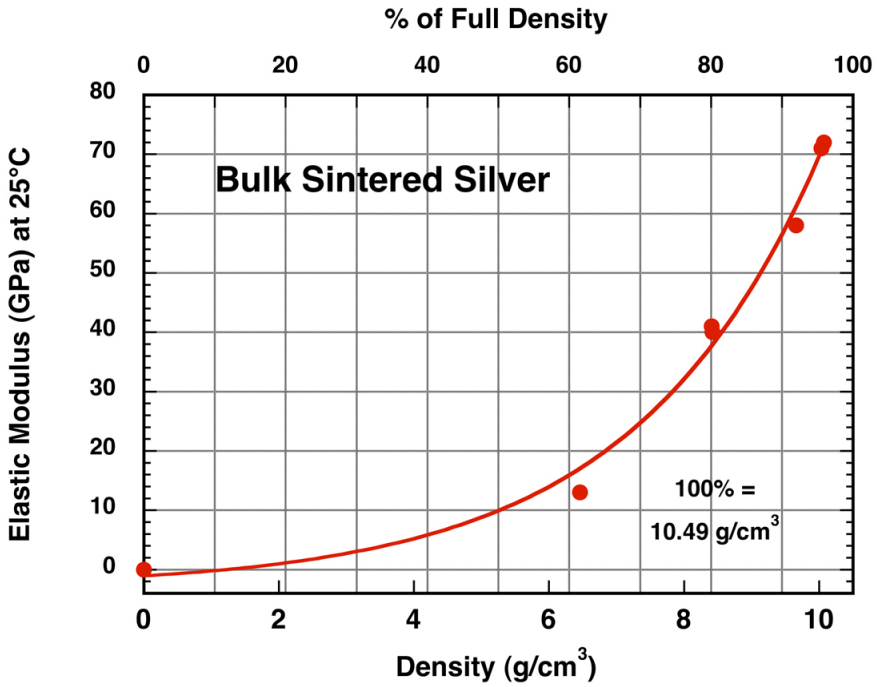

Figure 18. Elastic modulus (E) as a function of porosity at 25°C.

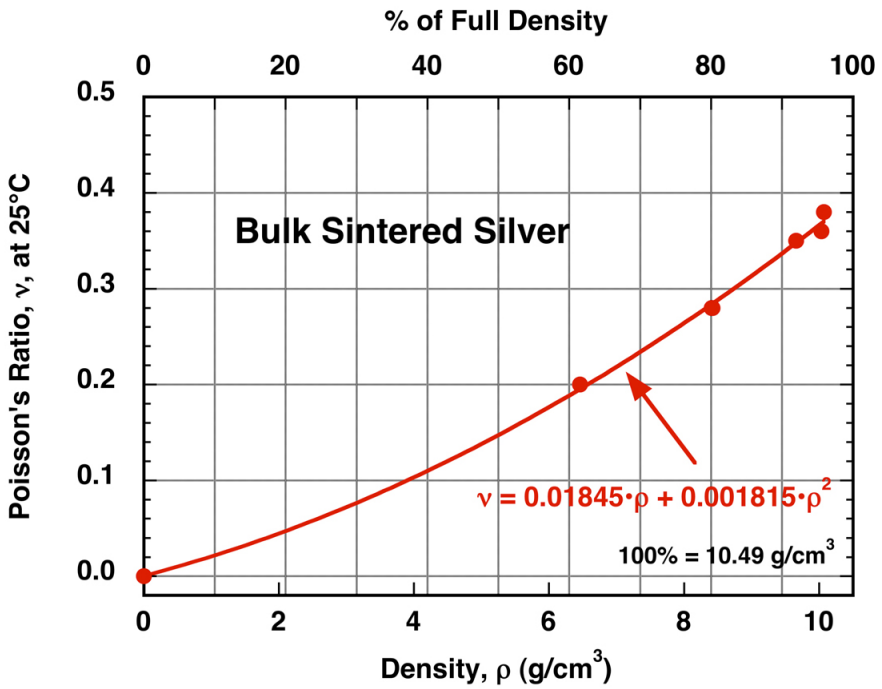

Figure 19. Poisson's ratio (ν) as a function of porosity at 25°C.

3.2.5. Yield Stress

Yield stress as a function of porosity is shown in Fig. 20. Yield stress decreased by ~ 70-80% when the density decreased from 97% to 62%. The yield stress was greater than 60 MPa for densities 83% and higher and ~ 20 MPa for a density of 62%.

Although the microstructure of the silver itself probably did not significantly affect the electrical, thermal, and elastic properties, it could have affected the yield stress response. A finer-grained structure usually deforms easier (i.e., has a lower hardness or yield stress) than a coarse-grained structure of the same material. It may then be suggested that micrometer-sized particle silver paste and nano-sized particle silver pastes produce equivalent electrical, thermal, and elastic properties but that nano-sized particle silver paste could have a lower yield stress than micrometer-sized particle silver paste (for the same porosity level).

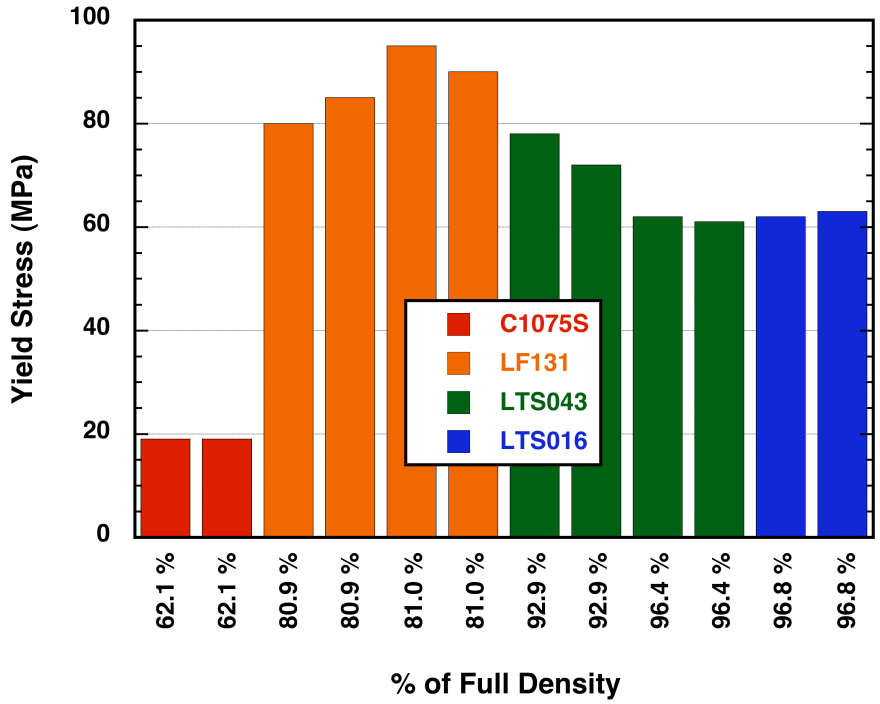

Figure 20. Yield stress (σ_Y) as a function of porosity at 25°C.

4. CONCLUSIONS

- Electrical resistivity. Electrical resistivities quadrupled from when density decreased from 97% to 62% and increased with temperature. At room temperature electrical resistivity was ~ 2 μΩ•cm for 93-97% dense silver, ~ 4 μΩ•cm for 81% dense silver, and ~ 8 μΩ•cm for 62% dense silver.
- Electrical conductivity. Given reciprocity exists between electrical resistivity and conductivity, electrical conductivities decreased by approximately one-fourth when density decreased from 97% down to 62% and they decreased with temperature. At room temperature electrical conductivity was 40-50 MS/m for 93-97% dense silver, ~ 25 MS/m for 81% dense silver, and ~ 10 MS/m for 62% dense silver.

- Thermal conductivity. Thermal conductivity decreased by approximately 80% when the density decreased from 97% to 62%. Thermal conductivities were temperature independent between -50 and 200°C for any given porosity level. At room temperature thermal conductivity was ~ 375 W/mK for 96% dense silver, ~ 350 W/mK for 93% dense silver, ~ 175 W/mK for 81% dense silver, and ~ 75 W/mK for 62% dense silver.
- Coefficient of thermal expansion. The average CTE up to 250°C was independent of porosity and was approximately 20 x 10^{-6}/°C.
- Elastic modulus. Elastic modulus decreased by approximately 80% when the density decreased from 97% to 62%. Elastic modulus was 72 GPa for 96-97% dense silver, 58 GPa for 93% dense silver, 40 GPa for 81% dense silver, and 14 GPa for 62% dense silver.
- Poisson's ratio. Poisson's ratio decreased by approximately 45% when the density decreased from 97% to 62%. Poisson's ratio was ~ 0.37 for 96-97% dense silver, ~ 0.28 for 81% dense silver and 0.20 for 62% dense silver.
- Yield stress. Yield stress decreased by ~ 70-80% when the density decreased from 97% to 62%. The yield stress was greater than 60 MPa for densities 83% and higher and ~ 20 MPa for a density of 62%.
- Although the silver microstructure probably did not significantly affect the electrical, thermal, and elastic properties, it could have affected the yield stress response. A finer-grained structure usually deforms easier (i.e., has a lower hardness or yield stress) than a coarse-grained structure of the same material. It may then be suggested that micrometer-sized particle silver paste and nano-sized particle silver pastes produce equivalent electrical, thermal, and elastic properties but that nano-sized particle silver paste could have a lower yield stress than micrometer-sized particle silver paste (for the same porosity level).
- The results show using appropriate electrical, thermal, and mechanical properties of sintered silver joints in the modeling power electronic devices will involve knowing what porosity exists in the sintered silver joint.

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APPENDIX: Silver Paste Manufacturer Technical Literature

Heraeus

Conductors

C 1075 S / SD

Silver Conductor Paste

Description:
C 1075 S / SD are low cost, oxide-bond pure Ag conductor materials. They offer cost savings over standard Ag / Pd formulations, while maintaining the advantages of leach resistance and aged adhesion. C 1075 S is for use on alumina, and C 1075 SD is for use in multilayer applications, in combination with the dielectric IP 9117 series.
Resulting films are dense and uniform. These pastes offer the best characteristics of a fritless material, together with the advantages of a mixed-bond system.

- Excellent solderability and leach resistance
- Solderable on alumina and dielectric IP 9117 series
- Compatible with HERAEUS resistors
- Good initial and aged adhesion, even after multiple firings
- Inner layer for multilayer applications
- Outstanding conductivity

Processing:
1. Spatulate well prior to processing. When stored in a fridge: The paste should have acquired room temperature before being opened, to avoid condensation.
2. Print trough a 200 – 325 mesh stainless steel screen. Total thickness: 50 – 110 µm
3. Level at room temperature for 5 – 10 minutes.
4. Dry at 150°C for 10 – 20 minutes.
5. Fire at 850°C (peak) for 10 minutes, and with a total firing cycle time of c. 30 – 60 minutes.

Thinner: HVS 100

Properties (Pastes):

Viscosity:	30 – 50 Pas (25°C, D = 100 s^{-1})
Solids:	81.5 % +/- 1.0 %
Printing Speed:	Up to 20 cm / s
Coverage:	c. 80 cm^2 / g (FFT: 12 µm)
Shelf Life:	6 months, with correct storage (2 to 23°C, in a cool, dry, dark place, and with the container tightly shut).

Properties (Fired) [1]:

Fired Film Thickness [2]:	C 1075 S	13 – 16 µm
	C 1075 SD	12.5 – 15.5 µm
Line Definition:	≥ 125 µm	
Resistivity [2]:	≤ 2.2 mΩ / □ (FFT: 12 µm)	
Solderability: (62Sn / 36Pb / 2Ag)	Good – ≥ 95% (235°C, 5s dip) (assessment acc. DIN 41850-2E)	
Adhesion: (62Sn / 36Pb / 2Ag)		
Initial:	C 1075 S	≥ 22 N
	C 1075 SD	≥ 20 N
Aged: (48 hrs, 150°C)	C 1075 S	≥ 20 N
	C 1075 SD	≥ 18 N
Leach Resistance: (62Sn / 36Pb / 2Ag)	≥ 4 dips (235°C, 10s each)	

Compatibility:

Dielectrics:	IP 9117 series
Resistors:	R 8900 / D / E / ED series. R 400 H / L series

1 Typical property based on laboratory test methods. For optimum results all materials should be fired in a profiled furnace supplied with dried, hydrocarbon-free and other contaminant-free air (PP-1).

2 Measured after printing with a 200 mesh steel screen; screen thickness and emulsion thickness combined was c. 100 µm, and the resultant printed track was 500 µm wide.

Heraeus

Conductors

C 1075 S / SD

Silver Conductor Paste

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DuPont LF131

SILVER CONDUCTOR

Technical Data Sheet

Product Description

DuPont LF131 silver conductor composition is intended to be applied to ceramic substrates by screen printing and firing in a conveyor furnace in an air (oxidizing) atmosphere. It has been developed to form interconnection tracks and pads for component and lead attachment, in hybrid microcircuits and networks.

Product Benefits

- Excellent fine line resolution
- Lead, cadmium and nickel free*
- Excellent solderability with SnPb, SnAg and SAC solders.
- Excellent green-strength
- Compatible, sequentially or co-fired, with DuPont LF151 dielectric as a crossover or inner layer conductor

*Cadmium, lead and nickel "free" as used herein means that these are not intentionally added to the referenced product. Trace amounts however may be present.

Processing Conditions

Printing

200 - 325 mesh stainless steel, 0.3 - 0.5 mil emulsion. Print speeds up to 20 cm/s.

Drying

Allow prints to level for 5 - 10 minutes at room temperature, then dry for 10 - 15 minutes at 150ºC.

Firing

850ºC peak held for 10 minutes on 30 minutes cycle in air (oxidizing) atmosphere.

Typical Composition Properties

Test	Properties
Viscosity (Pa.s) Brookfield HBT, UC&SP @10 rpm, 25°C]	83 - 145
Thinner	4553

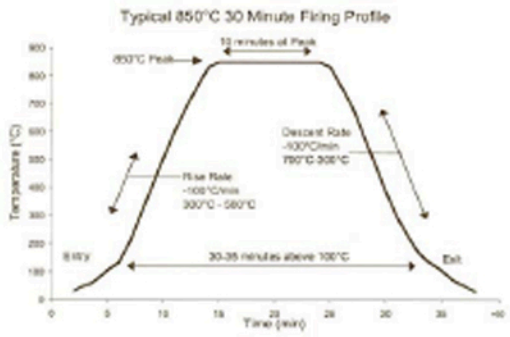
Typical Fired Properties

Shrinkage (dried to fired) [%]	56 - 62
Mean fired thickness: (using 200 mesh) [µm]	13 - 19, typical 16µm
Coverage @ 16µm fired (cm²/g)	67 - 72
Resistivity (mΩ/sq @ 16µm)	< 2.0
Soldered Adhesion[1] Initial (N) Aged (1000hrs@ 150ºC)[N]	 > 20 ≥ 18

[1] 90º wire peel test on 2mm x 2mm pad soldered with 95.5Sn/3.8Ag/0.7Cu Solder using mildly activated flux, Alpha 611 on both Alumina. DuPont LF131 is recommended for use on dielectric only for crossover and inner layer applications

This table shows anticipated typical physical properties for DuPont LF131 based on specific controlled experiments in our labs and are not intended to represent the product specifications, details of which are available upon request.

Typical 30-minutes fire profile



Storage and Shelf Life

Containers should be stored, tightly sealed, in a clean, stable environment at room temperature (<25°C). Shelf life of material in unopened containers is six months from date of shipment. Some settling of solids may occur and compositions should be thoroughly mixed prior to use.

Safety and Handling

For Safety and Handling information pertaining to this product, read the Material Safety Data Sheet (MSDS).

DUPONT
The miracles of science™

For more information on DuPont LF131 or other DuPont Microcircuit Materials products, please contact your local representative:

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MCMLF131 (3/2010)

Heraeus

Technical Datasheet

Silver contact paste
LTS 016 & 043 Series
Silver Paste For Low Temperature Sinter Technology (LTST)

mAgic
Microbond Silver Interconnect

1. Description

The silver pastes were developed for the Low Temperature Sinter Technology (LTST)
The pastes are used for power electronic applications for operating temperature above 150°C and replaced lead free and high lead containing solder alloys. They also increase the reliability of standard devices.
At the moment 2 versions available. The LTS 016-01P1 for printed layer thicknesses until 50 µm and the LTS 043-04P2 for layers above 50 – 100 µm.

Characteristics

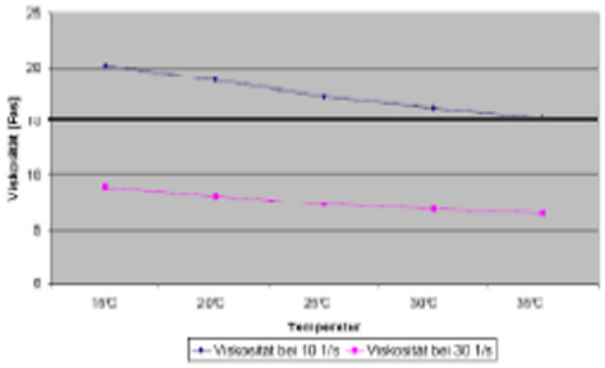
- Excellent printing
- Screen and stencil printing
- Long process time
- Long green strength
- Some processing parameters between 20 and 32°C
- Defined drying
- High electrical and thermal conductivity

2. Typical Properties Of Pastes Before Sintering

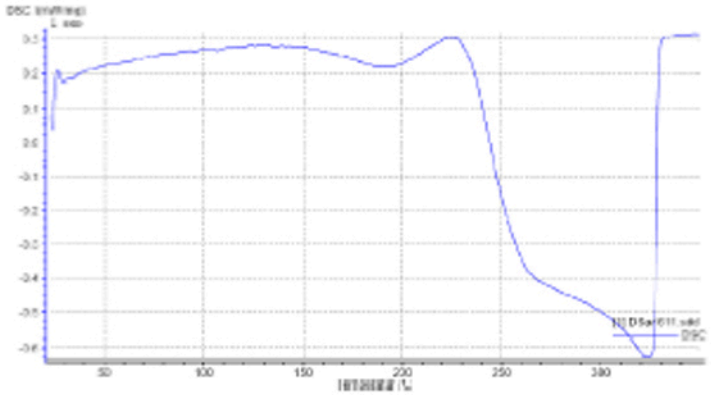
Silver content	83 ± 2 %	
Particles	< 20 µm	
Viscosity[1]	5 - 15 Pas	LTS 016-07P1
	15 - 35 Pas	LTS 043-04P2
Processing time[2]	4-6 h	
Time between print and place [3]	4-6 h	

1) At shear rate D=30 s^{-1}. Platte cone system with cone 2°, Temperature 23°C.
2) Time which the pastes can proceed on the printer
3) Max. time between printing and placing the components (depends on the environment)

Dependency of viscosity to temperature



DSC Analysis
Atmosphere air; Heat rate 10 K/min



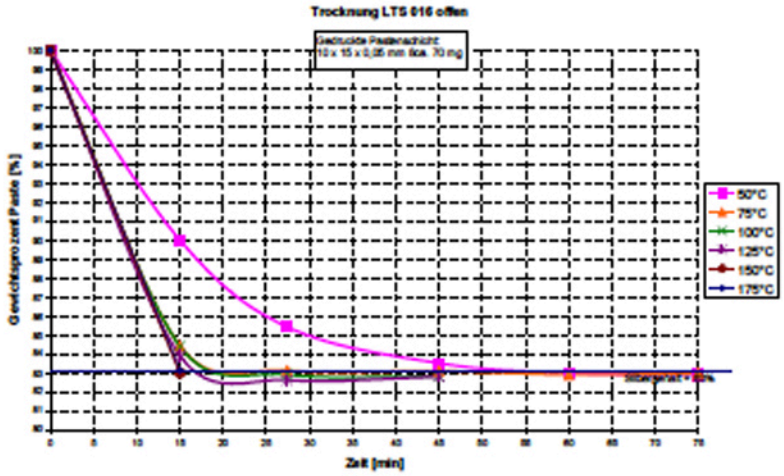
The silver contact pastes sintered between 220 and 250°C.
Recommended process temperature ≥ 250°C

3. Recommended process parameters

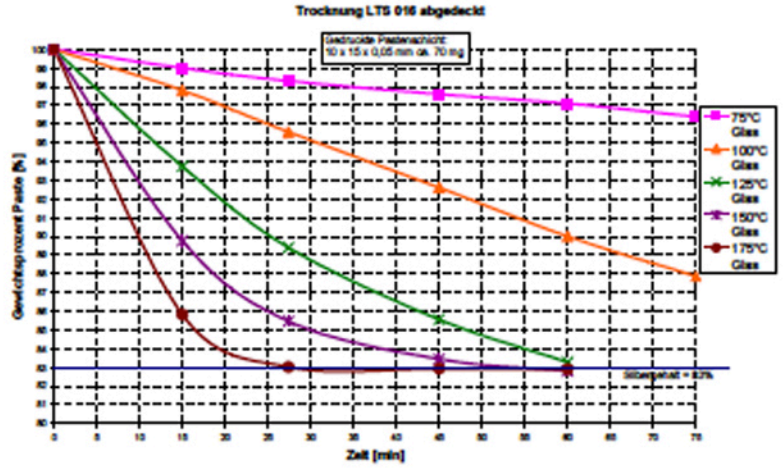
Print

- The jars should reached the room temperature before opened to prevent condensation.
- Before using the paste should be homogenized.
- Pastes can print with screen and stencil.
- Typical parameters for screen printing:
  Mesh 200 – 325mesh; 45°-60° PU-squeeze
- Typical parameters for stencil printing:
  50 µm stencil thickness **(LTS 016-07P1)**
  50 – 100 µm stencil thickness **(LTS 043-04P2)**
  50 mm/s print speed
  0,1-0,3 N/mm print pressure (200mm force 20-60N)
  5-10 mm/s separation speed
- Possible print time at 20 – 32°C is 4 -6 hours.
- The pastes keeps sticky between 2 and 6 hours depending on the environment
- The paste wills typical dried before sintering. The graph shows the printing behavior of a 10x15x0,05 mm printed layer at different temperature.

Drying of an unsealed paste layer



Drying of a sealed paste layer



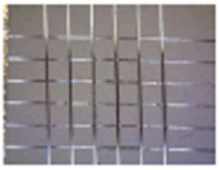
Sintering

- Gold- and Silver surfaces are recommended
- The parameters are defined by the customer
- Literature (German):
  - Die Niedertemperatur-Verbindungstechnik der Leistungselektronik; Mertens Christian, VDI Verlag 2004; ISBN 3-18-336521-9
  - Aufbaukonzepte für die Leistungselektronik mit der Niedertemperatur-Verbindungstechnik; Rudzki Jacek; VDI Verlag 2006; ISBN 3-18337621-0

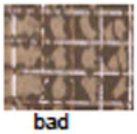
4. Sintering test

Profile: Peak time / -temperature	30˝ / 280°C
Grid cut (acc. to DIN EN ISO 2409)	pass

Grid cut LTS 016-01P1 on DCB-Substrate (surface gold)



good

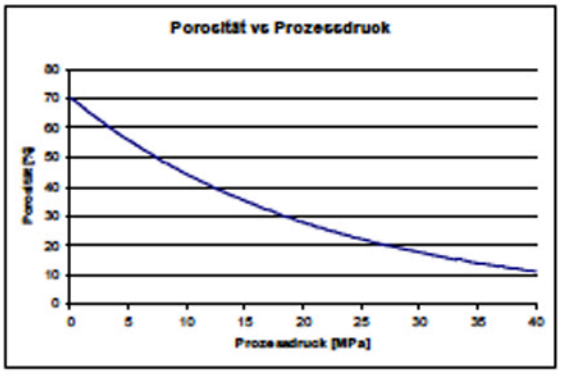


bad

Porosity (without pressure)	60 – 70%

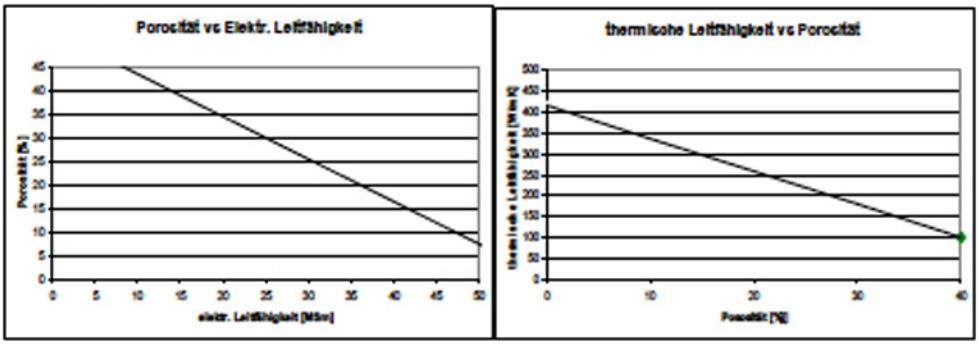
For low porosity and high conductivity a high pressure while sintering is necessary.

See reference curve (source VDI Verlag; Autor Mertens)



Porosity vs. Process pressure

Electrical and thermal conductivity (source VDI Verlag, Autor Mertens)



5. Packaging

Available in jars
50, 150 und 250 g
On request in cartridges

6. Storability

- Keep in jars
- Min. 6 month at 2-10°C
- Min. 3 month at 20-25°C.
- Before using the paste must be homogenized

Production Locations

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