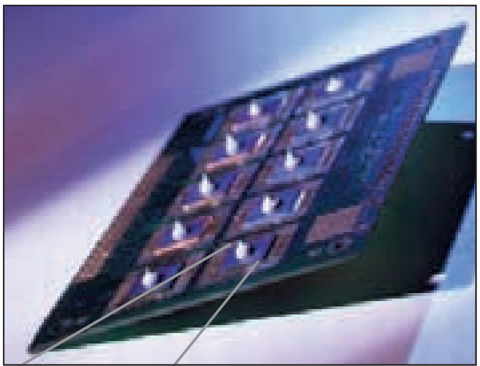
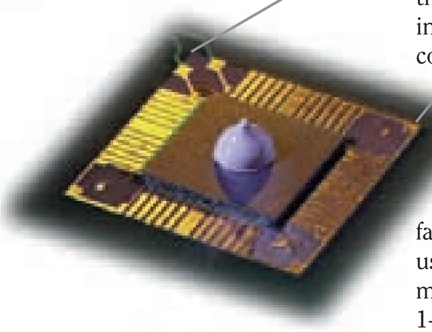
Greases with high thermal conductivity and low resistance

Minimise the thickness of grease in the interconnection

Many applications require the use of a removable interface material along with the need to minimise the bond line and thermal resistance. The cost efficient Gelease Grease will be a perfect solution for volume production.





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Since the thermal interface material is typically the least thermally conductive material in the heat path away from semiconductor die inside the package to the heat sink (FanSink), it is best to minimise the thickness of this material. Ideally, if the heat sink and device package surfaces were truly flat, one could use a wide variety of interface materials in a thickness of 1-2 mils. Unfortunately, the cost of controlling the planarity of these surfaces is prohibitive and therefore materials which compensate for the gap variation and surface roughness are preferred. In addition, one wants to minimise the pressure placed on devices in flip chip and other sensitive packages (to eliminate die cracking during temperature or power cycling) but still achieve good surface contact. Good interfacial contact is critical in order to achieve the lowest thermal resistance and this makes greases an ideal material for use between heat sinks and devices.

Many earlier developed greases could not keep the systems at their preferred operating temperatures. Isothermal thermal gravimetry analysis was used to gather weight loss data at specific temperatures. These tests were typically run from several hours to 48-60 hours (over a weekend). To gather data over a longer period of time, a 30-day weight loss test at 100°C was run using several 2 gram samples in small aluminum pans. The samples were weighed at 25°C at predetermined intervals. Viscosity was measured using a Brookfield Viscometer, Model DV-II+ at 1 and 10 RPM at 25°C. Specific gravity was determined according to ERF 3/82.

Dispensability was determined initially by dispensing candidate materials from a 10 cc EFD syringe on a EDF XL-1000 air-driven dispenser onto an appropriate substrate. Further testing was performed on Asymtek Automove 402 and Century Dispense systems.

Bleed or separation was determined by hot centrifuge testing for 66 hours at 65°C at 425 RPM. This testing was accomplished by placing 25.0 grams of the material in a glass tube, running the test and then measuring the amount of fluid that had separated and floated to the surface. Bleed was also determined by placing the material in question on a small aluminum pan, heating at 150°C for 24 hours and then doing an optical measurement of the bleed/separation.

Thermal conductivity of samples was determined using a Dynatech C-matic Conductivity Tester as per ASTM F-433, Thermal Conductivity by Heat Flow Meter. This equipment was modified slightly with a ring to hold the grease in place between the platens during the test. Thickness of the grease could be adjusted by changing the thickness of the ring.

Thermal greases should exhibit high thermal conductivity, high thermal stability and low surface tension (to allow conformance to surface roughness and wet the heat transfer surface). In addition, they should be non-corrosive, electrically insulative, phase stable and resistant to shear-induced flocculation.

Critical to success were choice of the appropriate non-reactive fluid, incorporation of a high percentage of a suitable high thermal conductivity filler and the selection of the appropriate low outgasing additives to improve performance.

Two products were developed which met the above criteria and

Table of Gelease key achievements
Viscosity - 150,000-500,000 cps @ 10 RPM and < 1,000,000 @ 1 RPM
Phase Separation (by hot centrifuging) < 1%
Excellent Dispensability/Screen Printability
Thermal Conductivity > 3 watts m/°C
Weight loss < 1% after 30 days @ 100°C
Weight loss < 1% after 1 hour @ 300°C
Projected lifetime of > 10 years @ 100°C with < 1% weight loss
Pass Temperature Cycling from -55 to +150°C, Power Cycling from 25 to +110°C,
85°C/85% RH and High Temperature Bake @ 135°C

PROPERTY	**GREASE A**	**GREASE B**
Carrier Type	Silicone	Silicone
Viscosity - 25°C		
@ 1 RPM	600,000 cps	825,000 cps
@ 10 RPM	165,000 cps	- -
Thixotropic Index	3.6	3.9
Specific Gravity	2.92	2.95
Color	Grey	Grey
Continuous Operating Temperature (°C)	200	200
Shelf Life @ 25°C	6 months	6 months

***Table I:** Physical properties of Greases A and B*

PROPERTY	**GREASE A**	**GREASE B**
Thermal Conductivity (watts/m°C)	3.3	4.1
Dielectric Constant @25°C		
@ 1 kHz	--	8.34
@ 10 kHz	7.62	7.82
@ 100 kHz	7.40	7.53
@ 1 MHz	7.21	7.30
Dissipation Factor @25°C		
@ 1 kHz	--	0.1050
@ 10 kHz	0.0257	0.0389
@ 100 kHz	0.0189	0.0244
@ 1 MHz	0.0215	0.0252

***Table II:** Thermal and electrical properties of Greases A and B*

PROPERTY	**GREASE A**	**GREASE B**
Weight loss after 1 hour @ 300°C	1%	1%
Weight loss after 30 days @ 100°C	0.129%	--
Separation by hot centrifuge testing	0.26%	--
bleed	nil	nil

***Table III:** Weight loss and separation test results*

TEST	**CONDITIONS**	**RESULTS**
Power Cycle	5000 Cycles @ 25-110°C	Passed
Temperature Cycle	500 Cycles @ -55 to +150°C	Passed
Humidity	500 Cycles of 85°C/85% RH	Passed
Aging	500 hours @ 135°C	Passed

***Table IV:** Reliability test results for Grease A*

a summary of their physical and electrical properties is given in *table I* and *II*.

Both greases are silicone; based systems which contain the same carrier but differ in filler content. (Grease B having the higher filler content). Both Greases A and B are lower in viscosity than comparative high thermal conductivity greases which allows them to be easily dispensed in automated equipment or screen printed/stencilled. Both materials were reproducibly dispensed using both Asymtek Automove 402 and Century Dispense systems. Although Greases A and B are lower in viscosity that many commercially available systems, they contain higher filler loadings and are sufficiently thixotropic to resist separation. This was confirmed by Hot Centrifuge testing (shown in *table III*) where Grease A had only 0.26 percent separation after 60 hours of centrifuging at 66 C at 425 RPM. In addition, these products showed virtually no bleed in laboratory tests.

As described in *table II*, the thermal conductivity of A is 3.3 and that of Grease B is 4.1. These numbers are significantly higher than most available boron nitride and aluminum nitride greases and comparable to diamond-filled greases. Although there are claims that a number of diamond-filled greases have thermal conductivity as high as 10-20 watts/m C, these systems test out in the 3-5 watts/m C range. The other electrical properties shown in this table also indicate that these two greases show excellent electricall insulative properties.

More appropriate for actual applications is thermal resistance testing. Theta JC for Grease A on one flip chip device was measured at 0.5 C/watt. Thermal resistance is affected by bond line thickness and in another study with Grease A and B, the thermal resistance for both materials was approximately 0.2 C/watt at 1 mil and approximately 0.6 at 10 mils. For this reason, it is suggested to keep the cross sectional thickness of the grease as thin as possible.

Weight loss results are summarised in *table III* and the testing run under both conditions show that Greases A and B are very thermally stable. They met the less than 1 percent weight loss requirement at different temperatures and conditions as outlined in our “Targeted Properties List.” The weight loss of Grease A at 100°C after 30 days is only 0.129 percent. Grease A exceeds our targeted 10-year lifetime target and should provide a greater than 20-year lifetime.

Greases A and B were subjected to a variety of environmental and reliability tests and have performed very well. The results from some of the typical reliability tests are summarised in *table IV*. Both materials survived greater than 5000 power cycles from 25 to 110°C with the thermal resistance changing less than 20 percent. Grease A showed less than a 15 percent thermal resistance change after 500 temperature cycles from -55 to +150°C. Grease A also passed 500 hours of 85 C/85 percent RH testing as well as 500 hours of high temperature bake at 135°C.

Greases A and B have been shown to have superior performance over conventional thermal greases and thermal performance on par with greases containing exotic fillers such as diamond dust. They have shown low weight loss at elevated temperatures, good temperature and power cycling performance. As judged by Hot Centrifuge Testing, these greases show a very low tendency to separate over time. In addition, these greases are easily applied using conventional dispense and stencilling procedures, although we are continuing to do further testing on Greases A and B along with further development work on high thermal conductivity greases. Both greases met the target criteria and have been commercialised under the name Gelease. ■

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