Quality Report

Thermal paste analysis on FEASTMP modules variants

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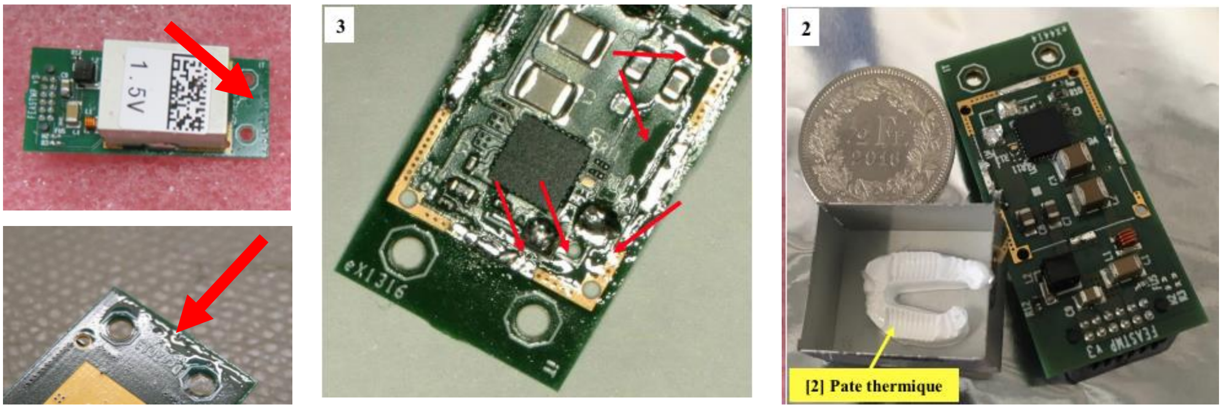
1. Introduction

The presence of oil residues on the power modules printed circuit board were recently reported. This residues can be easily wiped out during assembly. The origin of this leak is the dissociation of the thermal paste located between the shield and the main coil. This thermal paste is a silicone based compound, filled with ceramic powder to provide the required thermal conductivity. The dissociation results from the intrinsic properties of the silicone oil, it leaks very slowly from the coil towards the printed circuit board. Some of this oil can leak under the shield and becomes visible.



2. Material identification

The thermal paste in the FEASTMP modules and FEASTMP-CLP modules is a silicone compound, ceramic filled thermally conductive paste with reference Thermally Conductive Paste Type H from Termopasty (datasheet in annexes). The silicone provides the required viscosity to apply the paste, and the ceramic powder is the thermal conductor material. This thermal paste has been chemically analyzed at the CERN chemical analysis laboratory, confirming the exclusive presence of silicone compound:

https://edms.cern.ch/document/2109354/2

3. Radiation tolerance properties of silicone oils

The radiation tolerance refence material proceeds from the Radiation Damage and Radiation Tolerance CERN site:

https://radiation-damage.web.cern.ch/

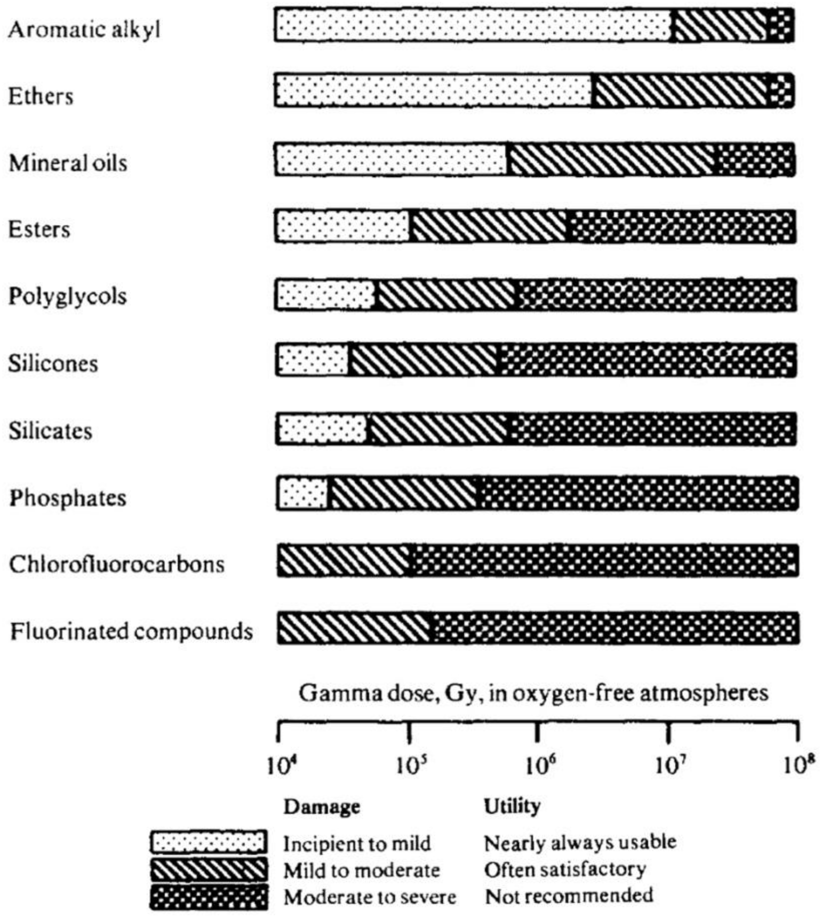
Silicone oils are normally used in high energy accelerators, primarily used as electrical insulators in magnets (CERN-2001-006, page 14):

Radiation Damage Materials Table

CERN-2001-006 on CDS

The silicone oils are listed to moderately stand radiation up to 50 Mrad. The upper dose limit listed for silicone oils in CERN-HS-RP-093 is set at 50 Mrad (Annex 6, page 31).

Compilation of Radiation Damage Test Data



The degradation of the tested insulating silicone oil is a reduction of its insulation properties (CERN-HS-RP-093, Insulating Oil tests, page 157):

- The breakdown voltage and the viscosity is increased by 13% at 50 Mrad.
- The insulation resistance is reduced by 33% at 50 Mrad.
- The oil gelatinises above 100 Mrad.

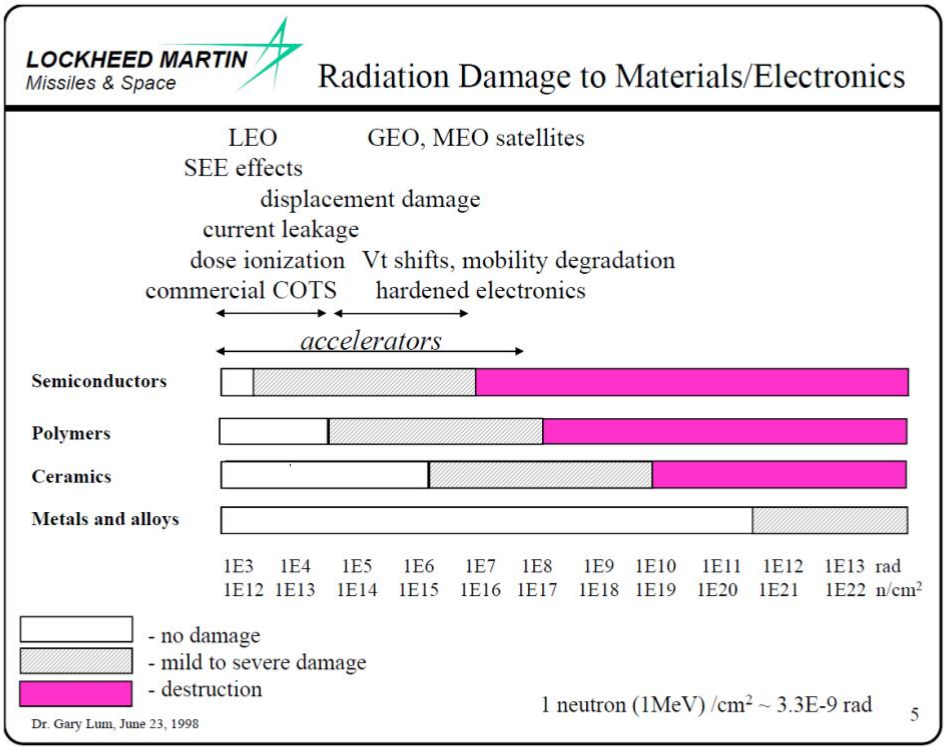
It must be noted that the dielectric strength of silicone oils is very high, of at least 10 MV/m.

The volume resistance is typically 10^{14} Ω.cm at room temperature and 10^{13} at 150 ºC, comparable to the volume resistance of glass. The observed resistivity degradation at 50 Mrad leaves the volume resistance still above 10^{13} Ω.cm and still two orders of magnitude larger than that of air (10^{11} Ω.cm). These properties are fully compatible with the low voltage operation of the FEASTMP power modules.

4. **Radiation tolerance of the ceramic filler**

The filler is made of ceramic powder and is tolerant to radiation. There is no damage up to 100 Mrad and the damages develop at 10 Grad. Its use is safe for the power modules.

Radiation Damage Materials Reference



5. **Improvements**

The thermal paste type H from Termopasty has a thermal conductivity of 0.78 W/m.k. It will be replaced by the KP98 thermal paste from Kerafol (datasheet in annexes) that is also a silicone based paste but with a thermal conductivity of 6 W/m.K. It is used by the new CMS Pixel power modules and was successfully operated up to 1 Mrad already without issues. Because it is still a silicone based paste, minor leaks can still occur.

6. **Conclusions**

- The thermal paste is a ceramic powder filled silicone oil. It has a large resistivity and breakdown voltage.
- The silicone can leak slowly onto the printed circuit board. Because of its high volume resistivity, this has no incidence on the performance of the power module.
- The radiation damage reference documents indicate that silicone oils, comparable to those used in the thermal paste, will typically degrade at 50 Mrad. The volume resistance is reduced but is still larger than the one from air and is comparable to glass.
- Beyond 100 Mrad the viscosity of the oil is degraded, the oil will gelatinise. This will however fix the paste in place, and the thermal contact through the ceramic filler is preserved.
- Besides the silicone leak, the material will preserve its performance during all the lifetime of power module, up to 50 Mrad. The degradation of the oil up to 100 Mrad will have no effect on the thermal properties of the paste.
- The Type H thermal paste will be replaced by the KP98 paste from Kerafol that has improved thermal conductivity. Silicone residues can still potentially leak, but this will have no effect of the power module performance.

7. Annex

TermoPasty®

Product Technical Data Sheet

PRODUCENT: AG Termopasty Grzegorz Gąsowski
ul. Kolejowa 33 E, 18-218 Sokoły, tel. 86 274 13 42

Thermal Conductive Paste H

Silicon compound facilitates the transfer of heat between electronic components and the radiator. It is essential to the proper operation of all kinds of temperature sensors, protects against weathering, prevents thermal breakdowns. It is characterized by a very good chemical resistance to oxidation; the effect of aqueous solutions of acids, alkali and salts; sulphur dioxide and ammonia. It has a wide operating temperature range: from - 50°C to 200°C.

Application:

- temperature sensors
- facilitates the flow between electronic components and the radiator

Physicochemical properties:

Parameters	Result
density at 20°C	2.58 g/cm3
flash point	350°C
solidification point	-50°C
refractive index:	1,405
specific heat at 50°C	0,243 Cal /g K
heat transfer coefficient at 0-150°C	0,78 W/m K
dielectric constant at 100 Hz	4,7 (±0,1)
volume resistance	5 x 10^{14} Ohm x cm
tangent of the angle of the dielectric loss index at f=100 Hz	0,020 (±0,003)
operating temperature range	-50-200°C

Packagings:

Volume	Collective packaging	Item Code
0,5 g (softpack)	20	ART.AGT-144
7 g (tube)	100	ART.AGT-055
25 g (syringe)	2 or 16	ART.AGT-056
100 g (container)	6 or 36	ART.AGT-057
800 g (cartridge)	4	ART.AGT-120
1 kg (container)	1	ART.AGT-058
5 kg (bucket)	1	ART.AGT-059

Warehousing

Store in a well-ventilated, cool and dry place. Keep containers tightly closed when not in use. Protect against sunlight exposure.

KP 97, 98, 99 & KP 12
KERATHERM® Thermal Grease

Applications
- notebooks
- desktop CPU´s
- IGBT unit

Benefits
- syrings: 5 ml
- cartouche: 75 ml / 310 ml / 360 ml
- cans: 0.5 kg / 1.0 kg

Properties	Unit	KP 97	KP 98	KP 99	KP 12 silicone free
Colour		white	grey	anthracite	silver
		← soft/pasty →			
Thermal Properties					
Thermal resistance R_{th}	K/W	0.0120	0.0100	0.0068	0.0060
Thermal impedance R_i	°Cmm²/W	4.5	4.1	2.7	2.2
	Kin²/W	0.007	0.0064	0.0042	0.0033
Thermal conductivity λ	W/mK	5.0	6.0	9.2	10.0
Electrical Properties					
Electrical conductivity (according to DIN 51412-1)	pS/m	0	0	0	53
Mechanical Properties					
Measured thickness (+/-10%)	mm	0.025	0.025	0.025	0.025
Physical Properties					
Application temperature	°C	-60 to +200	-60 to +200	-60 to +200	-60 to +150
Density	g/cm³	2.1	2.2	1.9	1.4
Viscosity *	Pas	70 - 110	110 - 150	90 - 140	30 - 60
Total mass loss (TML)	Ma.-%	< 1.3	< 1.5	< 0.80	< 0.1
Possible thickness	mm	← variable →			
Long therm stability (1000h / 85°C / 85 % relativ humidity)					
Thermal resistance 1000h	K/W	0.0120	0.0080	0.0068	0.0060

*Shear rate 4s⁻¹ / 25°C

KERATHERM® Thermal Greases are ceramic-filled single component silicones with a high thermal conductivity. The non-crosslinked thermal compounds do not dry out. The silicone components do not leak from the compound.

The thermal grease KP 99 is a high-quality thermal grease. The homogeneous and thixotropic grease shows a very good fluidity thanks to its good viscosity characteristics. An optimum surface adaptation is guaranteed.

The silicone free thermal compound KP 12 consists of synthetic, thermal polymers and is suitable for a fast and effective heat dissipation. The paste is particularly suitable for silicone sensitive applications.

The KP´s long-term stability guarantees full operability during the entire life time of the product. Under normal application conditions, KERATHERM® Thermal Grease does not cure, dry out or melt. Special storage of KERATHERM® "Thermal Grease" is not required, therefore it can be stored under normal climate conditions for up to 12 months after manufacturing date.

If any separation of the filler materials becomes evident, the KP´s must be mixed thoroughly before use.

✓ Special packing on request!

Data for engineer guidance only.
Observed performance varies in application.
Engineers are reminded to test the material in application.