THE THERMAL AND MECHANICAL PROPERTIES OF GLUES FOR SCT ATLAS MODULES ASSEMBLING

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Abstract

We perform the measurements of $C_{kt}-$the coefficient of thermal conductivity of two types of glue proposed for using in mechanical structure of the SCT modules of ATLAS .We compare the thermal property of the commonly used electronic industry applications glue family ARALDITE and $Si-organic$ glue "ELASTOSIL 137-182" . The coefficients of the thermal conductivity for Boron nitride filled ARALDITE 2011 and ELASTOSIL 137-182 are presented. The value of the strength at tension was tested. The main results of the our tests are in agreement with values specified by manufacturer.

Introduction

To assist power dissipation in high-density electronic devices, like the SCT ATLAS module ref.[1], there has been an increasing need for high-thermal-conductive materials. As shown in ref.[2], one of the "weakest" point in the module construction is the glued thermal contact between the AlN and TPG elements of the spine. So, the glue thickness in this connection, about $50\mu m$, raises the temperature of the detector by $\sim 2.2^0C$. There exist a few ways to reduce the weakness of this point: a reduction of the thickness of the glue layer to the minimum and by using the suitable type of glue with maximal value of the coefficient of the thermal conductivity. Our proposal is to use both of them. The minimization of the thickness of the glue layer in this connection can be made by using well controlled tolerances in connecting parts and by arrangements of dimensions inside regions of the tolerances . The use of the type of glue with highest value of the coefficient of thermal conductivity gives addition reduction of the temperature gradient across the connection detector to cooling point. Following this way, the thermal property for two types of commercial available glues, ARALDITE and ELASTOSIL 137-182, are tested.

ELASTOSIL 137-182 and ARALDITE 2011.

For this test we use Boron nitride filled ARALDITE 2011 prepared according to following (in the weight parts) mixture composition:

$$\textbf{Part A} : \textbf{Part B} : \textbf{Boron nitride powder} = \mathbf{1:1:1.25}$$

The main properties of ELASTOSIL 137-182 specified by manufacturer are given in Table.1.

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The experimental setup

The principle of the method consists of measuring the temperature gradient across the glue layer if one side of the sample is heated, the opposite side is cooled and the value of the thermal flow is known. The measurements were done using a setup with a configuration very close to the one used by us for measuring the value of the coefficient of the transverse thermal conductivity of TPG ref.[3].

The test sample is clamped between two copper blocks. One of them is equipped with a heater, the other is cooled by an external cooler. Every block is equipped with 4 thermal sensors (Pt100).The schematic drawing of the setup is shown in Fig.1, its "equivalent" electrical analog shown in Fig.2. All our measurements are done inside a vacuum vessel at temperature near 0^0C at residual pressure near $10^{-2} mbar$. We measured the samples of AlN bars glued one to the other as cross connections as shown in Fig.3 . The thickness of the glue layer was controlled and adjusted by using the special shims to three values : $50\mu m$, $100\mu m$ and $200\mu m$ for both types of glue. The width of the AlN bars was $8mm$ and the thickness $500\mu m$. The glues layer had a cross section of $8mm \times 8mm = 64mm^2$. Three samples for each type of glue were tested.

Measurement of $C_{kt}-$ coefficient of thermal conductivity.

The value of the thermal resistance R_t of the sample can be easy determinated as slope of a linear fit to the measured dependence of ΔT on P, where ΔT—the temperature gradient between cooling and heating blocks and P— the thermal power conducted through the test sample from heating block to the cooling sink. In our measurements we take ΔT as difference of the mean temperature of the heating and cooling blocks (both values are averaged from four read-out sensors).

The value of R_t includes the R_{inner}— thermal resistance of the setup (quality of thermal contact of the sensors to blocks, thermal resistance along the thermal runway through copper blocks from the sample surface to the sensors, etc.) and R_{AlN}— the transverse thermal resistance of two AlN bars. The value of R_{inner} can be measured by "shorting" the setup (independent measurement without the sample, when the heating block is pressed to the cooling block). The coefficient of the thermal conductivity of AlN bars is known from independent measurements ($185\frac{W}{m\times K}$).

The result of the measurement of thermal resistance is shown in Fig.4 . The dependence of the resistance of the samples as function of the thickness of the glue layer is plotted in Fig.5 . According to our measurements the value of the coefficient of thermal conductivity is:

ELASTOSIL 137-184: $C_{kt} = 1.79\pm0.1\frac{W}{m\times K}$

ARALDITE 2011: $C_{kt} = 0.87\pm0.06\frac{W}{m\times K}$

The measured value of C_{kt} of ELASTOSIL 137-182 just fits to region specified by the manufacturer. The value of C_{kt} of Boron nitride loaded ARALDITE 2011 is in good agreement with independent measurement performed by another group in ref.[4].

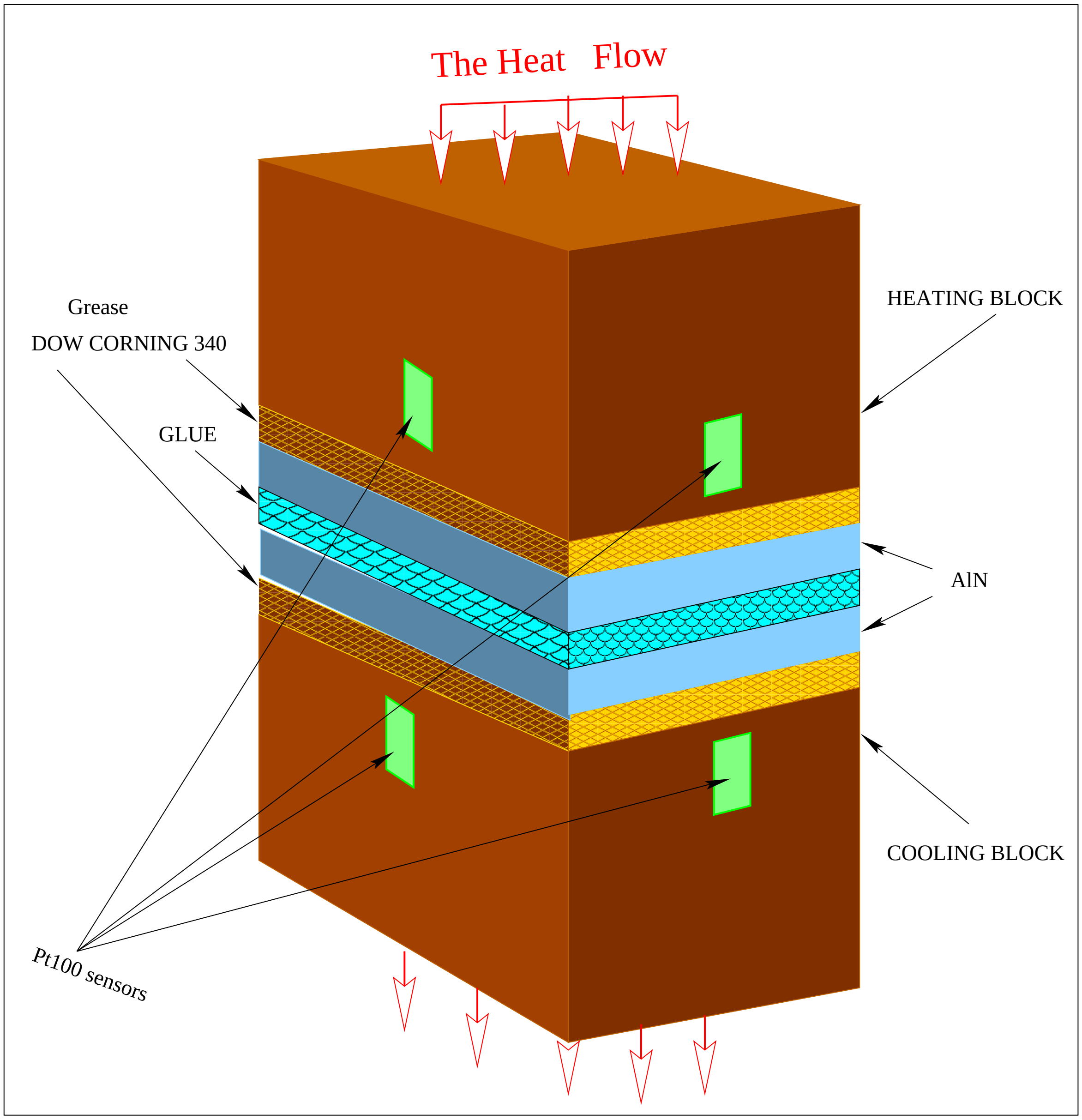

Figure 1: Schematic drawing of the measurement setup used for C_{kt}-measurement inside a vacuum vessel at pressure $10^{-2} mbar$.

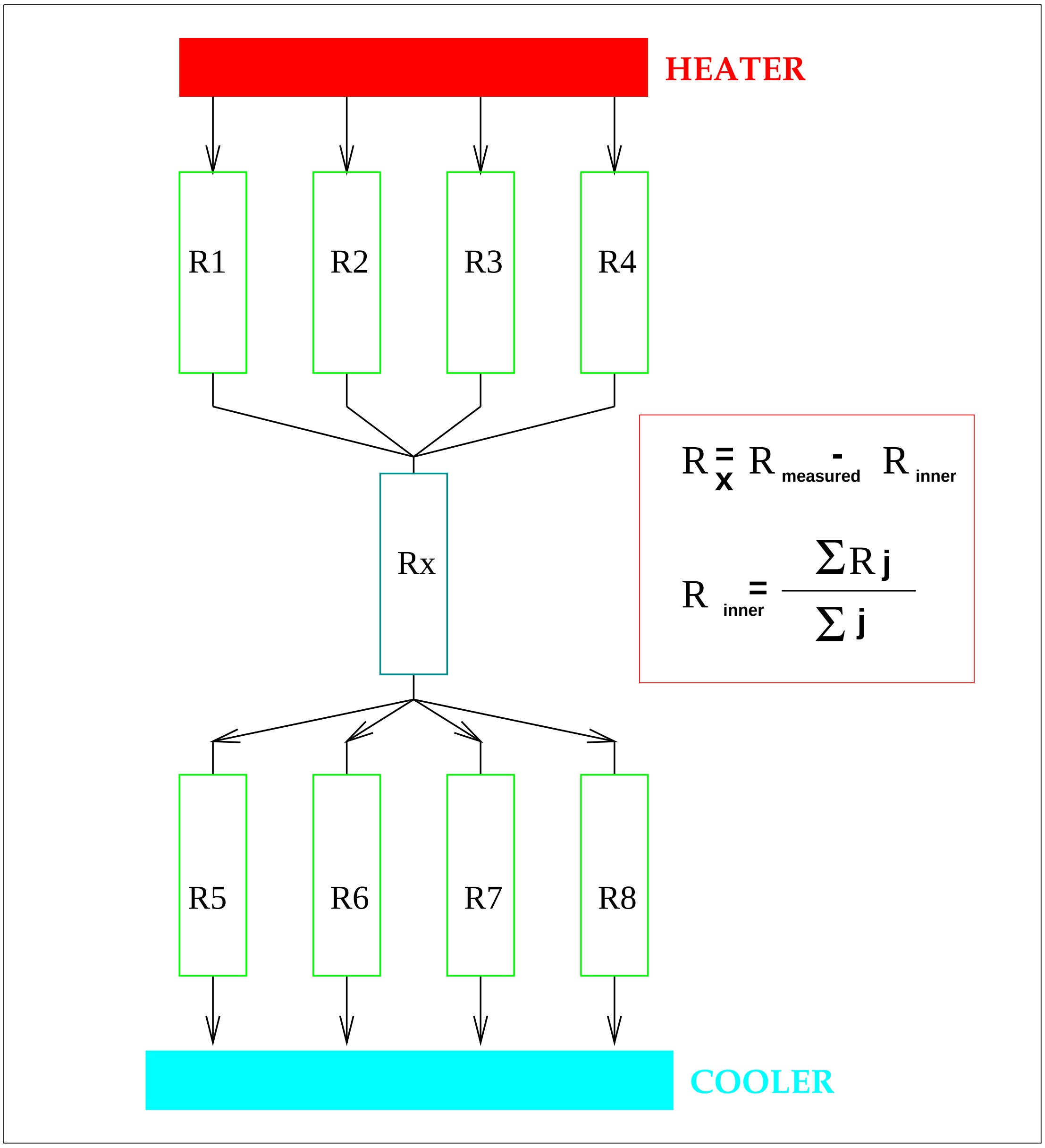

Figure 2: The "equivalent" electrical analog of the setup.

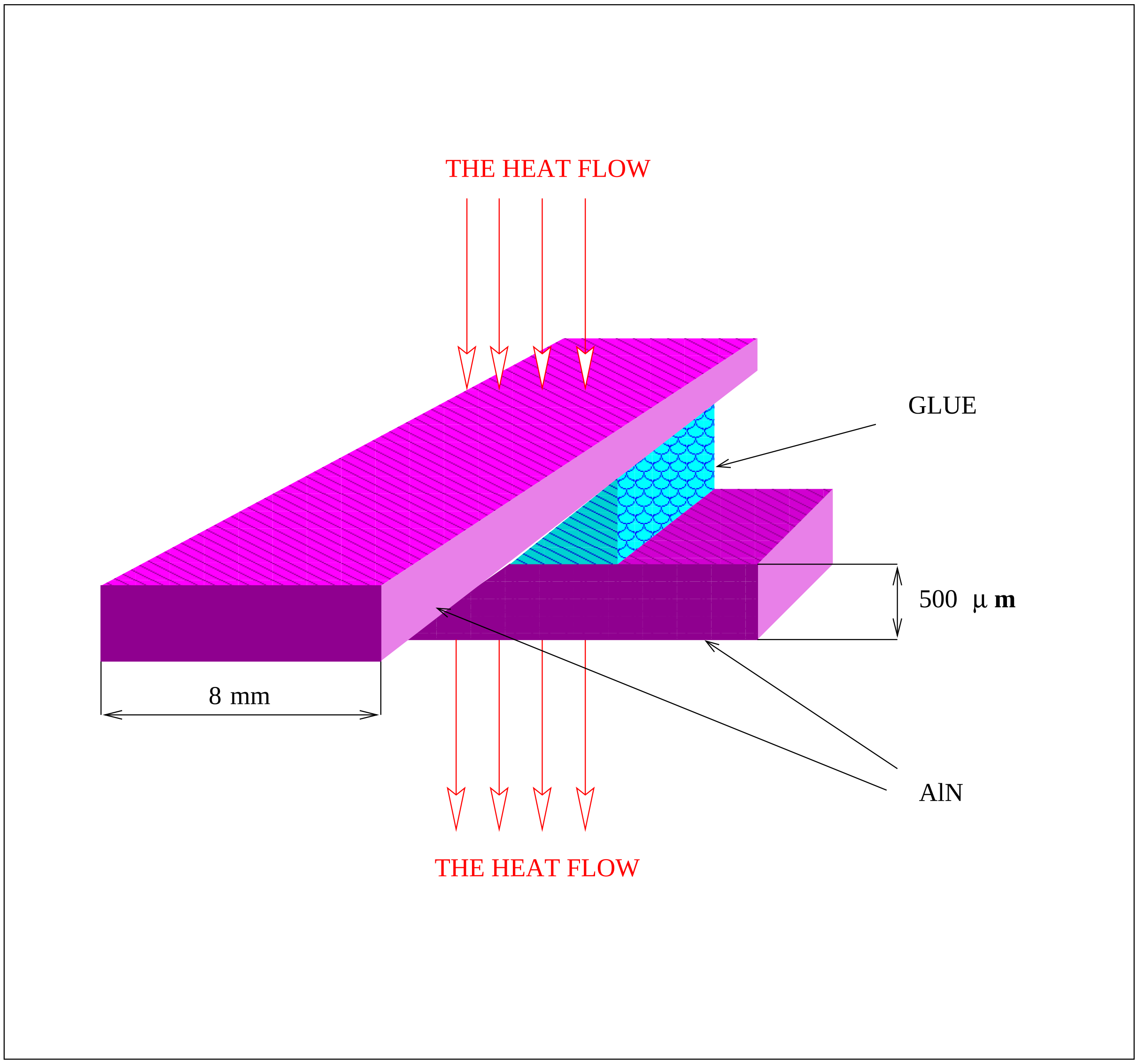

Figure 3: Schematic drawing of sample for the test.

ARALDITE RAPID and ELASTOSIL 137-182

Thermal properties

The comparison of the thermal conductivity of ARALDITE RAPID and ELASTOSIL 137-182 was done using a different setup, different configuration of the samples and completely different read-out system. The measurements were done inside of vacuum vessel at residual pressure about $10^{-1} mbar$ and at the mean temperature $\sim 10^{o}C$. Six samples with three thicknesses of the glue layers for each type of the glue were tested. The scheme of the measurement and the test sample are shown in Fig.6 and Fig.7 respectively. The sample consist of two Al bars connected by a TPG bar through two layers of glue. All samples were made with the same dimensions of Al and TPG bars and the same area of glue connection. The thermal runway along the test sample consists of double the thickness of a glue layer, double the thickness of the Al — bar $(2 \times 0.5mm)$ and the TPG—jumper ($\sim 30mm \times 10mm \times 0.5mm$). In this tests the thermal resistances of Al and TPG—bars are neglectibly small in com-

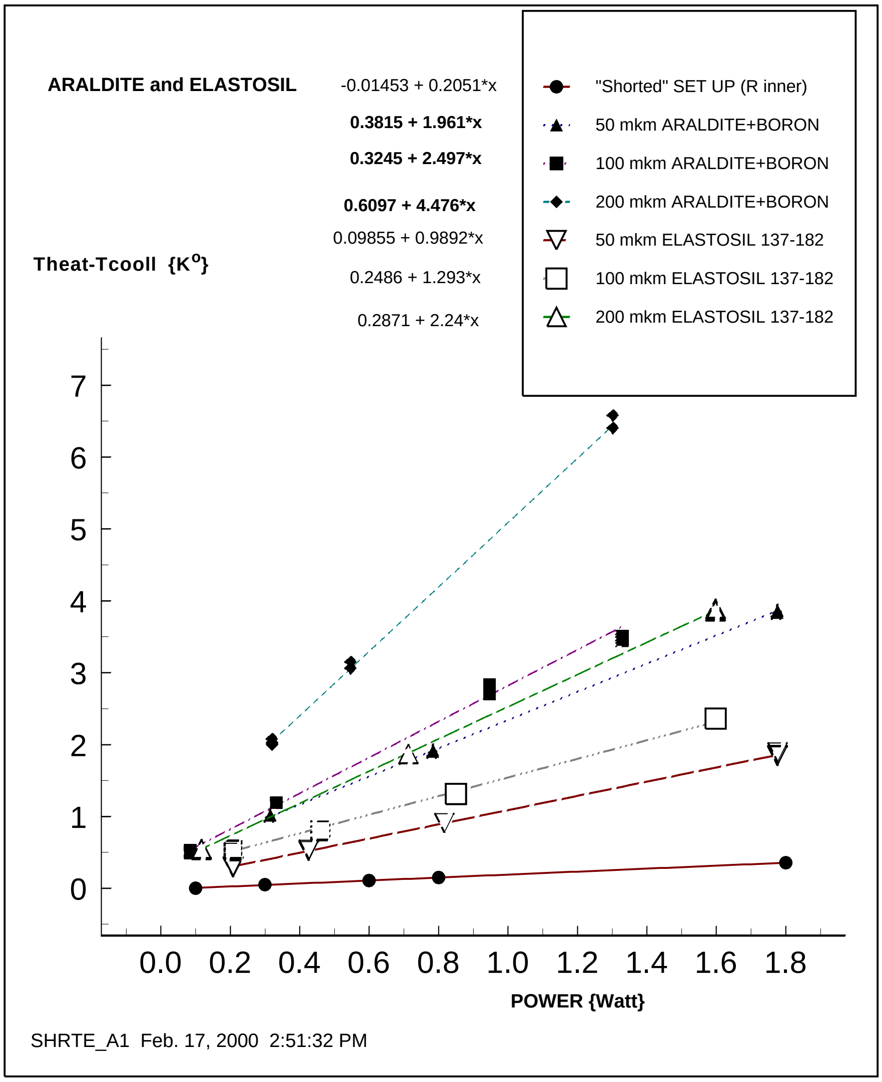

Figure 4: Measured value of the thermal resistance of the glued samples and "R''_{inner}— thermal resistance of the setup.

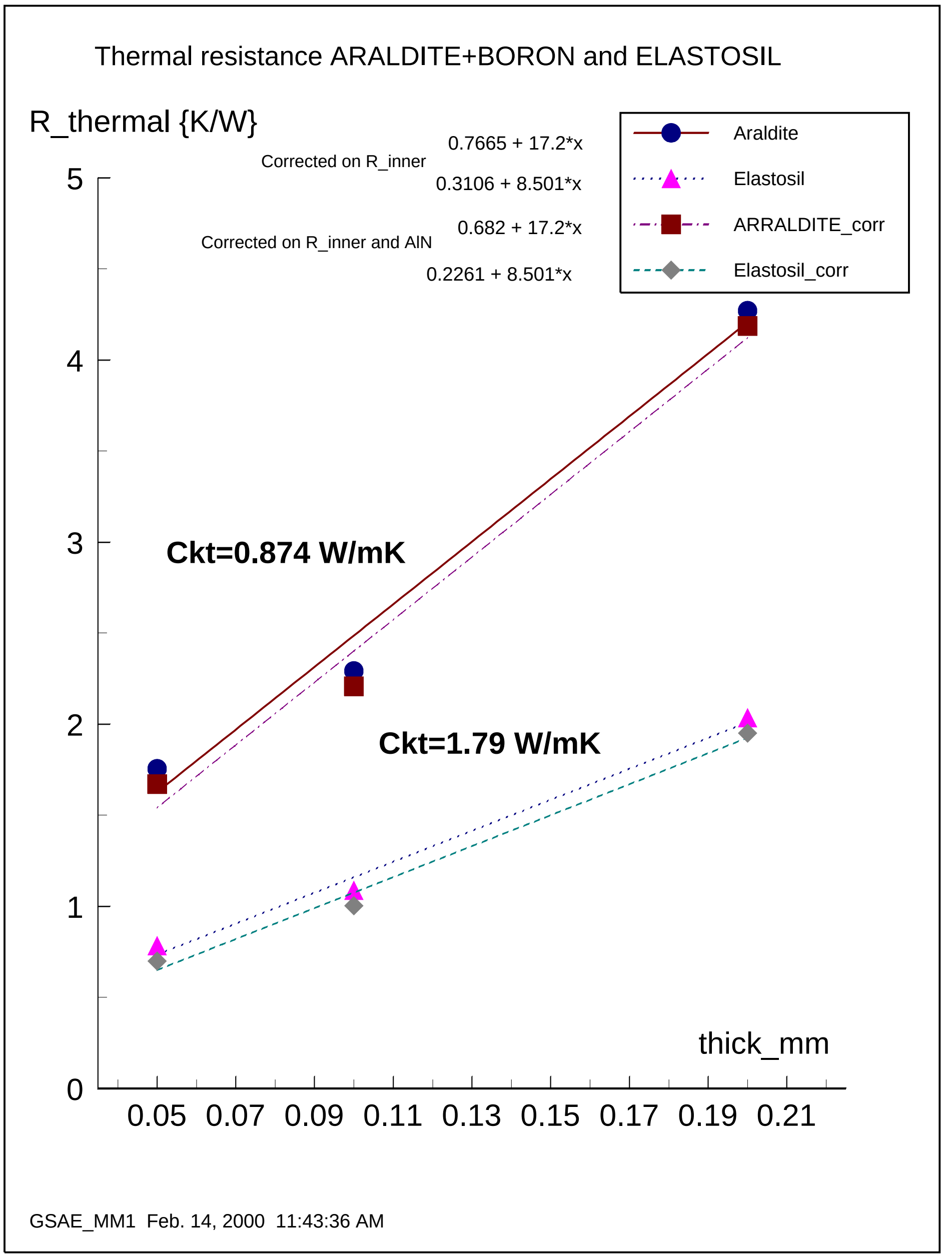

Figure 5: Thermal resistance of the glue layer as function of the layer thickness. Boron nitride filled ARALDITE 2011 and ELASTOSIL 137-182.

parison with the resistance of the double glue layers. The thermal resistance of the samples as function of the glue layer thickness is plotted in Fig.8. This value is not corrected for R_{inner}, R_{Al} and R_{TPG} . The ratio of the slope parameters of linear fits to this dependence shows the ratio of the thermal resistance of the samples. It is easy to see, that the difference of the thermal conductivity can be estimated as more than a factor of four.

Mechanical property

A series of strength at tension tests for ELASTOSIL glue was performed. The scheme of the measurement and the structure of the test samples is shown in Fig.6 . Some samples were irradiated in a proton beam ($p = 100 MeV/c$).

$N\ of\ sample$	1_1	3_1	5_1	6	2	4
Fluence[$\frac{proton}{cm^2}$]	1.3×10^{12}	4.1×10^{12}	1.3×10^{14}	2.6×10^{14}	8.5×10^{14}	2.7×10^{15}

The first series of the measurements started one day later after gluing of the samples. Six samples were tested. Every of them broke at the ARALDITE layer. We reglued the ARALDITE connection, pressed the AlN— bars to Al—bars by using additional external clamps and repeated the test two days later. Two samples out of three broke by AlN—ceramic destruction, one of them was disrupted at the ELASTOSIL layer. The other samples were tested after irradiation two weeks later. All irradiated samples disrupted by ceramic destruction. We repeated our measurements using three samples with one Al—bar glued to another Al—bar directly (samples number 10,11 and 12). We tested these samples 1, 5 and 9 days after gluing. The results of the strength at tension tests are summarized in Table.2. The tensile strength detachment as function of time after gluing is plotted in Fig.9. The point corresponding to two weeks time exposition is the value averaged from three samples.

color	gray
dynamic viscosity at 20^oC, $Pa \cdot s$	$300 \div 400$
duration skinning eff. at 20^oC, hours, maximal	6
viability at 20^oC, min, maximal	—
strength, MPa, minimal: at tension at shear	 $2.5 \div 3.0$ $2.0 \div 2.5$
electr. cubic resistivity, $\Omega \cdot m$	$1 \cdot 10^{10}$
electrical ε, at $10kHz$ and 20^oC, max	4.8
$tg(\alpha)$, at $10kHz$ and 20^oC, max	0.009
electrical strength, kV/mm, min	$9 \div 11$
thermal conductivity, $\frac{W}{m \cdot K}$	$1.6 \div 1.8$
operating temperature range, ^oC	$-60 \div +200$

Table 1: MANUFACTURER SPECIFICATION:Technical characteristics of thermal conductive silicon-organic glue "ELASTOSIL 137-182"

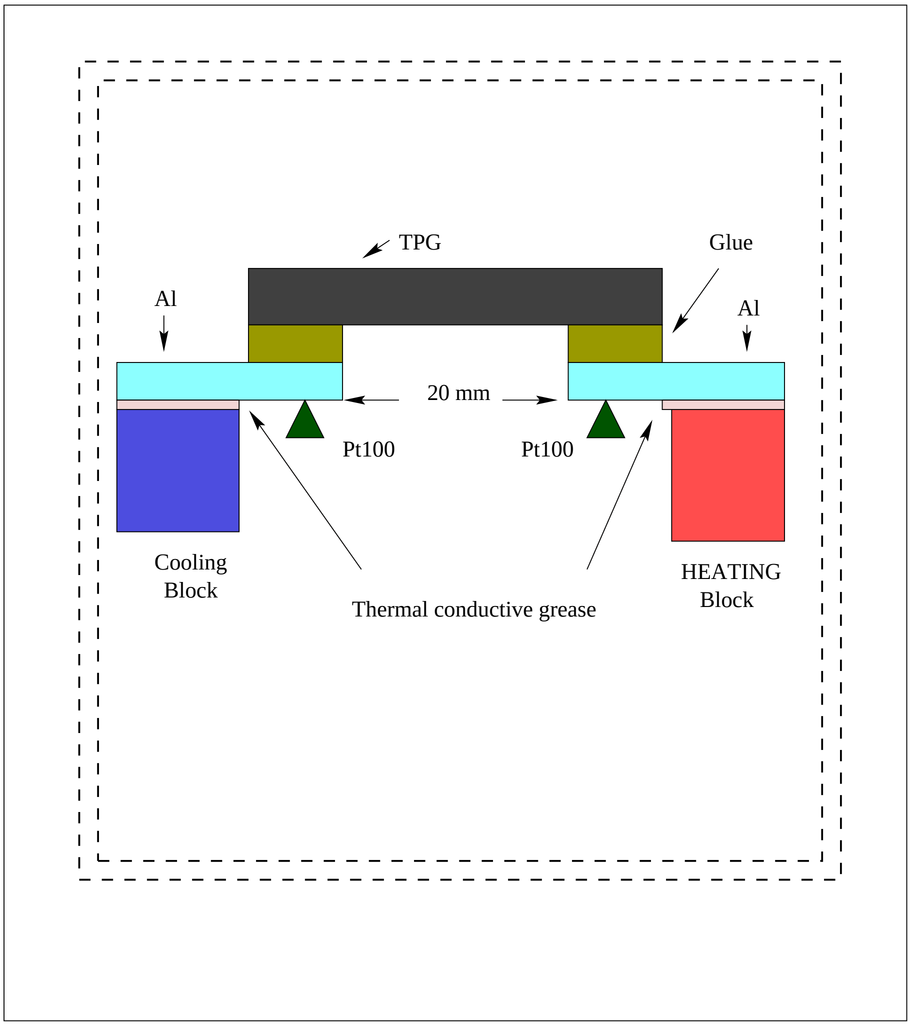

Figure 6: Scheme of the measurement. ARALDITE RAPID and ELASTOSIL 137-182 comparison.

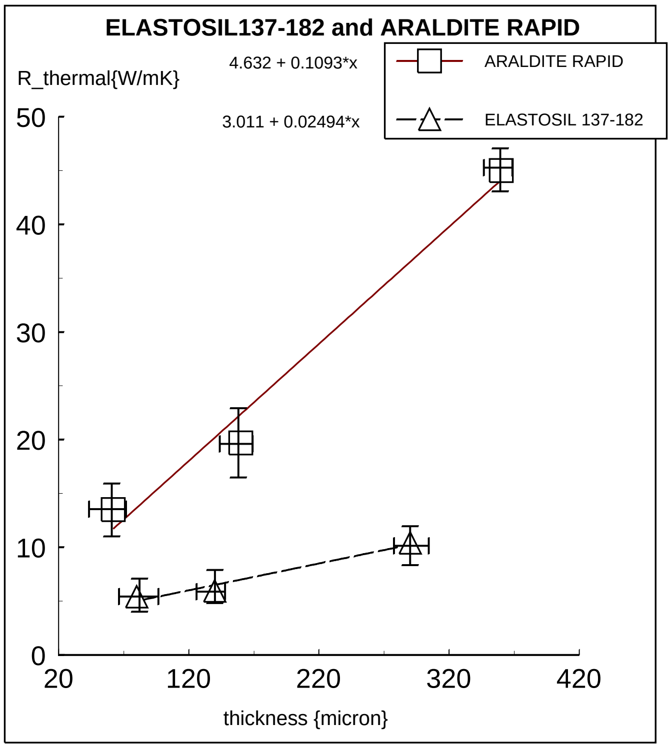

Figure 7: The thermal resistance of the glued samples.ARALDITE RAPID and ELASTOSIL 137-182 comparison

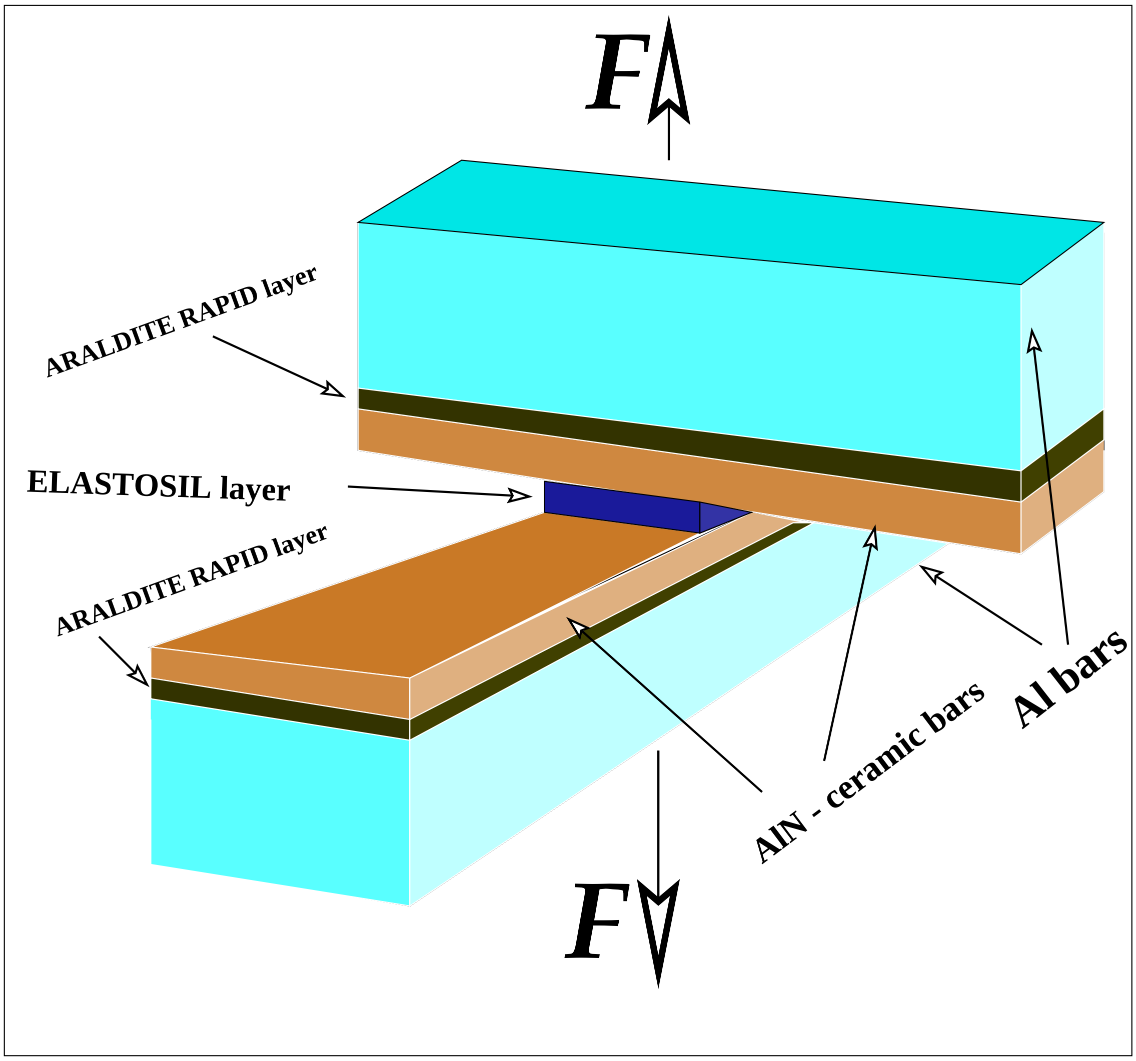

Figure 8: Schematic drawing of the sample used for strength at tension test.

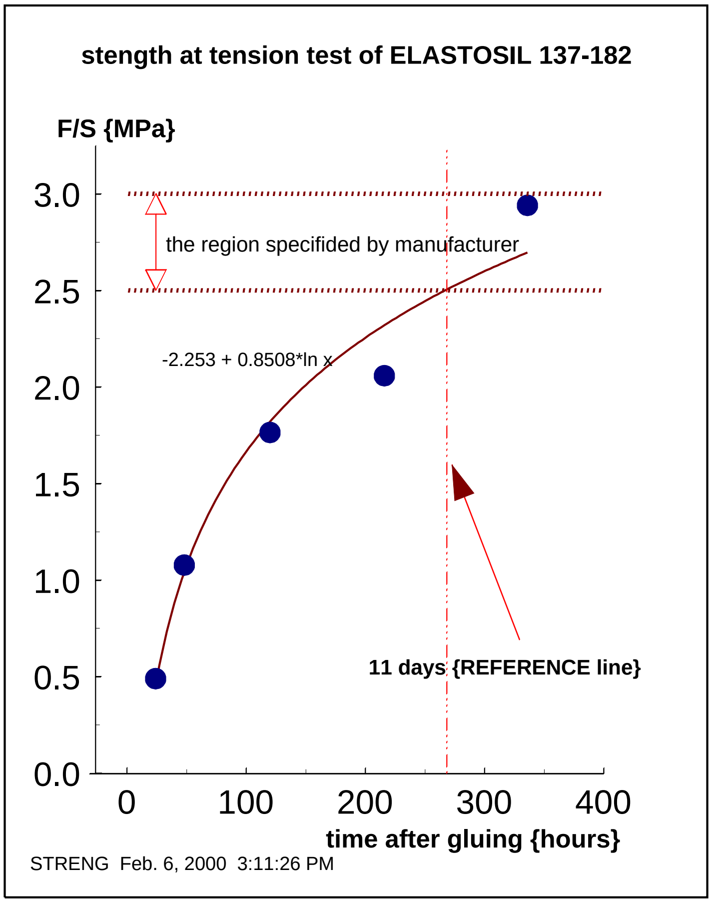

Figure 9: The rise of the strength as function of time after gluing.

N of sample	S_1 *area* mm^2 ELASTOSIL	S_2 *area* mm^2 ARALDITE	time after gluing (days)	F_1 *tensile strength detach.* Kg no clamp	F_2 *tensile strength detach.* Kg used additional clamp	comments
7	64	264	1	6.7		ARALDITE detachment
7_1	64	264	3		7.0	ELASTOSIL detachment
9	64	296	1	4.7		ARALDITE detachment
9_1	64	296	3		7.6	ceramic destruction
8	64	304	1	5.2		ARALDITE detachment
8_1	64	304	3		6.0	ceramic destruction
1	64	304	1	4.1		ARALDITE detachment
1_1	64	304	~ 14		9.8	ceramic destruction
3	64	200	1	4.0		ARALDITE detachment
3_1	64	200	~ 14		6.0	ceramic destruction
5	64	360	1	6.2		ARALDITE detachment
5_1	64	360	~ 14		5.6	ceramic destruction
6	64	~ 300	~ 14		19.4	ELASTOSIL detachment
2	64	~ 300	~ 14		13.2	ELASTOSIL detachment
4	64	~ 300	~ 14		21.5	ELASTOSIL detachment
10	100	no	1		5.0	ELASTOSIL detachment
11	100	no	5		18.0	ELASTOSIL detachment
12	100	no	9		21.0	ELASTOSIL detachment

Table 2: Results of the strength at tension test

Conclusion

According to our measurements:

- The measured value of C_{kt} for ELASTOSIL 137-182 fits the region specified by the manufacturer. The measured value of the thermal conductivity of Boron nitride filled ARALDITE 2011 is in good agreement with independent measurement.

- The thermal conductivity of ELASTOSIL 137-182 is more than four times better than ARALDITE RAPID and it is about two times better than value measured for Boron nitride filled ARALDITE 2011.

- The measured value of strength at tension for ELASTOSIL 137-187 :

  — is in good agreement with specifications;

— reached specifications at ~ 11 days after gluing;

— does not have a visible reduction of this value after irradiation in proton beam, $p = 100\frac{MeV}{c}$, up to fluence $F = 2.7 \times 10^{15}\frac{proton}{cm^2}$.

By our experience: the samples glued by ELASTOSIL 137-182 were ready for use about 24 hours after gluing at room temperature.

References

[1] T. Kondo et al., ATLAS-INDET-98-201, 98-202

[2] See,for instance, $http://wwwatlas.mppmu.mpg.de/atlas\_sct/simu.html$

[3] C.Heusch, A.Kholodenko and H.-G.Moser, Direct Measurements of the Thermal Conductivity of Pyrolytic Graphite (PG) and Thermal Pyrolytic Graphite (TPG) samples for use as heat spreader material in ATLAS SCT MODULES, to be sub. to NIM.

[4] See,for instance, $http://hepwww.ph.man.ac.uk/groups/atlas/module/glue.html$