BN100 filler technology

100% of compressed Boron Nitride Powder

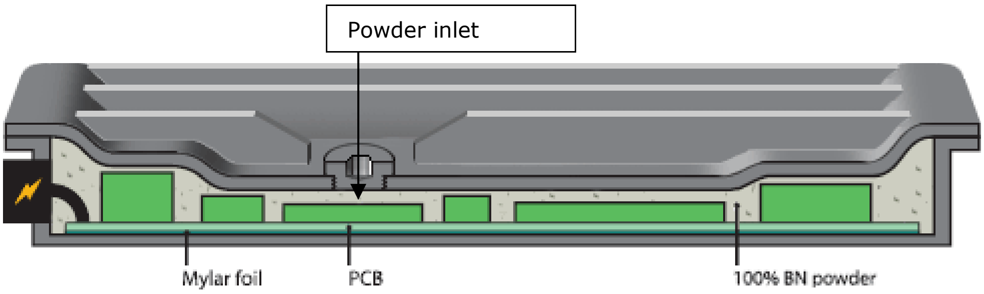
Patented technology

The BN100 high thermal conductive filler technology is a new filler technology, developed in partnership with the Laben Italian Space Company and the GE Advanced Ceramics Boron Nitride Manufacturer, that lets users increase the thermal dissipation of medium-high powered systems with furthermore other advantages going from being full accessible for maintenance to being free of resin and so cure-free for a faster and cheaper production process.

What differ the BN100 filler technology from other typical filler ones is its unprecedented capability to have a much higher thermal conductivity (over 14 W/mK), to reduce mass and vibrational environment, and to be rework able because not polymerized.

Traditional fillers are the mixture of a resin, normally two-component, polymerized sometimes around a thermal conductive charge with the result to have thermo-electrical properties that are always accomplished by 2 separated items bonded together by the resin polymerization. In a BN100-based filler there is no resin and only 1 item is used to meet thermo-electrical requirements.

The differences are so remarkable that the BN100 filler cannot be considered a simple filler but a filler technology that impacts the system design in the sense to render it more reliable, more performing and more flexible, with, furthermore, a much simpler and faster production process, all basic parameters for a lower cost product.



No resin inside

Heat power spreads easily thru the ECU cover thanks to the superior BN100 thermal conductivity.

- *Superior thermal conductivity of about 14W/mK*
- *Higher reliability for lower temperatures and reduced vibrational environment*
- *Outstanding dielectric strength*
- *Negligible thermal elasticity*
- *Absolute full maintainable for repairing*
- *Lower mass (0.7 g/cm^3)*
- *Faster, cheaper to fill any kind of sealed box*
- *Industrial plant maintenance free*
- *No resin: no cure time for polymerisation*
- *Not toxic and no health care protection required*

SPECIFICATIONS

With a thermal conductivity as high as 14-23 W/mK depending on the powder grade, the BN100 filler technology overcomes the thermal performance of traditional potting systems with almost 2 orders magnitude.

The following thermal, electrical and mechanical properties make the BN100 ideal for such applications such as component molding, strain-sensitive potting, high voltage potting, high power systems, vibration damper where dependability is of critical importance.

BN100 properties	
Thermal conductivity (W/mK)	14
Dielectric constant	2-4
Dielectric strength (V/mm)	7500
Specific density [1] (Kg/dm^3)	0.7-1.1
Elastic Modulus (N/mm^2)	12-37
Structural damping (η)	0.4

[1] compressed powder

THYPICAL PRODUCT CHARACTERISTICS

(THESE ARE TYPICAL DATA CERTIFIED ON GE ADVANCED CERAMICS BN GRADES)

The low mass density is due to the fact that about 2/3 of the overall volume are occupied by the air or vacuum depending on outside conditions, while only 1/3 is really due to the BN particles. The mass density of 0.7 g/cm^3 is typical of BN grades made up by low density particles, while the mass density of 1.1 g/cm^3 is typical of grades derived by BN high density ones.

Looking at the table it is obvious that we can talk of Elastic Modulus only for compression, whose value is dependent on the undergoing degree of BN powder compression.

Thermal conductivity either is dependent on the level of compression impressed to the powder. We can notice, however, that compression levels measured at the hole inlet as high as 4-5 bars do not mean to have as much pressure within the case that is less than 1/10 of this recorded level.

Even if it is difficult to exactly determine the pressure within the case, while at the inlet hole it is rather simple, from some FEM model analysis we have been able to extract this pragmatic law by modeling the shape and configuration of some test prototype and looking at the pressure that deform the case of a some extent. We could then conclude that the level of pre-compression within the case that produce a satisfactory thermal conductivity is not as high as to preclude from still designing a very low mass structure with thin walls as well required in some areas where mass efficiency is a top requirement.

TECHNOLOGY

As the name suggests, the BN100 filler is compounded by 100% of Boron Nitride (BN) Powder. Because no resin is used, the BN100 filler technology has no polymerized parts . This is why reworking is easy.

The BN powder grades used have particles ranging from 0.2 microns to 200 microns, whose selection is made in function of the product configuration and thermal performance to be obtained.

The very high thermal conductivity, more than 30 times higher than most traditional potting systems one, comes from the full exploitation of the outstanding thermal conductivity of the BN (140W/mK) thanks to the direct contact of the BN powder particles that, according to the technology, are mechanically compressed one another without any possibility to move, if not for friction micro displacements, even when undergoing the most severe dynamic loads such a Spacecraft launch mission.

If, in a traditional potting system, the ceramic powder particles are suspended into a resin that will polymerize to acquire a mechanical rigidity, in the BN100 filler-based electronic units, the BN particles are in contact one another under a certain pressure pre-load. The lubricious and not-abrading characteristics of the BN powder (not common to other ceramic powders) are fully avoiding the risk that particles could damage delicate electronic components and interconnections.

Please note that unlike a fluid, the BN100 filler compression is transmitted to the unit casing with a pressure level (some millibars) that is just a small fraction of that reached in the compression device. This permits not only to still design very light unit casings but, for the higher mechanical stability given by the filler compression that enhances the unit natural frequency, a lighter casing design is possible.

The BN100 filler compression can be applied once (by a piston, if pneumatic; by a die-press device if mechanical) or in more steps. When the compression device is released after each compression step, the powder internal pressure drops to zero and no particles try to escape from the unit casing. The memory characteristics in compression of the BN100 filler makes it very easy to be used with common shop tools and simple integration procedures.

For a medium-large productivity, a full automatic process equipment, like the one developed by ARTHE ENGINEERING and shown in the figure, is recommended, in which the powder filling is accomplished through one unique M8 (other options are M6 or M4) hole doing vacuum inside the casing just before filling and the whole process takes only few seconds for relative small products such as solid-state relays thanks to the large flowability of the lubricious BN powder.

After the cap closure the unit is ready for the final certification run. Via a whole automatic filling process the filling cycle time is reduced to a few seconds.

CONTAINEMENT

Standard silicon or epoxy based adhesives can be used to contain the BN powder.

Once compressed into the case through a filling hole that can preferably range from 6 mm to 30 mm, the powder is statically stable, that is, if the package is put top-down the powder particles do not drop from their compressed conditions. This eases the handling operations and simplify the choice of the closure device that can be a simple potting over the compressed powder, a screw or a lock-pushing cap.

ARTHE engineering solutions s.r.l.

REI

AUTOMATIC FILLING EQUIPMENT

DIELECTRIC PROPERTIES

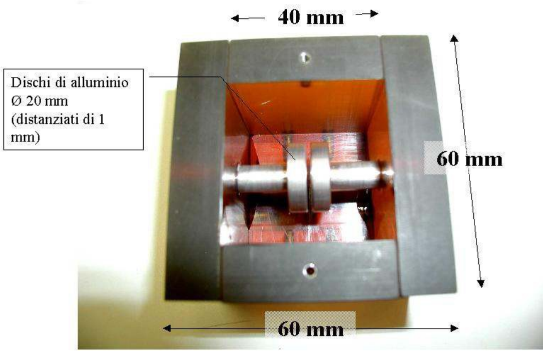
1. *Leakage current measurement in function of the DC tension carried out at ambient temperature.*

   1st test with CTL40:

   the breakdown has occurred between 6000V and 7000V

   2nd test with SHP705 and a kapton film:

   the breakdown has occurred after 7000V



Dimensioni interne 40x40x40 mm
(materiale ULTEM)

By courtesy of Galileo Avionica

2. *Partial discharge test carried out in AC 50 Hz.*

1st test with CTL40:

During the CIV research, Corona Inception Voltage, a tension of 4000Vrms has been reached without trace of partial discharge. Over 4000V the discharge is so strong to overload the measurement system.

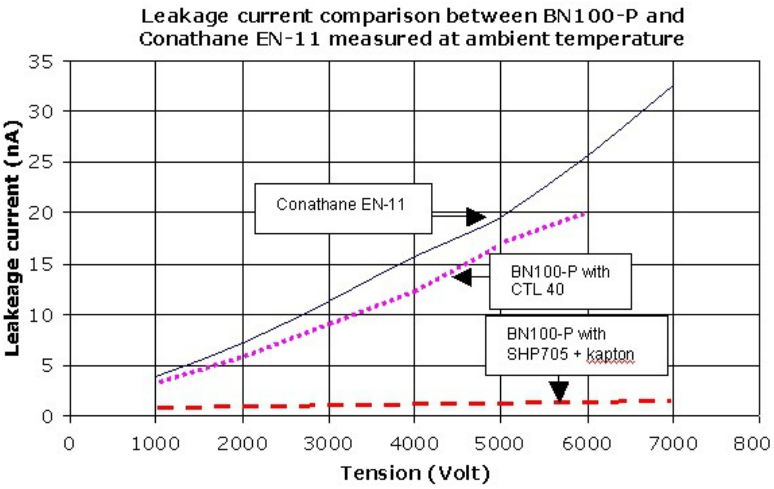
2nd test with SHP705 and a kapton film:
CIV at 4700 Volt A.C. with events between 30 e 70 pC

CIV at 5200 Volt A.C. 100 pC max.

CIV at 5700 Volt A.C. 100 pC max.

CIV at 6300 Volt A.C. 130 pC max.

CIV at 7000 Volt A.C. discharges out of scale.



Note:

CTL40 is a BN powder from 0.0004 ÷ 0.2 mm (ave. 0.29 mm).

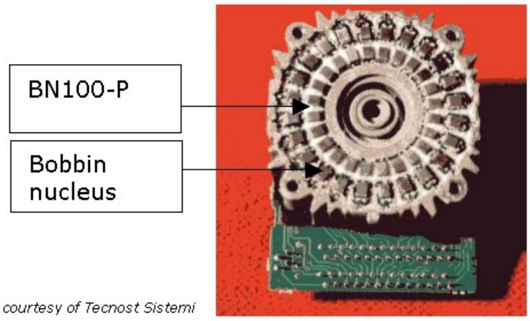
SHP705 is a BN powder from 0.0004 ÷ 0.027 mm (ave. 0.007 mm)

For comparison, the results of the leakage current test carried out on the same sample characteristics are shown when the filler used is the polyurethane resin Conathane EN-11, one of the leading filler currently used in aerospace systems.

From the figure it can be noted the wide difference of leakage current between a traditional filler and the BN100, when also a Conformal Coating is used.

THERMAL PROPERTIES
(PROTOTYPE: BOBBIN GROUP OF A PRINTER HEAD)

Note: in this special application, because no cover could be used to maintain the BN particles in place, the upper surface has been painted to create a tough, hard surface.

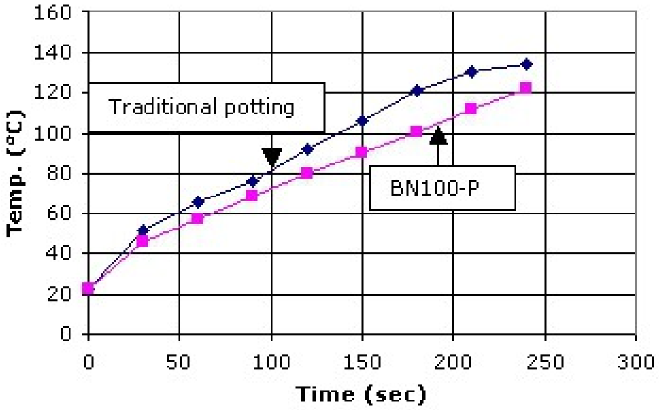


By courtesy of Tecnost Sistemi

1. *Transient test*

The thermal conductivity of the BN100 filler technology is well demonstrated by the temperature difference of about 20°C, at 120°C, with respect to a traditional potting technology, a difference that, by looking to the line gradients, would be still higher if the printer S/W would not control the output power to maintain the temperature below 130°C.

Bobbin temperature

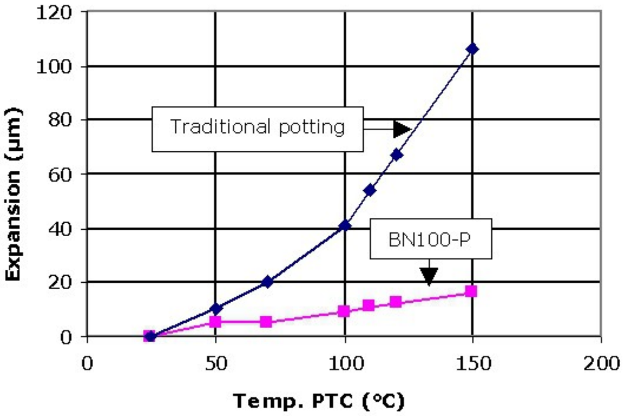


2. *Elastic deformation due to the temperature*

Micro-displacements of the BN100 filler particles are possible without affect at a larger scale appreciable movement of the whole filler.

This physical property typical of the only BN100 technology induces a lower level of stress deformation of the bobbins that, in this way, can control the printer actuators at an higher printing resolution.

Thermal stress test

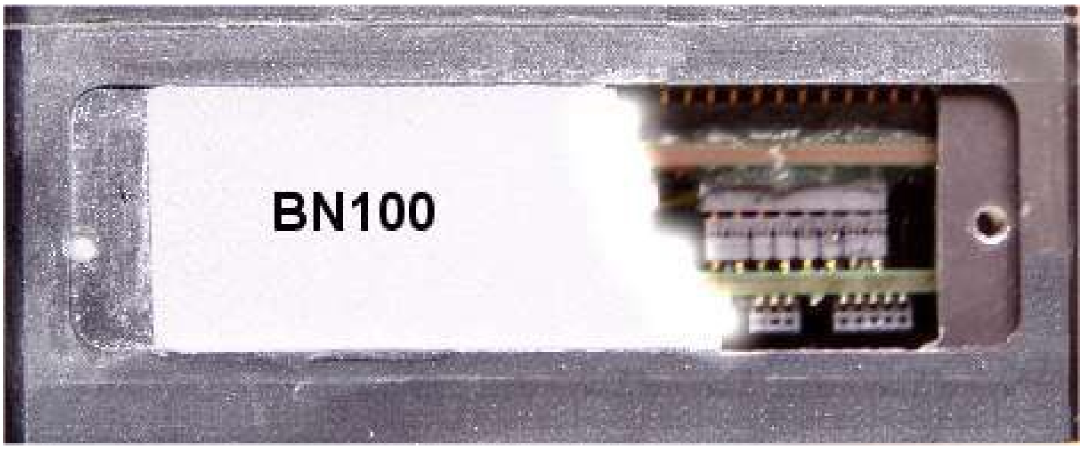


ENGINE CONTROL UNITS

With a thermal conductivity as high as 14 W/mK, the BN100 filler technology permits to design encapsulated units, such as ECUs, with a cover that increases the thermal dissipation through the BN powder.

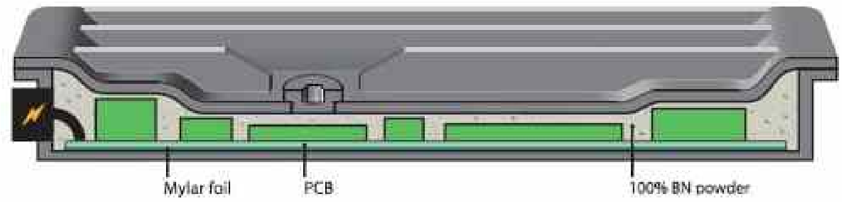
The thermal, electrical and mechanical properties make the BN100 ideal for such applications in which an higher reliability is fundamental to reach the highest quality standard. Low powder volumes obtained with an optimized cover shape along with an higher productivity rate due to the high BN flowability are also key elements to reduce costs.

In the case of the Engine Control Units more thermal paths via the unit cover (see figure) and the vibration damping are the most fundamental advantages. Temperatures on delicate components such as FPGA have been reduced of about 17°C and much lower gradients have been recorded.



AN ECU PROTOTYPE FILLED WITH BN POWDER

Lower temperatures and higher reliability are obtained with a productivity cost that is globally more convenient than using traditional methods.



ARTHE has been able to demonstrate, in the case of a MAGNETI MARELLI ECU (see fig. above), that the optimization of the ECU configuration aimed at minimizing the powder volume takes to have procurement costs lower than if it were used other material such as a polypad in Aluminum Oxide or other.

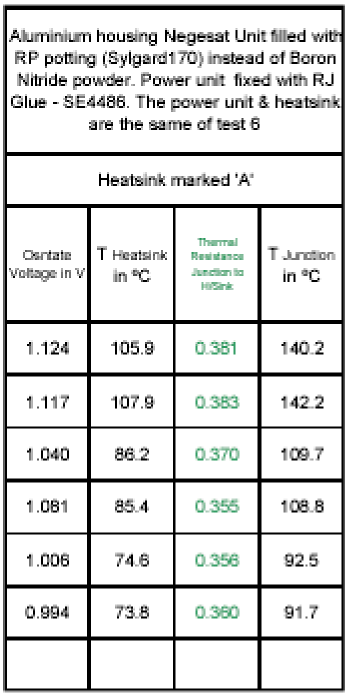
The own capability of the BN100 technology to lower the components temperature open, furthermore, the way to render acceptable the use of lower graded components or, eventually, to re-design PCB surfaces in such a way to decrease components size by maintaining the same power output and increasing the power density.

SOLID STATE RELAYS

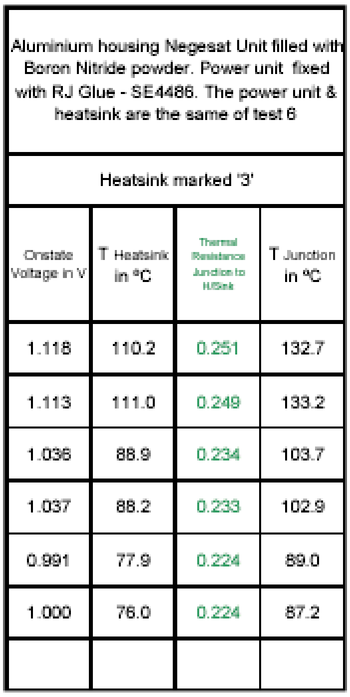
A Prototype test campaign has been carried out on a relay power unit.

The heat sink used during the tests is the same as the one currently in use and, then, not optimised to spread heat from the powder side.

In the next table the results are resumed:



Aluminium housing Negesat Unit filled with RP potting (Sylgard170) instead of Boron Nitride powder. Power unit fixed with RJ Glue - SE4486. The power unit & heatsink are the same of test 6			
Heatsink marked 'A'			
Osntate Voltage in V	T Heatsink in °C	Thermal Resistance Junction to H/Sink	T Junction in °C
1.124	105.9	0.381	140.2
1.117	107.9	0.383	142.2
1.040	86.2	0.370	109.7
1.081	85.4	0.355	108.8
1.006	74.6	0.356	92.5
0.994	73.8	0.360	91.7



Aluminium housing Negesat Unit filled with Boron Nitride powder. Power unit fixed with RJ Glue - SE4486. The power unit & heatsink are the same of test 6			
Heatsink marked '3'			
Onstate Voltage in V	T Heatsink in °C	Thermal Resistance Junction to H/Sink	T Junction in °C
1.118	110.2	0.251	132.7
1.113	111.0	0.249	133.2
1.036	88.9	0.234	103.7
1.037	88.2	0.233	102.9
0.991	77.9	0.224	89.0
1.000	76.0	0.224	87.2

By courtesy of Carlo Gavazzi

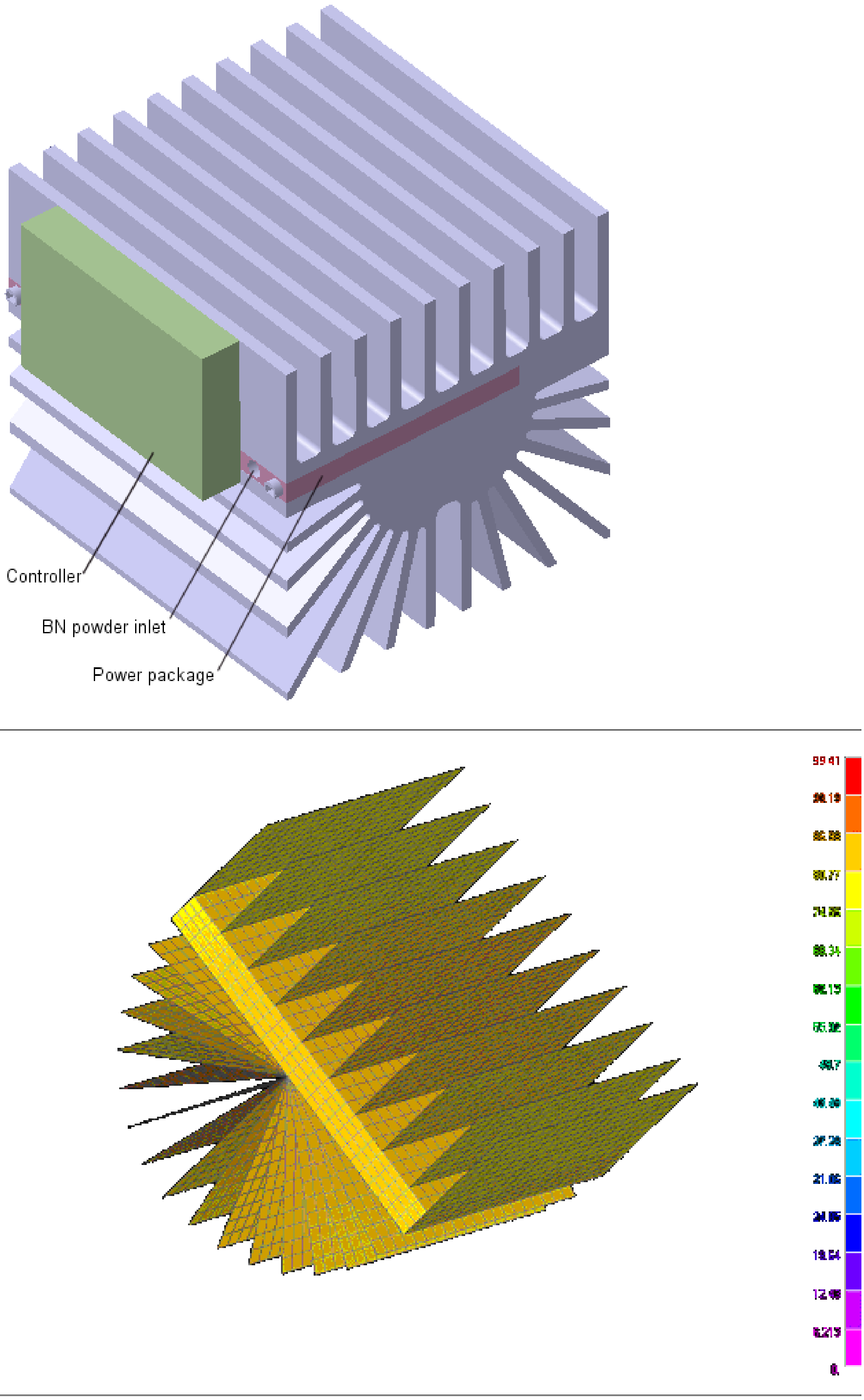
TEST COMPARISON BETWEEN RESIN-BASED AND BN100-BASED RELAY

The difference of about 9°C has been recorded with a not optimised heat sink.

From these test results a FEM model has been tuned up to see the improvement margins that could be achieved by designing a BN100-based heat sink.

The FEM model tuning has been carried out by searching the right natural convection parameters that permit to obtain the same test results. Once the right parameters have been found the same have been used to prepare the new heat sink design model.

Next figures show the CAD design and FEM model results:



CAD MODEL AND FEM RESULTS ON A NEW HEAT SINK DESIGN

From this analysis it appears that the Temperature drop can achieve as much as 42 °C, due to much shorter and efficient thermal paths.

REFERENCES

F. Boer, BN100 filler technology, ARTHE Engineering Solutions s.r.l., 2004.

J. Ciantar, Standard RMs with Electrolube HTS thermal Compound vs ARTHE Unit with Power units, Carlo Gavazzi S.p.A., 2004

A. Zamboni, Thermal Vacuum Test Report of 80A Sensing Resistor Using Boron Nitride filler, Galileo Avionica S.p.A., 2003.

C. Maletta, Thermal Measurement Report on the ECU 5NF EU, Magneti Marelli S.p.A., 2003

C. Marangon, Comparison between ARTHE Printer Head and current Production one, Tecnost Sistemi S.p.A., 2002

R. Hill, Characterisation and performance of thermally conductive epoxy compound fillers, Advanced Ceramics Inc., 1996

E.K. Sichel, R.E. Miller, Heat Capacity and thermal conductivity of hexagonal pyrolitic Boron Nitride, 1976

REI SRL
Via E. Majorana 8/B
I-35010 CADONEGHE PD Italy
T +39 049 701725 - F +39 049 8872986
www.reipower.it - info@reipower.it