

# SiC Schottky Diodes Reliability Testing for Bepi Colombo

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## INTRODUCTION

This paper reports on the fabrication technology and packaging strategy for 300V-5A Silicon Carbide Schottky diodes with a wide temperature operation range capability (between -170°C and 300°C). These diodes have been designed for harsh environment space applications such as inner Solar System exploration probes. More specifically these diodes are being tested to be the blocking diodes of the solar panels for the Bepi Colombo mission. Different endurance tests have been performed to evaluate the diode behaviour when working at high temperature and under severe thermal cycling conditions (comprised from -170°C to 285 °C). The radiation hardness capability has been also tested. It has been found that the hermeticity of the package is a key aspect to avoid electrical parameters drift. Moreover, the use of gold metallization and gold wire-bonds on the anode allows reducing the diode surface and bonding degradation when compared to Al containing technology. On the backside cathode contact, the Ti/Ni/Au metallization and AuGe combination has shown a very good behaviour. As a result, the manufactured diodes demonstrated high stability for a continuous operation at 285°C. The reliability test performed included mechanical test with strong levels of vibration and shocks and constant acceleration, life test at maximum operating conditions with 1500 hours at 285°C at 5A forward current and 500 hours at 250 reverse voltage and 4000 thermal cycling from -150°C till 230°C with forward current of 0.8A for temperature over 25°C while the voltage drop was being monitored. The paper includes also a description of the setup solutions and the main lessons learnt for future testing of high power devices operating at a wide temperature range.

The increasing demand for high temperature electronics has stimulated the research for alternatives to Silicon (Si) capable to operate under extreme working conditions; e.g., in harsh environment, at temperature above 300°C, under high pressures, experiencing intense vibrations or withstanding corrosive liquids. Wide band gap semiconductors are materials that have attracted much attention, especially due to their superior electrical, mechanical and chemical properties. Currently, the wide band gap material which presents a more mature manufacturing technology is SiC. The recent improvements in SiC material growth, with a strong reduction of defect density in the starting material, allow producing reliable SiC based devices [1, 2]. This fact has conferred to SiC to be the most adequate candidate for developing high efficiency converters and high power electronics [3, 4, 5]. The most advanced device from the technical and commercial point of view is the Schottky diode [6,7]. Commercial diodes produced by Infineon or CREE Inc. have shown to be efficient and reliable in standard power applications [8]. Schottky SiC-based devices are an interesting solution for the ever increasing demand required by space applications, such as BepiColombo mission [9].

BepiColombo mission will consist of two separate spacecraft that will orbit Mercury. Since Mercury is close to the Sun, the expected working temperature of the solar cell and related electronics ranges from -170°C to +270°C. In particular, the MPO (Mercury Planetary Orbiter) will be exposed to Sun intensities up to 10.7 times higher than in Earth's orbit. The high operating temperature is not the only challenge of this mission. When orbiting around Mercury, the MPO will experience seasonal eclipses. The minimum expected temperature in eclipse is -170°C and the number of cycles is in the range of 4,000. Therefore, this application requires that operating conditions of the blocking diodes must be extended far beyond the limits of existing Hi-Rel diodes.

This work aims to develop Schottky SiC-based devices capable to be used in the BepiColombo mission. However, the package of the commercially available devices is designed for a maximum junction temperature of 175°C. Regarding our BepiColombo application, 300V-5A diodes are required with a working temperature capability ranging from -170°C to 270°C. The two main challenges to extend the diodes' state of the art to this particular temperature range were: To define a reliable high temperature package and to modify accordingly the SiC die technology to fit in the novel package. Different technological approaches have been considered, with mainly variations on the interconnection technique and metallization layers. Batches of packaged diodes have been submitted to long term electrical stress to define the optimal design and process flow chart for the diode, focusing on the devices stability in DC mode. Thermal cycling tests have also being performed to evaluate the thermo-mechanical stability.

## SEMICONDUCTOR DEVICES PROCESSING

The SiC Schottky diodes have been processed on 4H-SiC wafers supplied by CREE Research Inc. The epilayer is 5µm thick and doped  $1 \times 10^{16} \text{ cm}^{-3}$ . The high voltage edge termination is made with the so-called Junction Termination Extension (JTE) technique. The JTE is implemented through an Aluminum implantation done at high temperature (300°C), followed by an annealing step at 1600°C for 30 minutes. SiO<sub>2</sub> was used as surface passivation layer. These processing steps are similar to the ones used for standard temperature range diodes [10]. The high temperature capability of the semiconductor die is mainly given by the selection of the metallization schemes. However, the choice of these metallization schemes is strongly linked to the packaging technology. A typical Schottky diode is made of a first thin metal layer (Metal 1) to form the Schottky contact on the semiconductor surface. On the top of this contact metallization, we add a thick layer (few microns) of metal (Metal 2) in order to reduce the parasitic resistance of the thin contact metal (Metal1) and increase the diode current capability. We already reported in [11] that the Titanium (Ti) and Nickel (Ni) metal layers typically used for commercial and our standard SiC Schottky diodes were not suitable for a high temperature operation. Forward voltage drift and double barrier effects with Ni and high reverse leakage currents with Ti are observed in these diodes under high temperature operation. This is why we used Tungsten (W) metallization as Schottky contact in our high temperature diodes. Regarding the thick metallization (Metal 2), Aluminum (Al) is typically used in standard power electronic rectifiers. However, we have evidenced that thick Gold (Au) layer is more suitable regarding the packaging technology we choose, as it will be shown later in this paper. The back-side ohmic contact is made with Ni. This contact has been proved to be stable for temperatures below 300°C. For the final back-side metallization, we kept our standard Ti/Ni/Au metallization scheme. Finally, we did not use the thick polyamide passivation usually present in standard diodes, to avoid any out gazing effects. This approach can be done for diodes with breakdown voltages up to 1.6kV. For higher breakdown voltages, an innovative solution should be found to make compatibles the high voltage and high temperature capabilities.

## PACKAGING STRATEGY

Packaging of high temperature SiC based components, is a challenging task, mainly requiring the compatibility of electrical, thermal and mechanical properties of the involved materials [12]. The packaging specifications of the proposed component have been fulfilled taking as departure point a modified TO-257 metallic package from Kyocera. Fig. 1 shows a cross section scheme of the package and its main parts. On the bottom, a 1 mm thick WCu flange ensures an appropriate thermal contact with the corresponding heat-extraction system; provides a mounting hole and provides also the required thermo-mechanical stability to ensure long term reliability under temperature cycling. Over this gold plated flange, a BeO slab is bonded with Ag. This 635 µm thick ceramic layer ensures electric isolation between the die and the case, as well as adequate heat extraction capability. Thermal properties of ceramics are difficult to evaluate because they depend on the fabrication process, impurity contents, etc., but typical values for BeO thermal conductivity are 285 W/m.K at 25°C and less than 100 W/m.K at 300°C [13]. On the top of the BeO, a 50 µm Ni plus 50 µm Au metallization is provided for chip attachment. The lateral frame of the case is made with gold plated Cu and it shows three ceramic through-holes for pin access. The Cu alloy pins plus ceramic through-hole combination is optimized to guarantee hermeticity in a wide temperature range. One of the pins (the cathode one) is directly connected to the Ni/Au metallization over the BeO slab, while the two remaining pin tips are suitable for wire-bonding towards the anode pad. Finally, the TO-257 case is completed with a Ni cap placed on the top using a seam sealing process in order to close hermetically the housing, under a neutral ambient of pure N<sub>2</sub>.

Two critical points of the assembly process concern the die front- and back-side interconnections. The back-side interconnection must provide correct thermal and electrical contacts, as well as a good mechanical stability in the whole operation range. The selected die attach material was the eutectic Au88/Ge12 alloy, showing acceptable thermal (44 W/m.K) and electrical (15 µΩm) conductivities, as well as a moderate coefficient of thermal expansion (13.4 ppm/K). Its melting point (358°C) allows operation temperatures around 300°C, and is compatible with relatively standard soft-soldering techniques. In this sense, the die-attach process was performed on a static reflow oven where the chip was placed over a 50 µm thick AuGe squared preform. The process was optimized by adjusting the temperature profile slopes (heating and cooling phases), the ambient (reductive in a first phase, vacuum in a second phase), the peak temperature (value and time) and the pressure applied to the die.

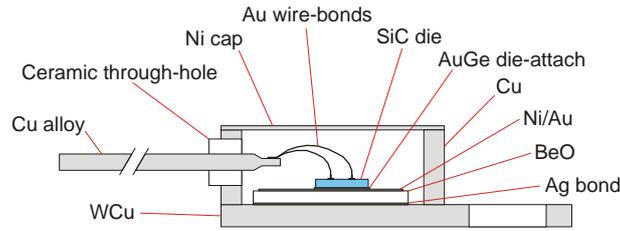


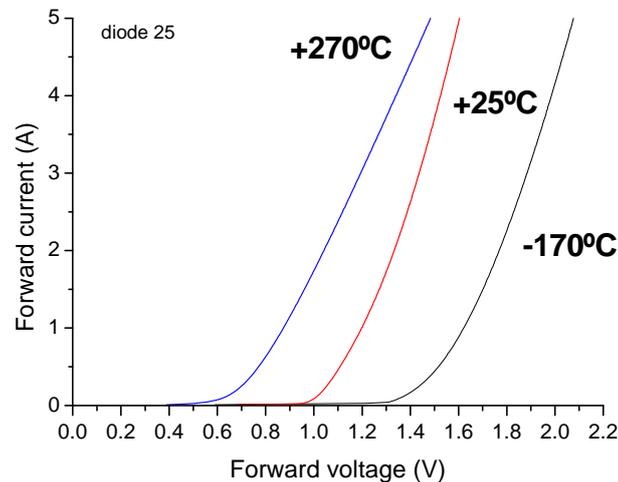
Fig. 1: Cross-section scheme of the packaged diodes showing the main parts.

A severe thermal cycling test campaign has also been started. The elementary cycle begins with the devices at  $-170^{\circ}\text{C}$  for 15 minutes. Then, the temperature rises up to  $+270^{\circ}\text{C}$  in less than 20 minutes, remains at this value for 15 minutes and descends again to  $-170^{\circ}\text{C}$  (maximum slopes of  $40^{\circ}\text{C}/\text{minute}$ ). After 4000 cycles under the described conditions any significant drift of the electrical characteristics has been observed and nor diode has failed. Therefore, the proposed Ti/Ni/Au backside metallization and AuGe die-attach combination, seem to be very stable allowing higher temperature operations than previously reported for SiC devices using this alloy [14]. Die-shear tests of the cycled diodes will be performed to confirm the integrity of the cathode contact, although the results are not available at this moment.

The front-side anode contact is also a critical part of the assembly. Due to the severe temperature conditions the connection between the  $3\ \mu\text{m}$  thick Au anode pad and the anode pins of the package is performed with  $50\ \mu\text{m}$  Au wire-bonds. There are 10 parallel wires in total, soldered by ultrasonic ball-bonding and distributed to the two anode pins. The bond-pull tests performed on diode samples have shown mean rupture forces of 18 gf and good adhesion at both wire edges: at the ball-bonding in the diode side and at the wedge-bonding in the pin side. The thermal resistance  $R_{\text{TH}(j-c)}$  has also been measured between  $25^{\circ}\text{C}$  and  $300^{\circ}\text{C}$ . The results obtained show an increase from  $0.92\ \text{K/W}$  at room temperature up to  $1.53\ \text{K/W}$  at  $300^{\circ}\text{C}$ . This leads to a increase of temperature that can be estimated. Assuming, for example, a diode dissipated power of  $5\ \text{W}$  (a realistic value for the nominal current and voltage drop of the devices) the junction-to-case temperature increment is  $4.6^{\circ}\text{C}$  at  $25^{\circ}\text{C}$  and  $7.6^{\circ}\text{C}$  at  $300^{\circ}\text{C}$ .

## STABILITY AND LIFE TESTS

Diodes have been first measured in forward and reverse mode at  $-170^{\circ}\text{C}$ , room temperature and  $270^{\circ}\text{C}$ . The I-V curve in forward mode is shown in Fig. 2. The reverse current values at  $300\text{V}$  of one representative diode at different temperatures are listed in the table.



$I_{\text{R}} @ 300\text{V}$ $-170^{\circ}\text{C}$	$I_{\text{R}} @ 300\text{V}$ $+25^{\circ}\text{C}$	$I_{\text{R}} @ 300\text{V}$ $+270^{\circ}\text{C}$
$<1\text{nA}$	$4\text{nA}$	$50\ \mu\text{A}$

Fig. 2: Forward and Reverse I-V characteristics of one diode measured at 3 different temperatures

To assess the potential degradation of forward and reverse characteristic for the high temperature environment, endurance tests have been performed. These tests consist in forward biasing the diodes for more than 500 hours at different ambient temperatures, higher than  $285^{\circ}\text{C}$ . The test is performed in inert atmosphere ( $\text{N}_2$ ) chamber and the diodes are DC biased at  $5\ \text{A}$ . Each endurance test was performed on 10 samples connected in series on a common

aluminum heat sink. The reference temperature is taken on the heat sink, while the temperature of each diode is also recorded (thermocouple fixed on the top of each diode case). The chamber temperature was regulated to get the test temperature when the diodes were biased at 5A, in order to take into account the increase of temperature due to the self heating. We also performed temperature stress steps consisting in having the parts at a starting temperature of 230°C during 96 hours. The next step consisted in increasing the temperature 10°C and stress the diodes 96 hours, and successively [16]. Finally we also performed a combination of endurance test with high temperature reverse bias stress (HTRB). Table II summarizes the different stress tests applied to the diodes Fig. 3 shows the evolution of the forward and reverse characteristics of a Schottky diode after 2000 hours of stress at 285°C. As we can appreciate, there is no drift of the forward characteristics. In reverse mode, we observed an initial decrease of the leakage current at 300V after the first 100 hours of stress. Then, the reverse current remains stable. It indicates that a preconditioning stress is necessary before using the diodes in order to stabilize the reverse characteristics. If we measure the low current characteristics of the diodes before and after stress them, we do not observe any significant differences as can be seen in the example of Fig. 3. The ideality factor and barrier height extracted before and after endurance stress or temperature step stress are similar. Then the decrease of the leakage current is not due to an overall variation of the barrier. However, it is possible that very local variation and improvement of the barrier height in defective areas of the Schottky contact can lead to a reduction of the leakage currents. In this way, the macroscopic barrier value of the contact do not change, but local leakage current path due to low barrier patches caused by local defects [17] are progressively removed with the thermal stress. Another possible reason for the leakage current reduction could be due to an improvement or stabilization of the charge effects in the device periphery.

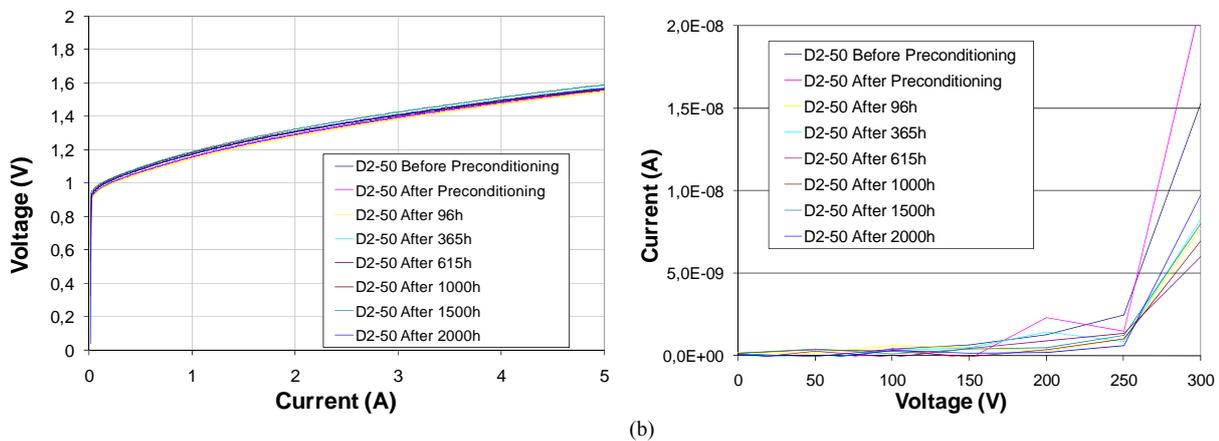


Fig. 3: (a) Forward characteristics after different duration of endurance stress, (b) Reverse characteristics after different duration endurance of stress.

We have performed similar endurance tests at 300°C (1000 hours) and 330°C (500 hours). After 1000 hours at 300°C, we had no drift of the forward characteristics and a similar behavior than the previously observed one in reverse mode, It is only when we stressed the devices at 330°C that we observed a first failure (one diode over 10). The following table summarizes the endurance tests performed to the diodes.

	Diode bias	Temperature	Hours	Parts failed
Endurance test 1	DC bias 5A	285C	2000	0
Endurance test 2	DC bias 5A	300C	1000	0
Endurance test 3	DC bias 5A	330C	500	1
Temperature step test	0V	From 230 till 370°C	96 hours every T° step	0
HTRB	-300V	270°C	500	0

Table II: Summary of the endurance and temperature stress performed.

In the failed diode, the forward voltage drifted 10% after 500 hours of stress. The reverse mode was stable. The package of this diode was analyzed using C-SAM and bond pull techniques. From the C-SAM images before and after the stress, we cannot observe a clear degradation of the back-side solder. Neither delamination nor increase of void density and size is seen. The variations observed between the C-SAM images of the die-attach are mainly due to the small scratches appeared on the flange surface after assembly and disassembly processes using a hard thermal interface material. Bond pull test has been performed on all the wires of the failing diode. From the 10 gold wires, 9 exhibited bond strength higher than 20 gf. Only one wire failed with bond strength of 3.9 gf. All the wires except one remain attached to the die and to the pin after bond pull. The only wire which failed ripped off the thick metallization of the diode. However, it is not clear whether this failure is due to the operation temperature or to a local metallization weakness created during the fabrication process.

The temperature step stress was performed up to a diode case temperature of 370°C. At this temperature, we do not observe degradation of the diodes neither in forward (Fig. 4) nor in reverse mode. This results clearly state that the back-side soldering is able to withstand higher temperatures than the Au88/Ge12 alloy melting point (358°C). This is due to the fact that the melting point of the AuGe alloy increases with the Au content. When we soldered the AuGe preform on the top of the Au plated BeO slab, part of this Au diffuses and we increased the Au percentage in the alloy, increasing in this way the maximum working temperature allowed by the AuGe alloy.

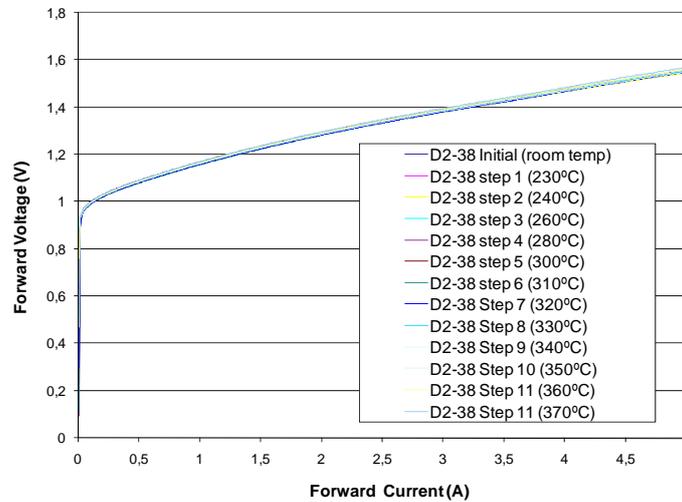


Fig. 4: Forward I-V characteristics of one diode at different temperature steps of the stress

High temperature reverse bias stress has been also performed. Indeed, we combined 1000 hours of 5A DC stress at 230°C, followed by 500 hours in reverse bias (-300V) at 270°C and followed by 500 extra hours of DC stress at 5A 230°C. As it can be seen in Fig. 5, after the initial reverse leakage current decrease already commented above, there is no drift of the reverse current after the different steps of forward DC bias and HTRB.

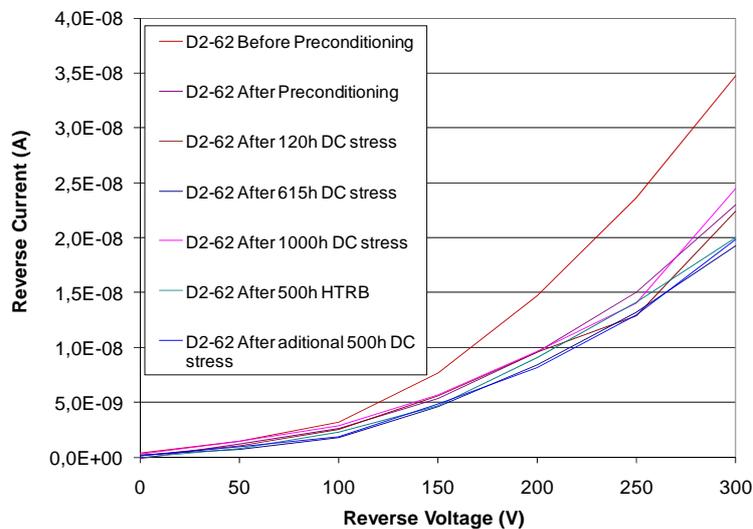


Fig. 5: Diode reverse characteristics after different combined steps of endurance test (5A 230°C) and HTRB (-300V, 270°C).

This is linked to the presence of Oxygen inside the package, which affect both the top metallization layers and the back-side layers. We clearly observed a different aspect and colour of the top metallization after the stress when compared to the initial devices. However, it is worth to note that the bond strength of the wire-bonding is higher than 20 gf on these samples, indicating that the bonding is not affected by the oxygen degradation. We also observed that if we increase the stress temperature till 330°C, the die can be detached off the case by die shear with a force lower than 1kgf. The oxygen seems to affect the parasitic resistance of the top metal layers. The extracted values of the Schottky barrier and the ideality factor of the Schottky contact are very similar before and after the forward voltage drift, indicating that the degradation is only affecting the resistive components of the diode. The oxygen can not modify the SiC layer properties since the diffusion coefficient of oxygen in SiC are extremely low. The impact of the oxygen is then mainly on the metal layers and interfaces of the metal stacks. On the other hand, for this application, organic protection layers such as glob-top is not recommended to avoid outgasing.

We want to stress that the hermetic sealing is absolutely compulsory to get stable operation of these devices at high temperature. To confirm this, we performed the endurance test 1 (5A - 285°C) on devices which were not hermetically sealed. The case was welded but with a given content of Oxygen inside the package (5%-18%). As we can infer from Fig. 6, we observe a progressive drift of the forward characteristics of the diodes with the endurance stress time.

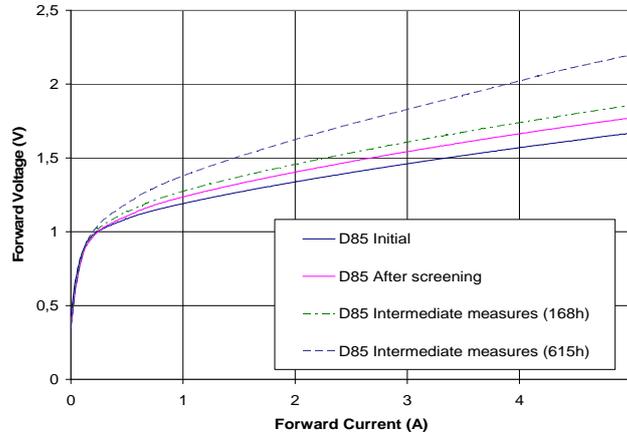


Fig. 6: Forward characteristics of a diode with 10% oxygen content after an endurance stress at 285C during 615 hours.

## RADIATION TESTS

Since the proposed devices are designed for a space application in the inner Solar System, radiation tests have been performed on the diodes. Gamma rays have been first applied to the diodes, with a dose up to 570 Krad and a rate of 3.6 Krad/hour. Table III summarize the forward and reverse electrical parameters before and just after irradiation on 5 parts. As we can infer, no significant change in the forward characteristics is seen. In reverse mode, we observe an increase of the reverse leakage current. Even if we remain with very low leakage current levels, the current increase after stress is significant. However, if we measure again the reverse current of the diodes several days after the irradiation, the measured values are similar to the initial one. The effect of gamma irradiation on the diode behaviour is then reversible. This type of behaviour is characteristic of a semiconductor interface with charges [18]. Silicon Carbide interface usually presents at least one order of magnitude of interface charges higher than silicon [19]. Fast and slow traps are filled with charge during irradiation. After a given time, depending on the trap capture cross section and the time constants, the traps return to their initial state. This directly affects the leakage current of the diode.

Diode n°	Forward mode			Reverse mode		
	Forward voltage @ 3A (V)		Forward voltage drift (%)	Reverse current @ 300V (A)		Reverse Current variation ( $\Delta I_R$ )
	Before test	After test		Before test	After test	
D39	1.86	1.88	1.22	3.4e-7	1.1e-6	7.13e-7
D38	1.63	1.64	0.51	1.1e-7	6.0e-7	4.94e-7
D31	1.54	1.64	0.31	2.1e-8	5.7e-7	5.49e-7
D30	1.60	1.58	-1.09	9.0e-8	5.2e-7	4.34e-7
D29	1.33	1.31	-1.06	1.8e-7	5.2e-7	3.39e-7

Table III: Electrical parameters of gamma irradiated diodes before and after stress; forward and reverse mode.

Proton irradiation has been also evaluated on these devices. The test has been done according to the following conditions: Three samples (D30, D33, D41) have been submitted to an energy of 100 MeV till fluence of  $1.6 \times 10^{11}$  p/cm<sup>2</sup>. Other three samples (D65, D66, D99) to 60 MeV and the same fluence. Finally, three more samples (D100, D102, D106) to 15 MeV. These values have been defined by the customer regarding its application. Each sample was reverse biased at 200V during the test. Resistors in series have been used to limit current to 1 mA. The overall current of the 9 samples has been monitored during the test. The irradiation was performed at room temperature. The results are listed in Table IV.

In the forward mode we do not detect any significant impact of the proton irradiation up to the tested fluence of  $1.6 \times 10^{11}$  p/cm<sup>2</sup> for the energies of 60 MeV and 100 MeV. For the lowest energy, 15MeV, we observe a slight increase of the forward voltage on the three tested diodes, in the range of 2%. We observe a slight increase of the barrier height due to Schottky interface modification, as evidenced in previously reported experiments using more damaging ion for irradiation [17]. It seems that the interface is more affected when the proton energy is low. The protons ionizing power

is higher at low energy than at high energy and could explain partially this behavior but this should be checked by a dedicated study. In the reverse mode, we can observe either no significant change or a slight decrease of the leakage current after stress. We can notice that the higher is the initial leakage current, the higher is the decrease of the leakage current (in percentage). This reduction of leakage current has been also observed in the first steps of endurance and temperature steps stress, and disappear after a preconditioning phase of 96 hours of electro thermal stress. It is important to note that the diode was DC reverse biased at 200V during the irradiation.

Neither Single Event Effects (SEE) nor catastrophic failure have been observed for these energies and fluences. Test under dynamic switching would be requested to complete the study. However, we can already conclude that the diodes present a high level of radiation hardness.

Diode n°	Proton energy	Forward mode		Reverse mode		
		Forward voltage @ 3A (V)		Reverse current @ 300V (A)		Reverse Current variation ( $\Delta I_R$ )
		Before test	After test	Before test	After test	
D30	100MeV	1.60	1.61	7.21E-9	8.01E-9	8.09E-10
D33		1.92	1.95	2.38E-7	8.77E-8	-1.50E-7
D41		1.75	1.77	2.55E-8	2.57E-8	1.49E-10
D65	60MeV	1.57	1.58	1.73E-8	2.62E-8	8.89E-9
D66		1.61	1.62	1.41E-8	1.54E-8	1.33E-9
D99		1.56	1.54	1.21E-6	5.38E-7	-6.75E-7
D100	15MeV	1.68	1.71	6.67E-7	4.58E-7	-2.09E-7
D102		1.66	1.69	3.32E-7	2.47E-7	-8.42E-8
D106		1.67	1.70	1.86E-6	6.99E-7	-1.16E-6

Table IV: Electrical parameters of proton irradiated diodes before and after stress; forward and reverse mode.

## SETUP CONSIDERATIONS

This section highlights setup related problems encountered during the testing of these diodes and the improvements done in the test setup in order to avoid them during screening and qualification of the flight diodes.

**Aluminium remains in the diodes.** This aluminium was used to cover the thermocouple washers to avoid corrosion and has been transferred to the diodes. A new more thick aluminium cover has already been implemented to avoid this problem. The direct contact of the thermocouples washers to the gold finishing of the package at high temperature had led to chemical reactions that lead to severe damaged packages.

**Scratches and colour changes.** Some little scratches were found in the back of the diodes. The scratches were made during the mounting of the diodes in the test setup. The aluminium block that fixes the diodes is going to be mounted after the diodes instead of before in order to completely avoid this problem. Color changes were produced by the metallic grid where the diodes were mounted for the High Temperature Stabilization Bake and Thermal Cycling. The samples are being hanged from a stainless steel rod to avoid the possibility of corrosion as shown in the following picture.

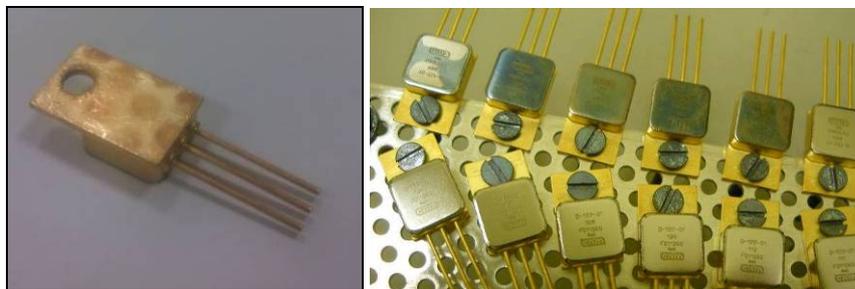


Fig. 7: Details of the color changes induced by the metal grid used.

**Gold receptacle contacts.** The direct contact between Cu wires stained some terminals after high temperature tests. Gold receptacle contacts were implemented in order to ensure electrical contact between Cu wires and the diode terminals without staining the diodes. Those contacts have been soldered using a high melting point soldering compound (5% tin, 93.5% lead, 1.5% silver) that melts at high temperature (296-301°C). This method assures that the diodes terminals only contact with the gold of the receptacle contact.

**Solder alloy in several terminals.** The soldering compound used to contact the pins wet a little surface of some terminals in those gold receptacles that were incorrectly soldered (excess of soldering alloy in receptacle).

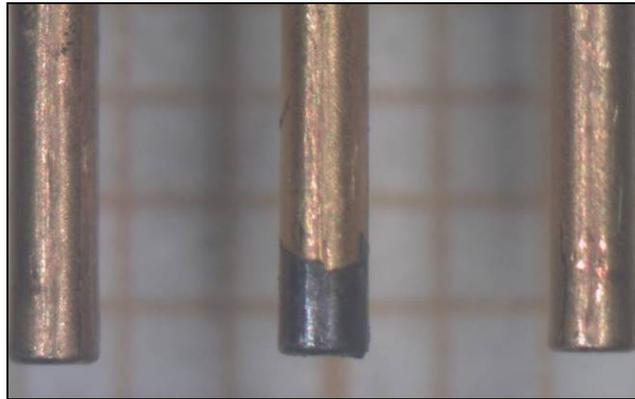


Fig. 8: Solder alloy on the end of one terminal.

After noticing this issue all the pins were replaced and more carefully soldered. It is not expected to encounter this problem anymore since the soldering compound is at a great distance of the terminals and the terminal only touches the golden surface of the receptacle. The new soldering method results are shown in the following picture where a diode has been connected to the receptacle:

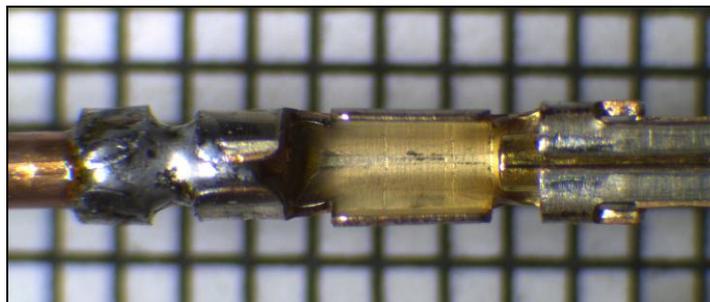


Fig. 8: Gold receptacle use to contact the gold terminals and soldered with high temp allow to a Cu wire.

**High temperature manipulation.** The following marks were found in one diode. Those marks were printed in the surface of the diode by touching it at high temperature with the protective ESD gloves used to handle the diodes. Those “glove finger prints” will not in any case be transferred to the diodes since all the temperature tests will be done in the future in the test made for this purpose.

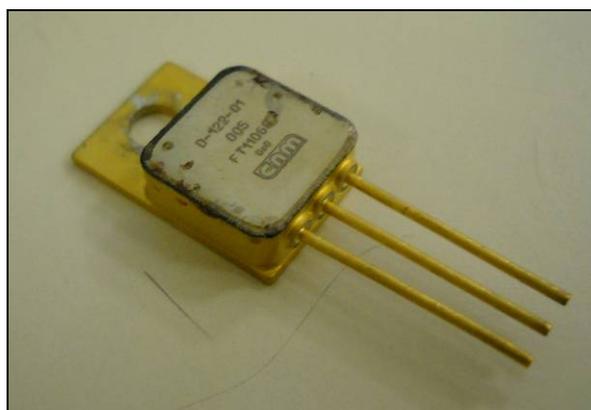


Fig. 9: Marks found on one sample induced to high temperature manipulation.

**The low temperature measurements cause the ambient humidity to freeze in the terminals creating small amounts of ice.** This ice can create a leakage path if melted and this can affect the reverse current measurements. In that case, the measurement is repeated while heating the external area of the wires (near the external PCB mounted on the chamber door). Heating this zone evaporates the water and allows the correct measurement.

## CONCLUSIONS

300V-5A Schottky diodes have been designed and fabricated for operating in solar panel arrays of BepiColombo space mission. The package and semiconductor technologies have been made compatible to reach an operating temperature ranging from -170°C to 270°C. W Schottky contacts have shown to be highly stable after the long time stress at high temperature. The main challenge was the interconnection and packaging schemes. This was solved using Gold wire bonding and electroplating Gold top anode metallization instead of sputtered Aluminum as high current anode metallization. On the cathode contact, the Ti/Ni/Au metallization and AuGe die-attach combination showed a very good behavior. The packaged diodes (metallic TO-257 case with an intermediate BeO isolation layer) exhibited a high stability up to working (case) temperature of 330°C. The diodes are also able to support thermal cycling from -170°C up to 270 °C. Finally, the diodes presented a good resistance to radiation test, even if some dynamic effect on reverse leakage current are seen in the total dose radiation test. These effects are due to the interface charges and are reversible. From the results presented here, one can conclude that the fabricated W+Au SiC diodes are suitable for the extreme working conditions required by the specific BepiColombo mission to Mercury. These devices are produced in a standard production line which includes 2 specific equipments: an Aluminum implanter and a high temperature (1600°C) furnace. For this application, only small series of parts are needed, in the range of 2000. The quality control of the parts is done through a screening procedure done on each part which includes conditioning step, measurements at low and high temperature, temperature cycling, HTRB test, power cycling and leak tests.

Testing high power devices at high and low temperatures leads to unusual problems that can be solved by preparing and checking the proper setup. The description of some of these problems and the implemented solutions has been described. A screening of 1200 diodes and a parallel qualification for the Bepi Colombo project is being done at the moment of writing this paper.

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