Progrese în aplicațiile complexe de temperatură ridicată ale dispozitivelor SiC

Advances in high temperature, complex applications of SiC device

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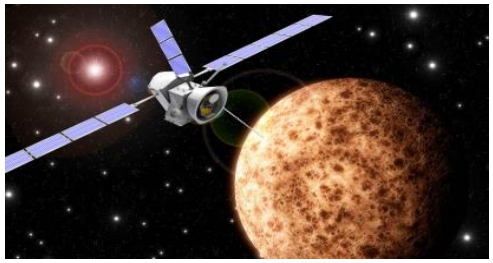
High Voltage and Temperature Applications



The high temperature and high voltage power devices are now demanded by the industry for new projects.

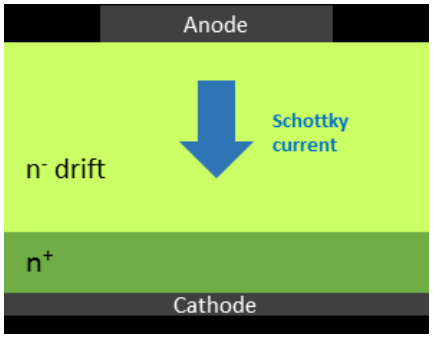
Cuprins

- Diode SiC
- Dispozitive de comutatie pe SiC
- Circuite integrate pe SiC
- Referinte de tensiune de inalta temperatura SiC
- Diode SiC pentru aplicatii spatiale

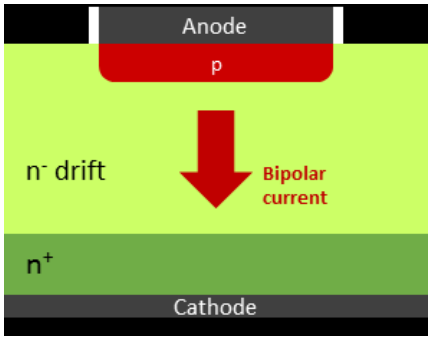
Diode pe carbura de siliciu

SiC Diodes

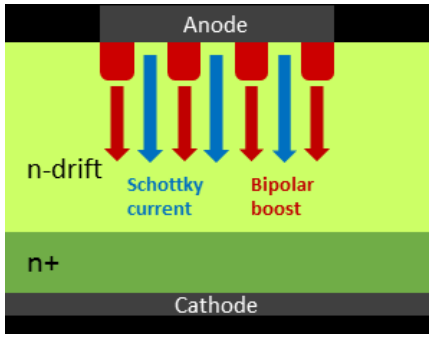
Schottky diode (SBD)

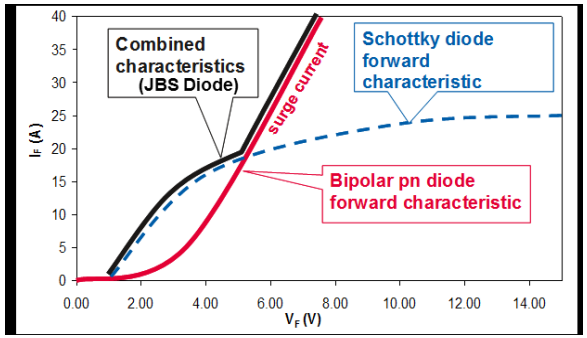


Bipolar diode (PiN)



JBS diode



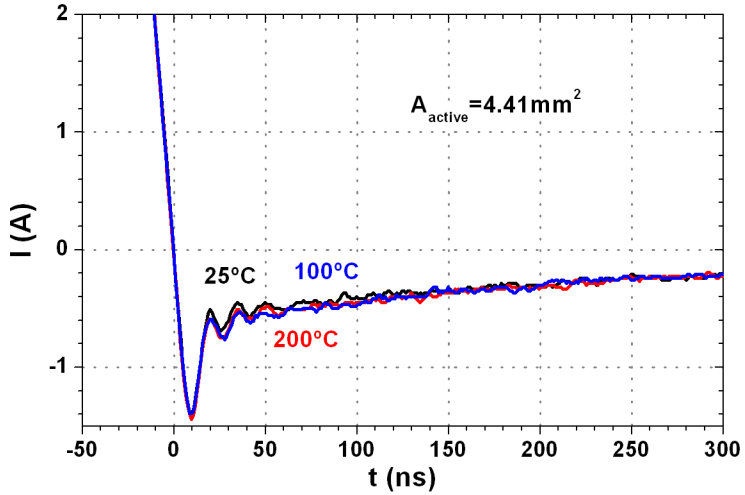


Typical forward I(V) characteristic of a SiC JBS rectifier

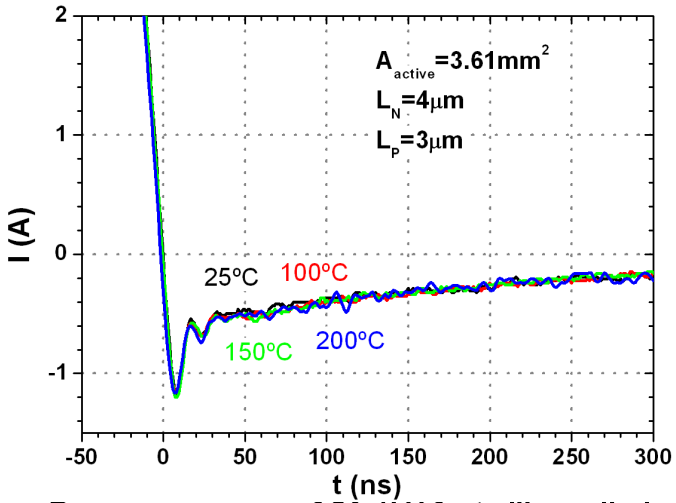
- **SBD: high switching speed and low on-state losses, but lower blocking voltage and high leakage current.**
- **PiN diodes: high voltage operation and low leakage current, but higher reverse recovery time during switching.**
- **JBS (or MPS) diodes: Schottky-like on-state and switching characteristics and PiN-like off-state performances.**

Switching Characteristics of Schottky and JBS diodes

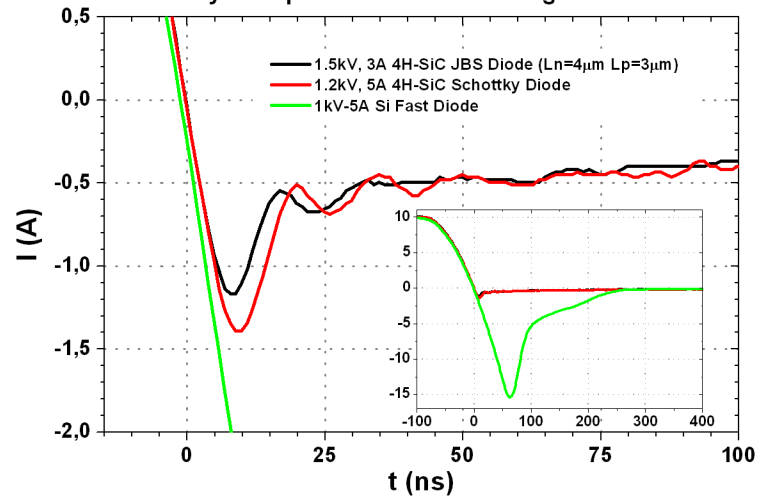
Reverse Recovery of 4H-SiC 1.2kV, 5A Tungsten Schottky Diode



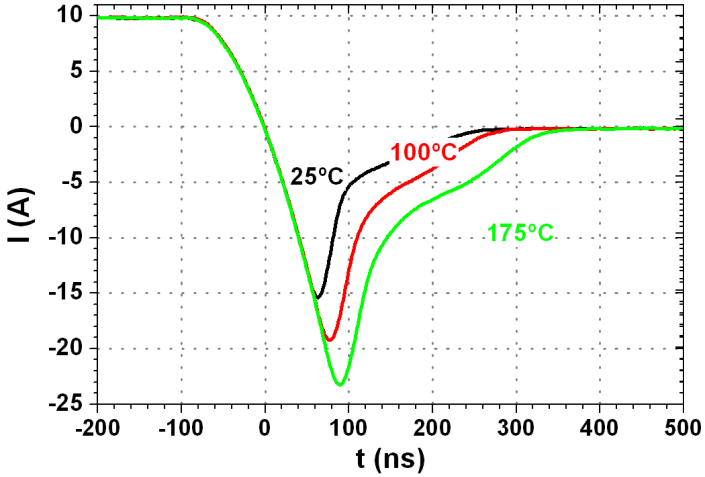
Reverse Recovery of 4H-SiC 1.5kV, 3A Tungsten JBS Diode



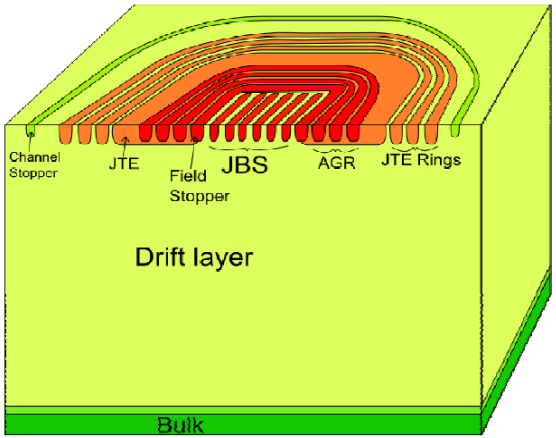
Reverse Recovery Comparison of Si and Tungsten SiC diodes



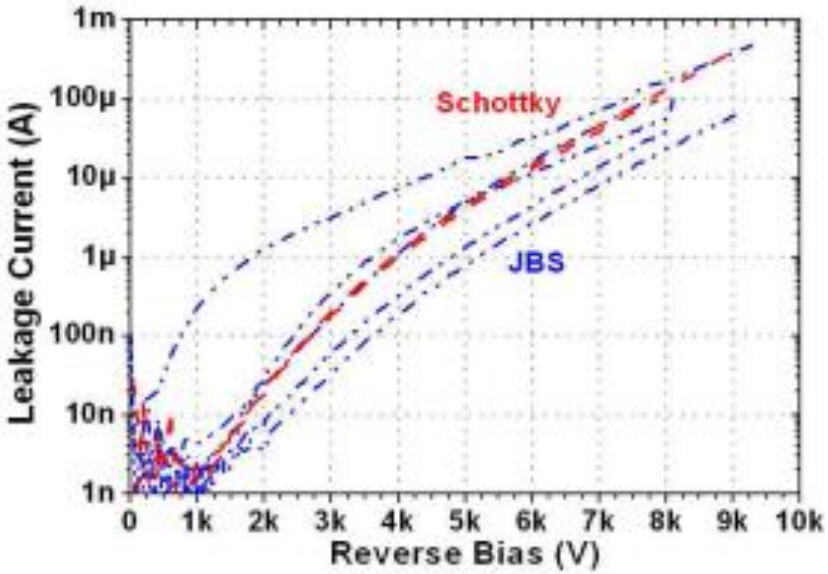
Reverse recovery of 5A,1kV fast silicon diode



9kV SiC Diodes



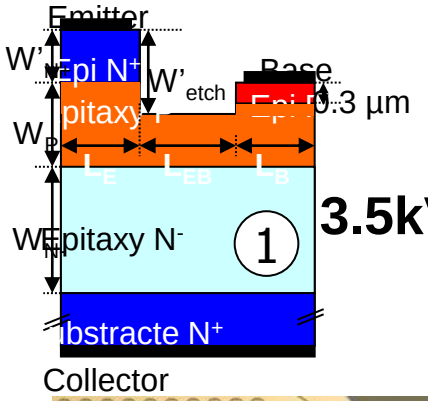
Schematic view of a JBS diode with the 10kV edge termination.



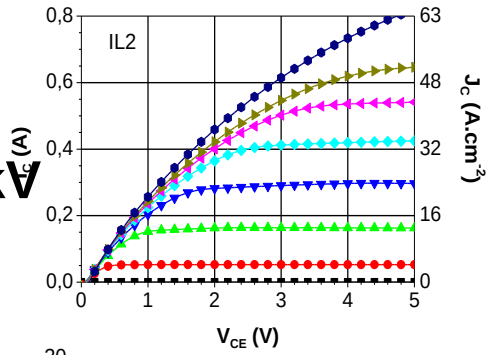
Reverse characteristics of 9kV JBS diodes measured at room temperature in a Galden bath.

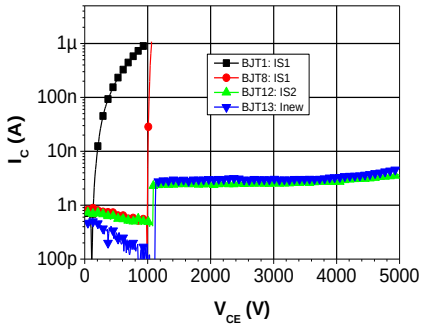
Dispozitive de comutatie pe carbura de siliciu

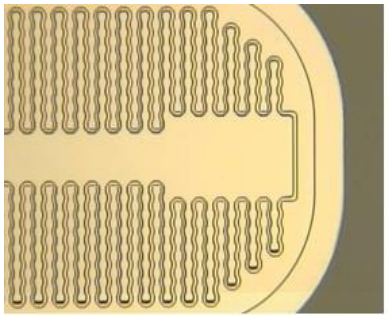
SiC Bipolar Transistor

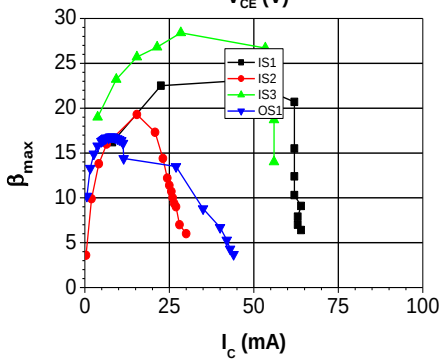


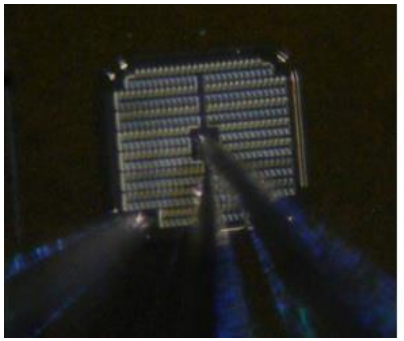
3.5kV – 5kV







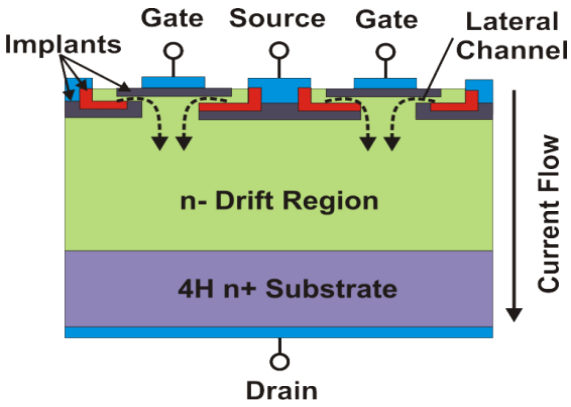




BJTs are able to sustain high voltage breakdown and high currents. However the presence of BE surface recombination reduce the transistor gain. Surface recombination remains a big issue to be solved.

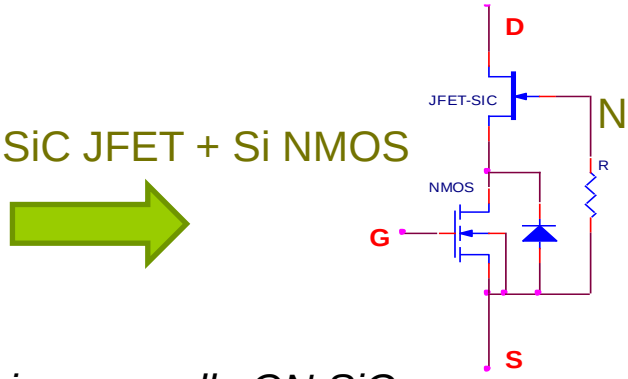
SiC JFETs + Si MOSFET

Normally ON



SiC JFET

Cascode SiC JFET + Si NMOS

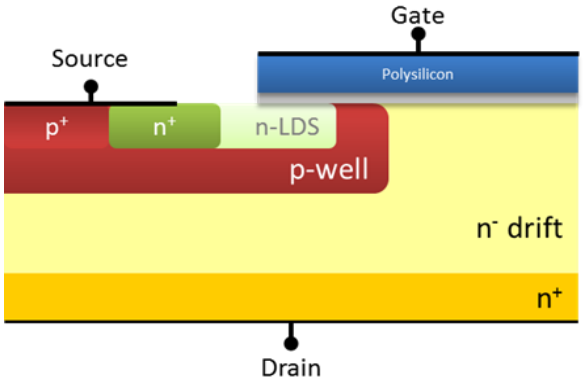


Normally OFF

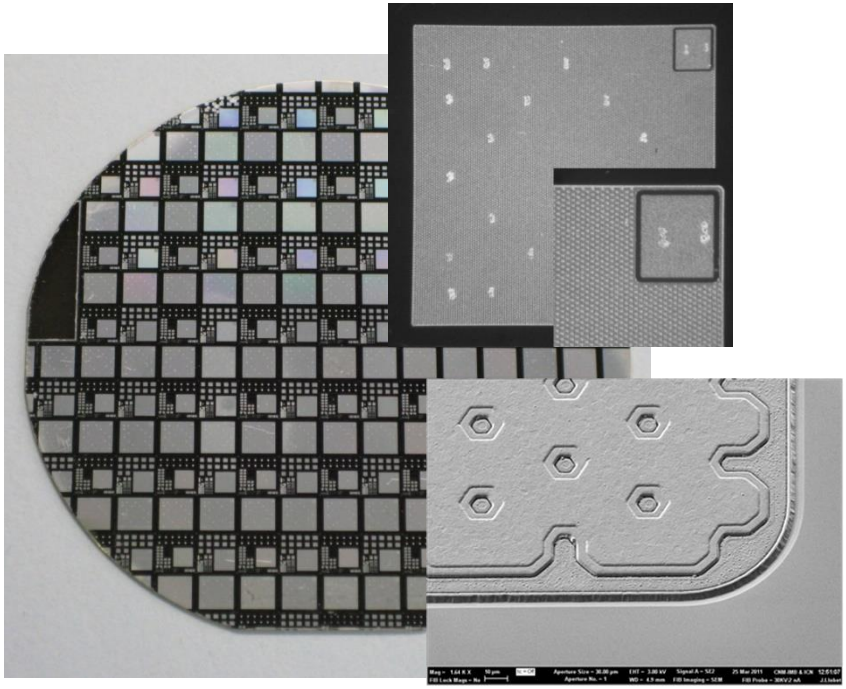
Combining normally ON SiC JFET with low voltage Si MOSFET, a normally OFF device is obtained.

- **SiC unipolar switches allow on-state conduction losses'reduction compared to Si IGBTs.**
- **Internal body diode can replace the freewheeling diode.**
- **Single SiC JFET also used for circuit protection (current limitation)**

SiC MOSFETs

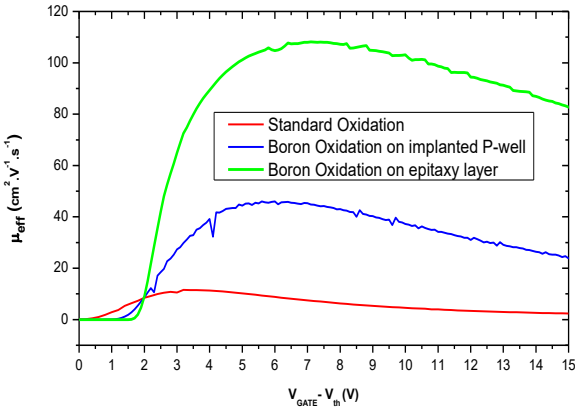


Schematic cross-section of a SiC planar VDMOS half-unit cell

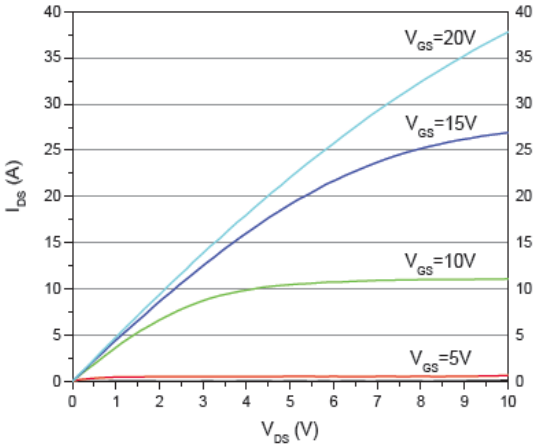


Important efforts are focused to solve the remaining issues of SiC MOSFETs.

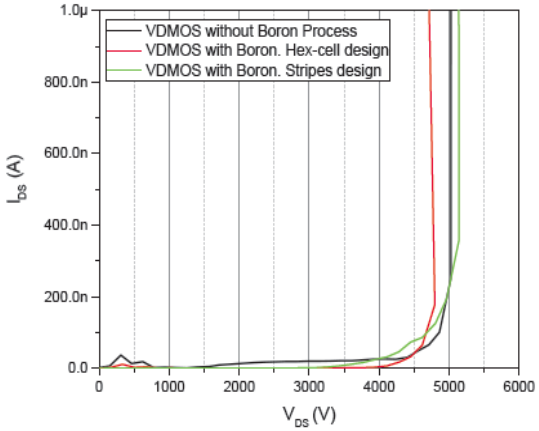
SiC Switches:MOSFETs



Experimental effective channel mobility



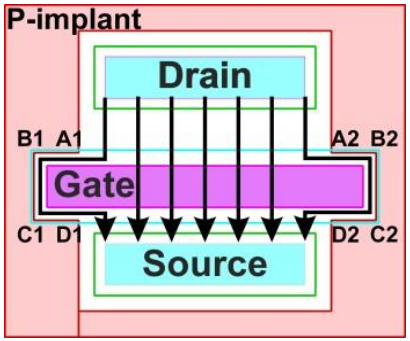
Experimental output characteristics of fabricated 25mm^2 VDMOS



Blocking characteristics of fabricated VDMOS with hexagonal and stripe designs.

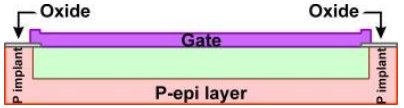
Circuite integrate pe carbura de siliciu

Finger Gate MESFET

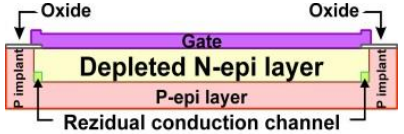


Basic finger gate MESFET layout and current flow distribution

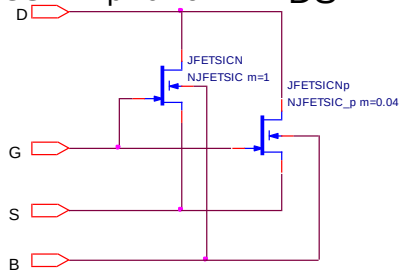
We have designed an original scalable finger- gate MESFET having implanted isolation rings. It was further used for the integrated circuits design and fabrication.



Cross section through the non depleted gat

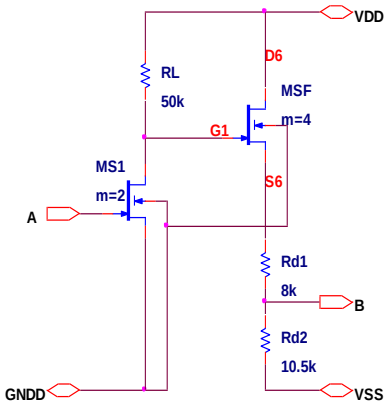


Cross section through depleted gate of the main transitor and residual channel @ $V_{GS}= V_{pinch-off}$, $V_{DS}=0$

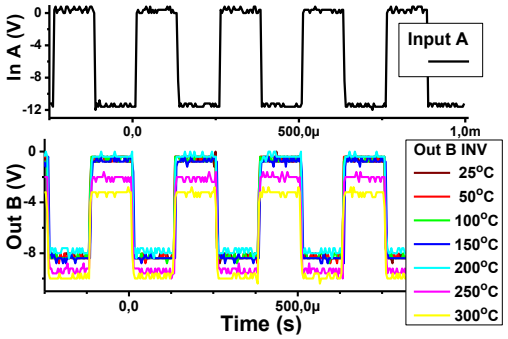


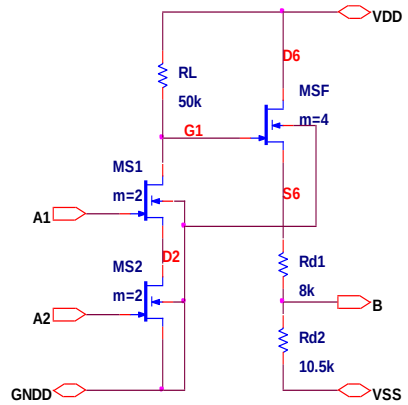
Electrical equivalent circuit of the composed MESFET

Basic digital gates schematics with MESFETs

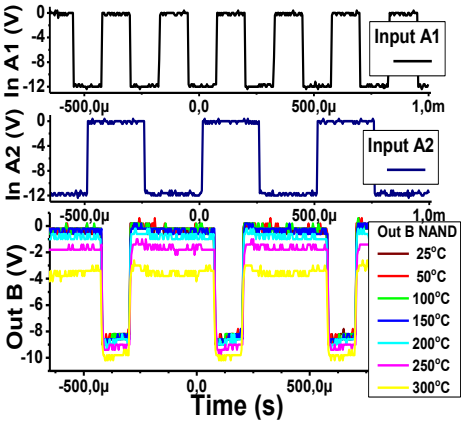


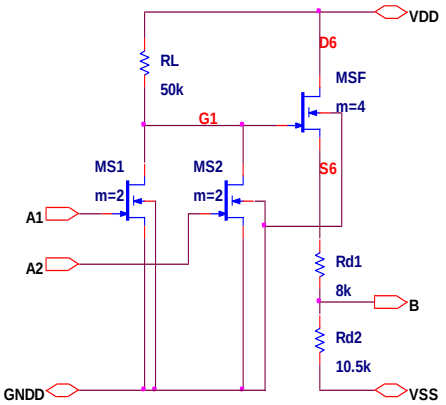
NOT(inverter)



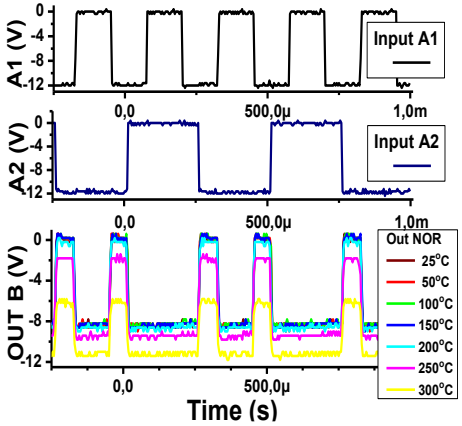


NAND

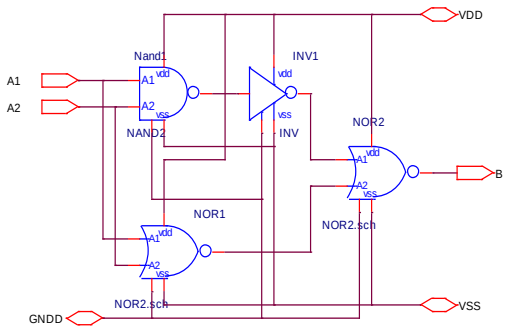


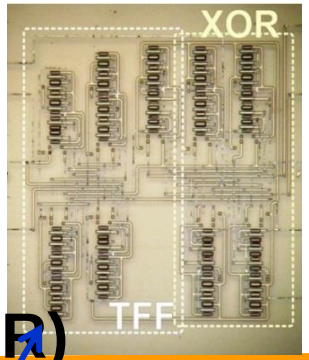


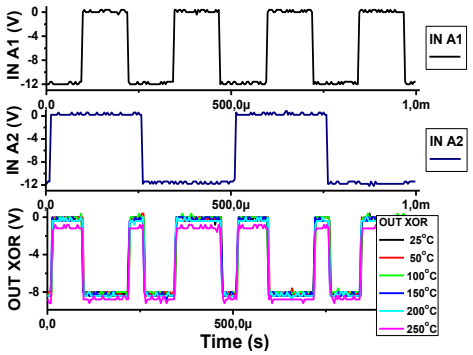
NOR



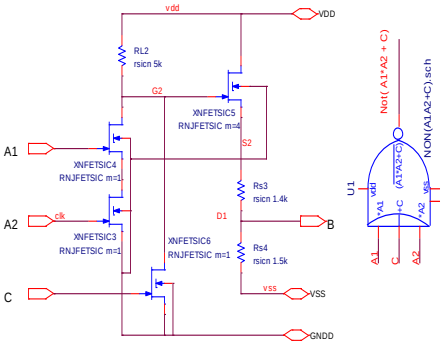
Basic digital schematics with MESFETs

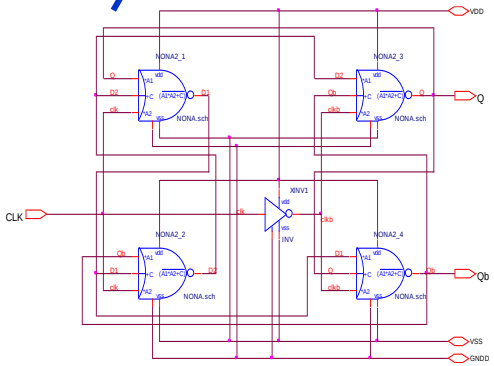


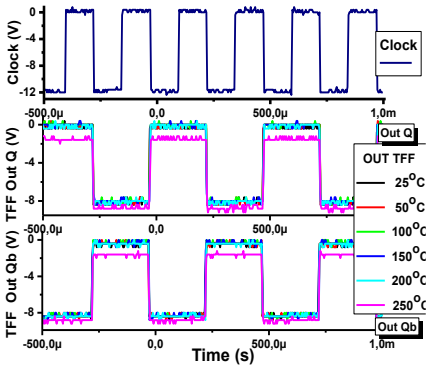




Exclusive OR gate (XOR)

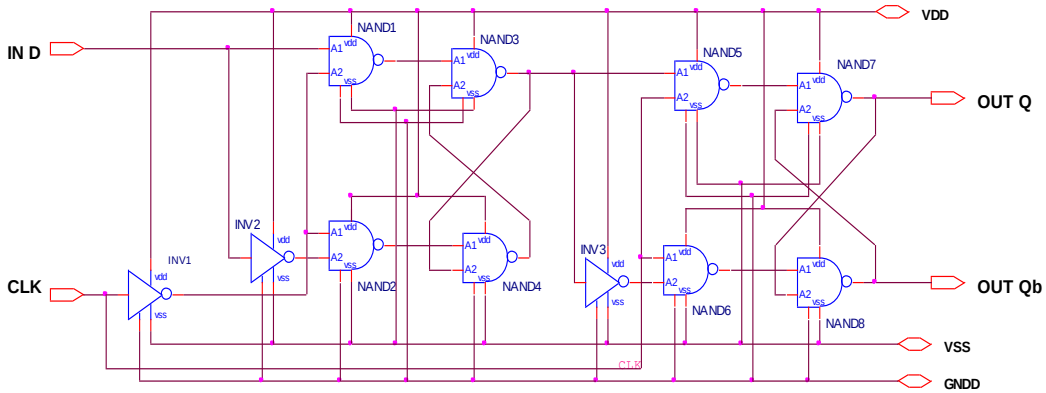


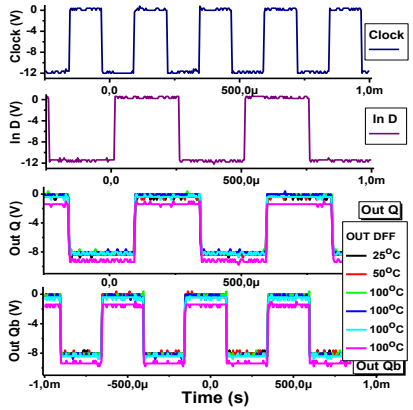


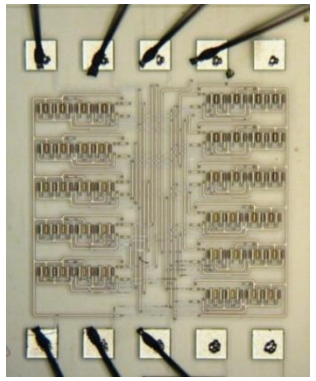


Toggle Flip-Flop (TFF)

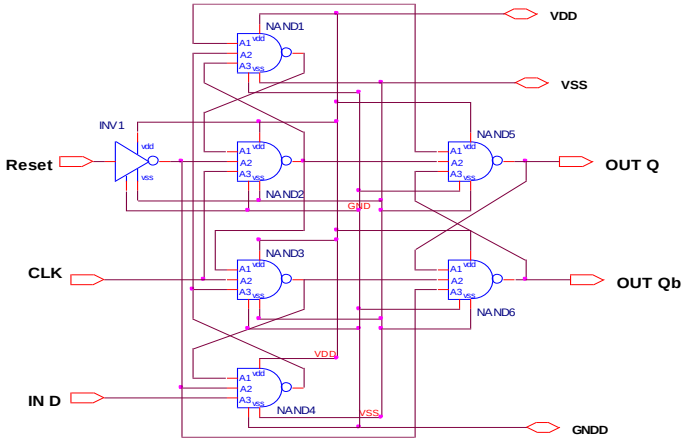
Basic digital schematics with MESFETs

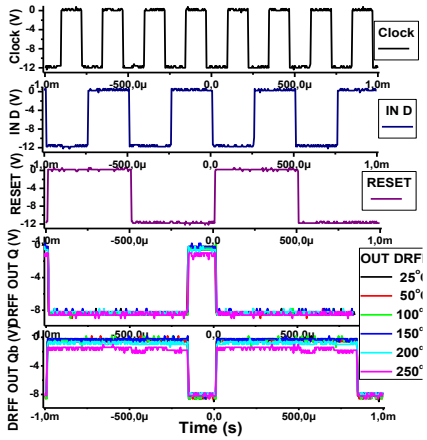


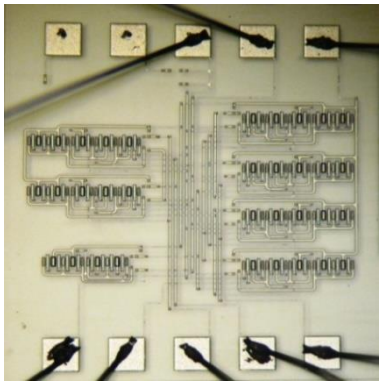




Data Master-Slave Flip-Flop (DMSFF)

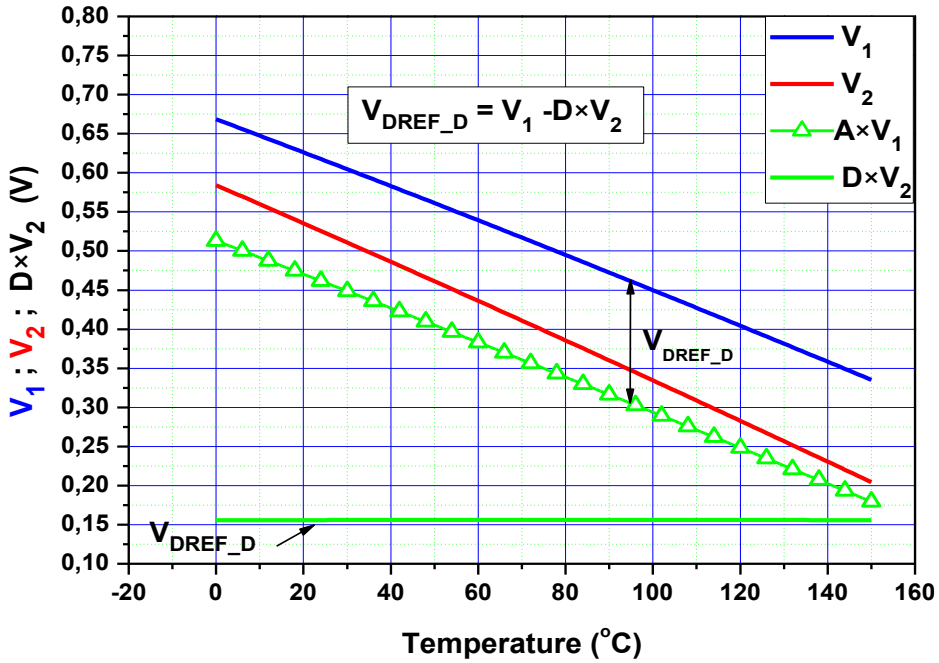


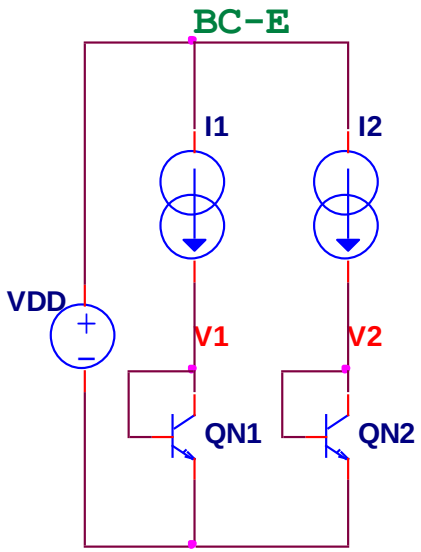




D-Reset Flip-Flop (DRFF)

Referinte de tensiune de inalta temperatura pe carbura de siliciu

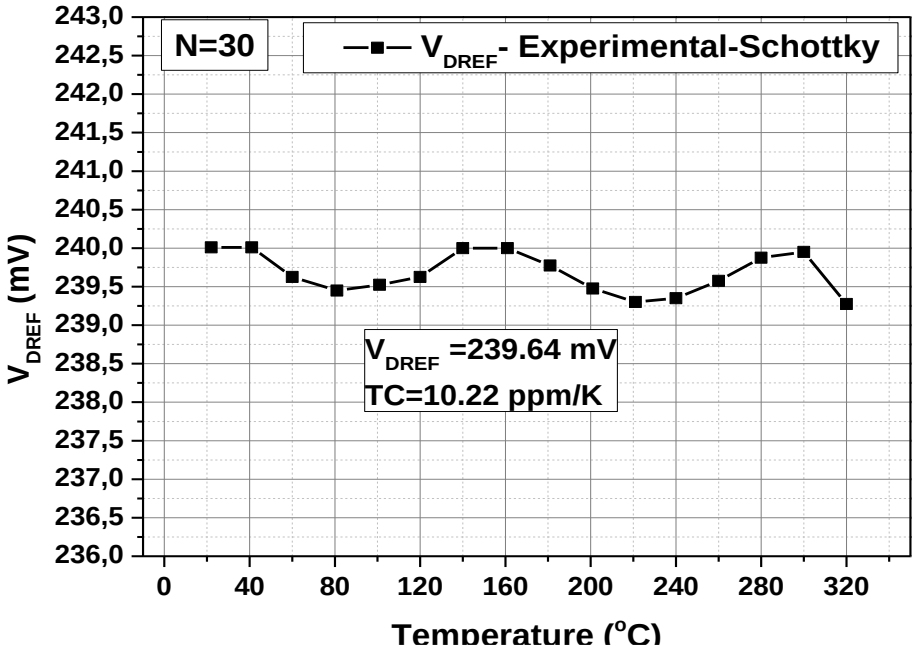


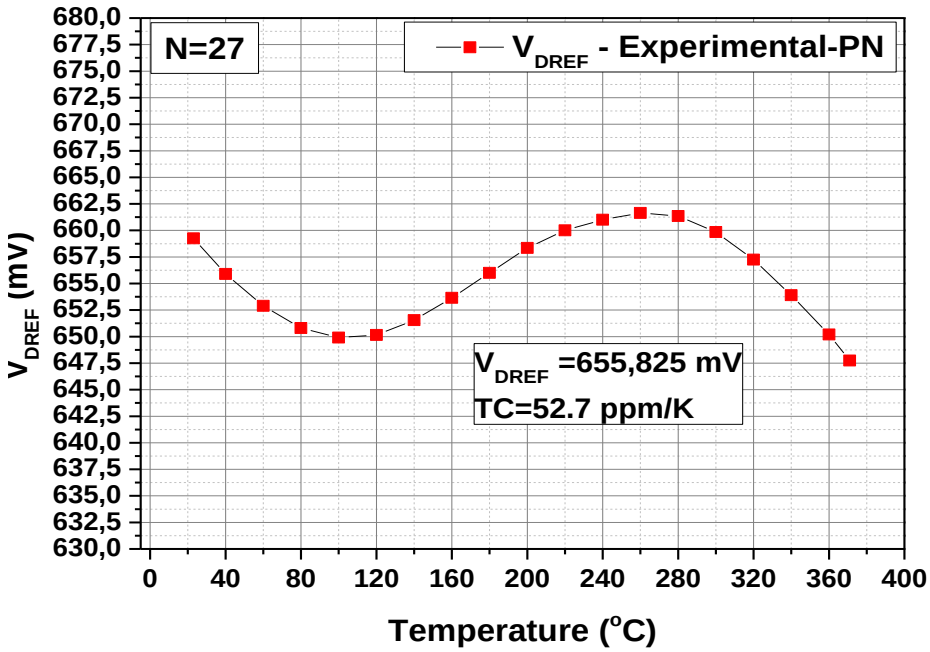


$$V_{DREF\_D}=V_1 - D\times V_2$$

$$D=m_1/m_2$$

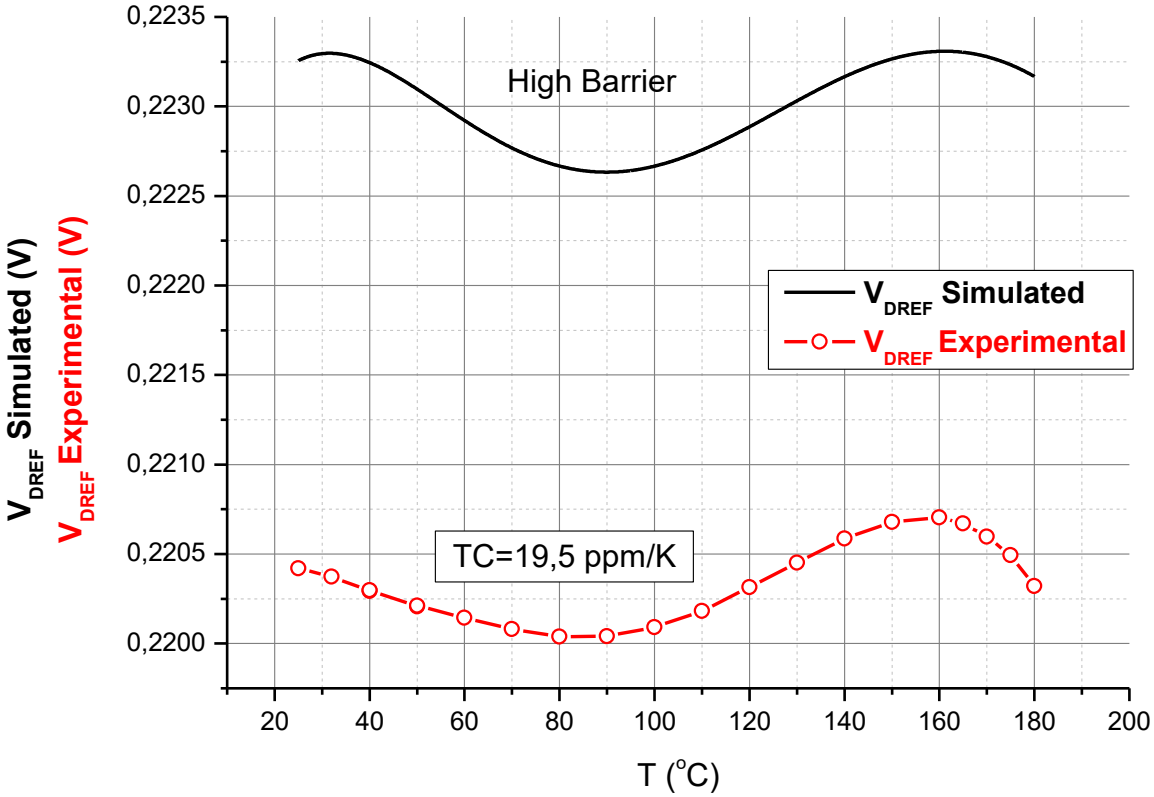
Measurements Results:SiC Schottky and PN diodes





The experimental characteristics of Delta-Reference voltage versus temperature for Schottky and PN diodes implementation illustrate good results considering such a wide temperature range. Both output voltages are less than 1 volt.

SPICE simulated and experimental comparison V_{DREF} using Barrier Shottky



Very good corelation between experimental and simulated characteristic.
The slight shift of the experimental characteristic is due to small differences between real diode's barriers in pair and parasitics of experimental approach.

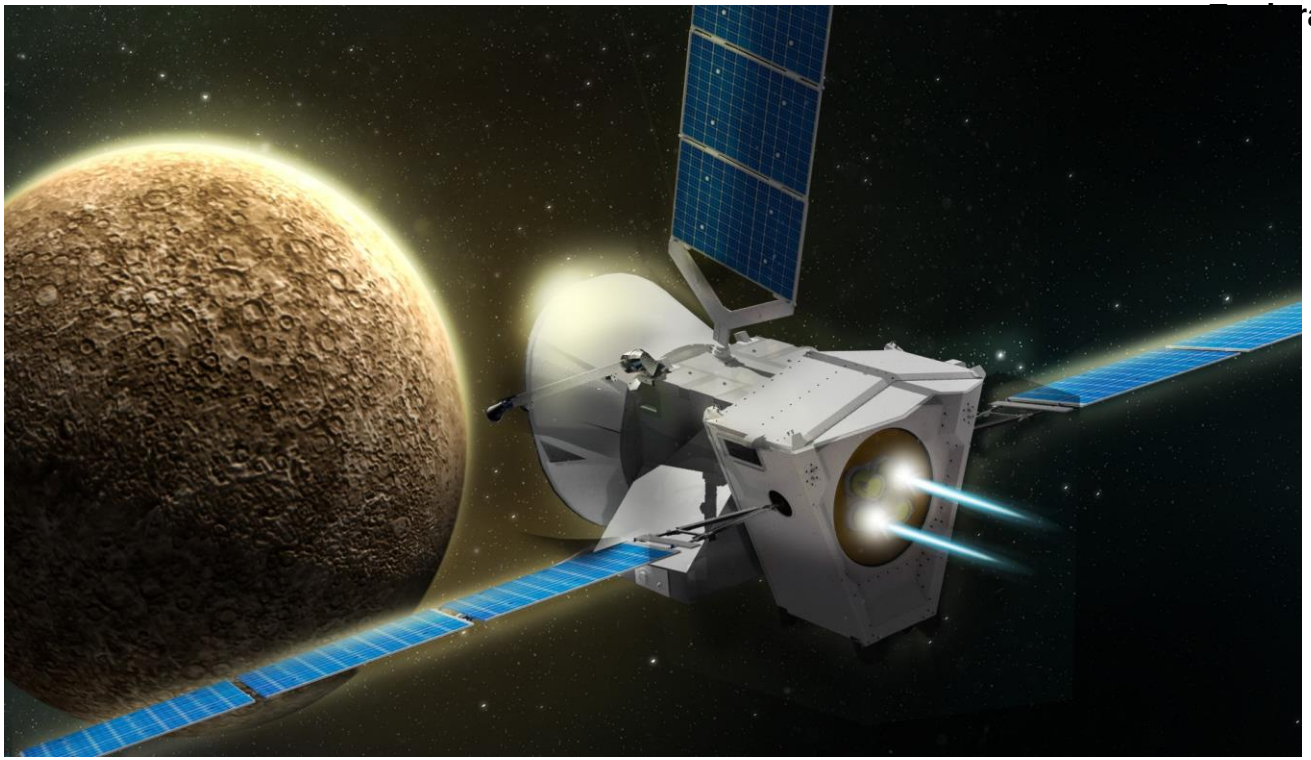
Diode pe carbura de siliciu pentru aplicatii spatiale

BepiColombo Mission: Exploring Mercury

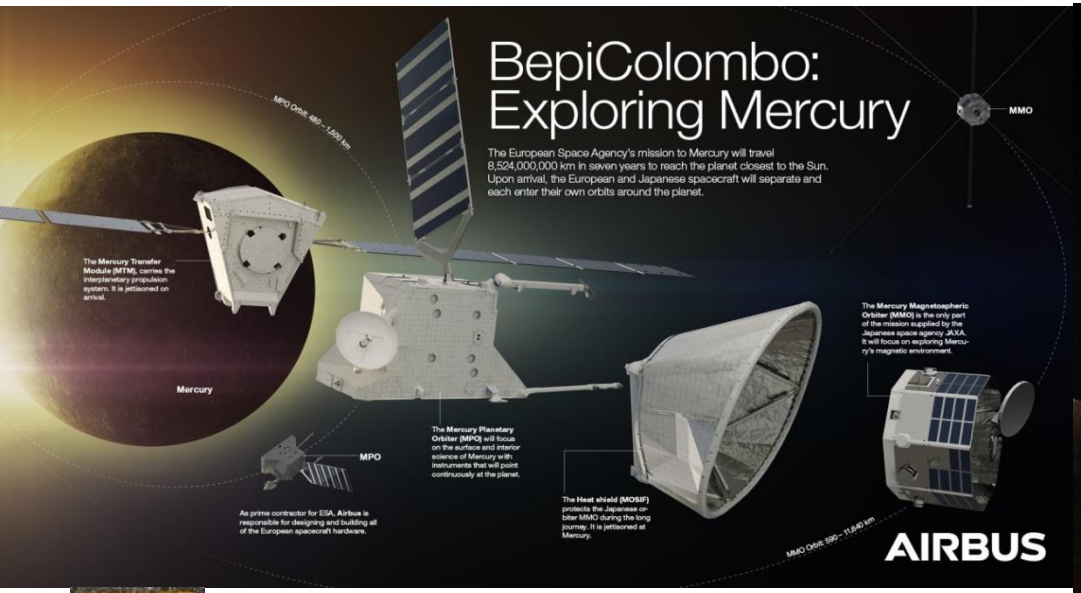
esa
European Space Agency

bepicolombo

JAXA
Japan Aerospace
Exploration Agency



BepiColombo is a joint endeavour between ESA and the Japan Aerospace Exploration Agency, JAXA. It is the first European mission to Mercury and the first to send two spacecraft to make complementary measurements of the planet at the same time.

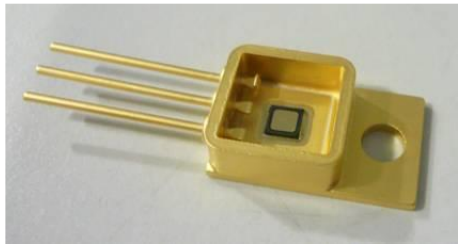


BepiColombo Spacecraft Launched on 20 Oct 2018 at 01:45:28 GMT (03:45:28 CEST)

Schottky Diodes for Solar Pannels*

***supplied by "Instituto de Microelectrónica de Barcelona", IMB-CNM (CSIC)**

BepiColombo is a ESA space mission to explore **Mercury.** Since Mercury is close to Sun, the expected working temperature range of the solar cell and associated electronics is from -150ºC to +260ºC

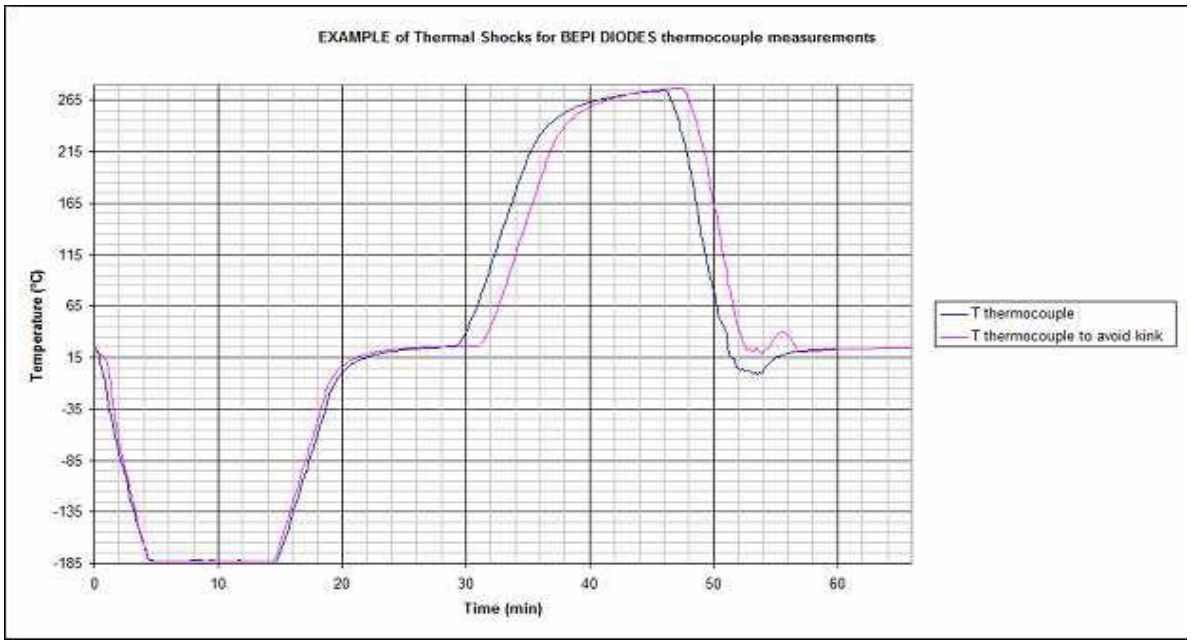


In state-of-the-art solar arrays each solar cell string is terminated by a protective blocking diode in series with the solar cells. The main task of these diodes is protecting the solar panel against string short circuit.
The diode is working in DC forward bias when solar panel is illuminated.

Protection Diodes Specifications

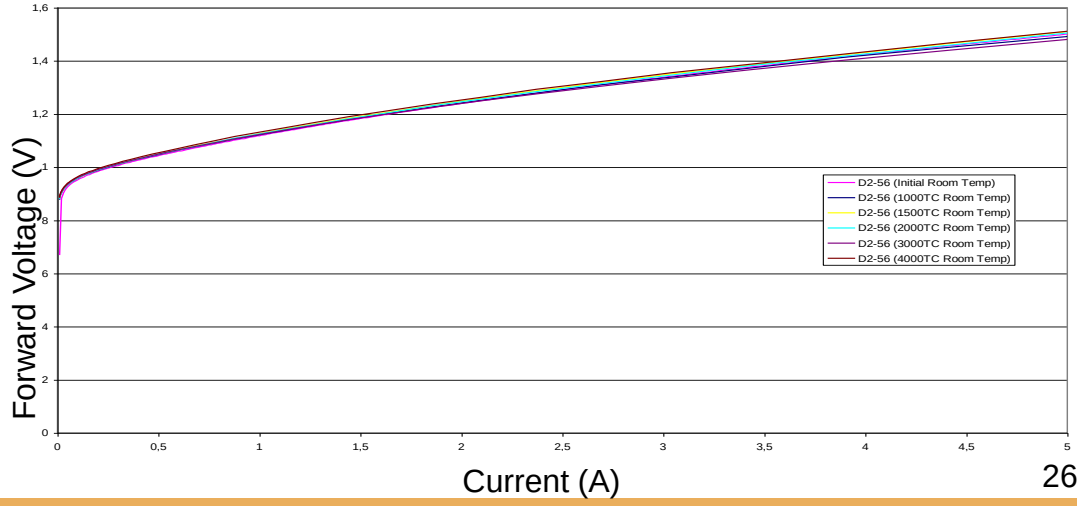
- Operation temperature range: -170ºC / +280ºC.
- Breakdown voltage >**300 V** over full temperature range.
- Reverse current < **1 mA** @ 300 V and 280ºC.
- Nominal DC output current: **5 A** over full temperature range.
- Maximum forward voltage drop at nominal current and 280ºC: **1.7 V.**
- Packaged diode weight < 5 g.

Diodes Thermal Cycling Test



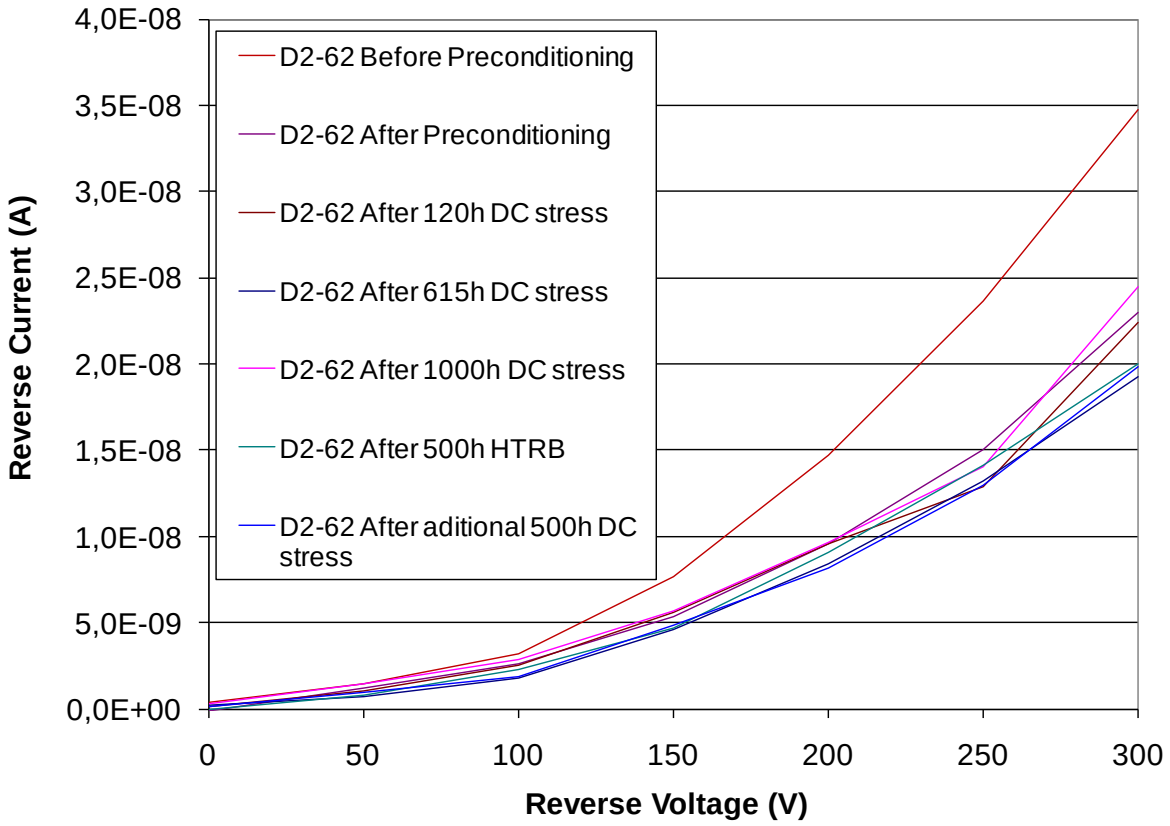
Thermal cycle in eclipse

- 4,000 thermal cycles
- 40º C per minute
- From -170ºC to +280ºC

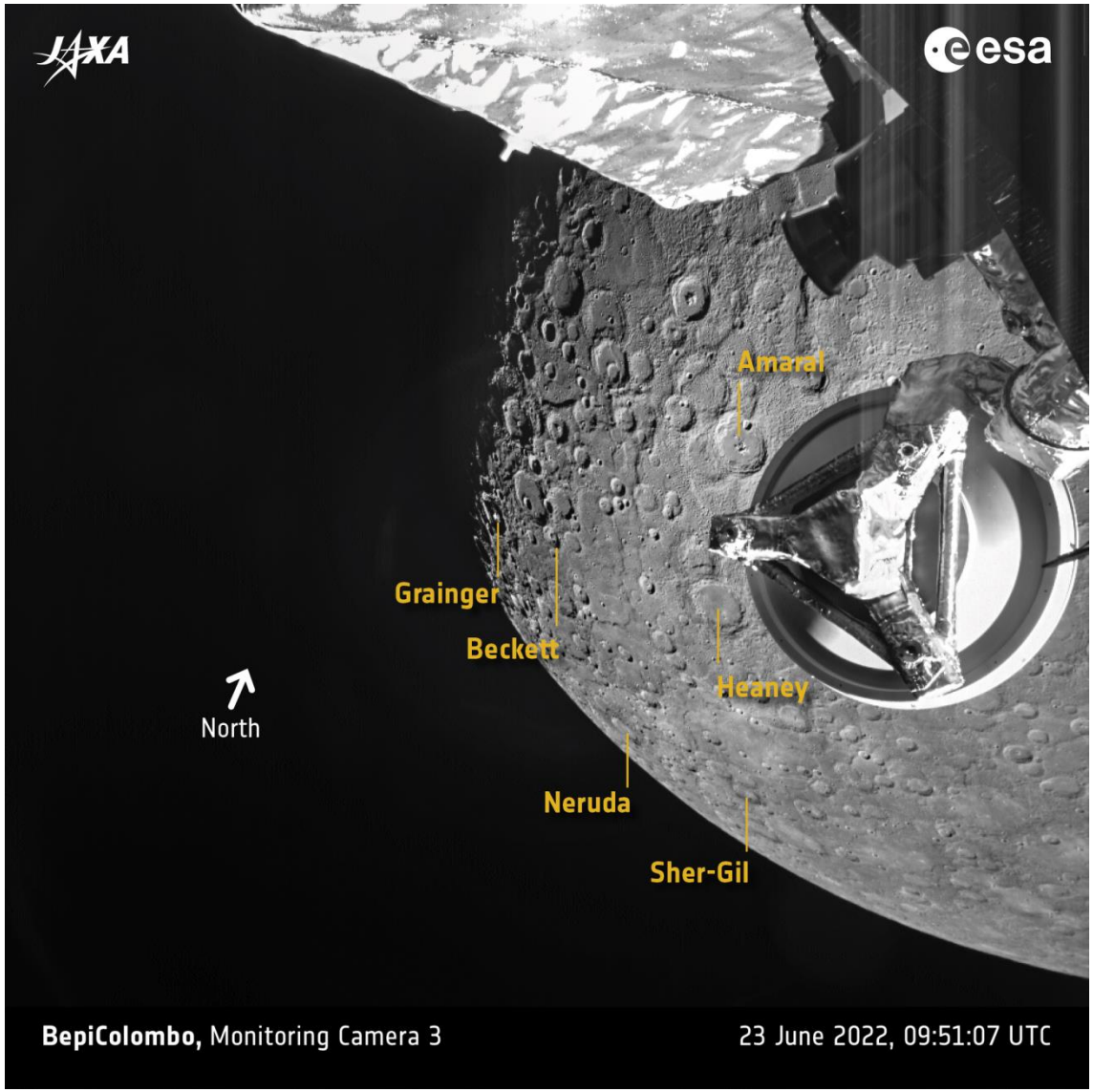


Diodes HTRB Tests

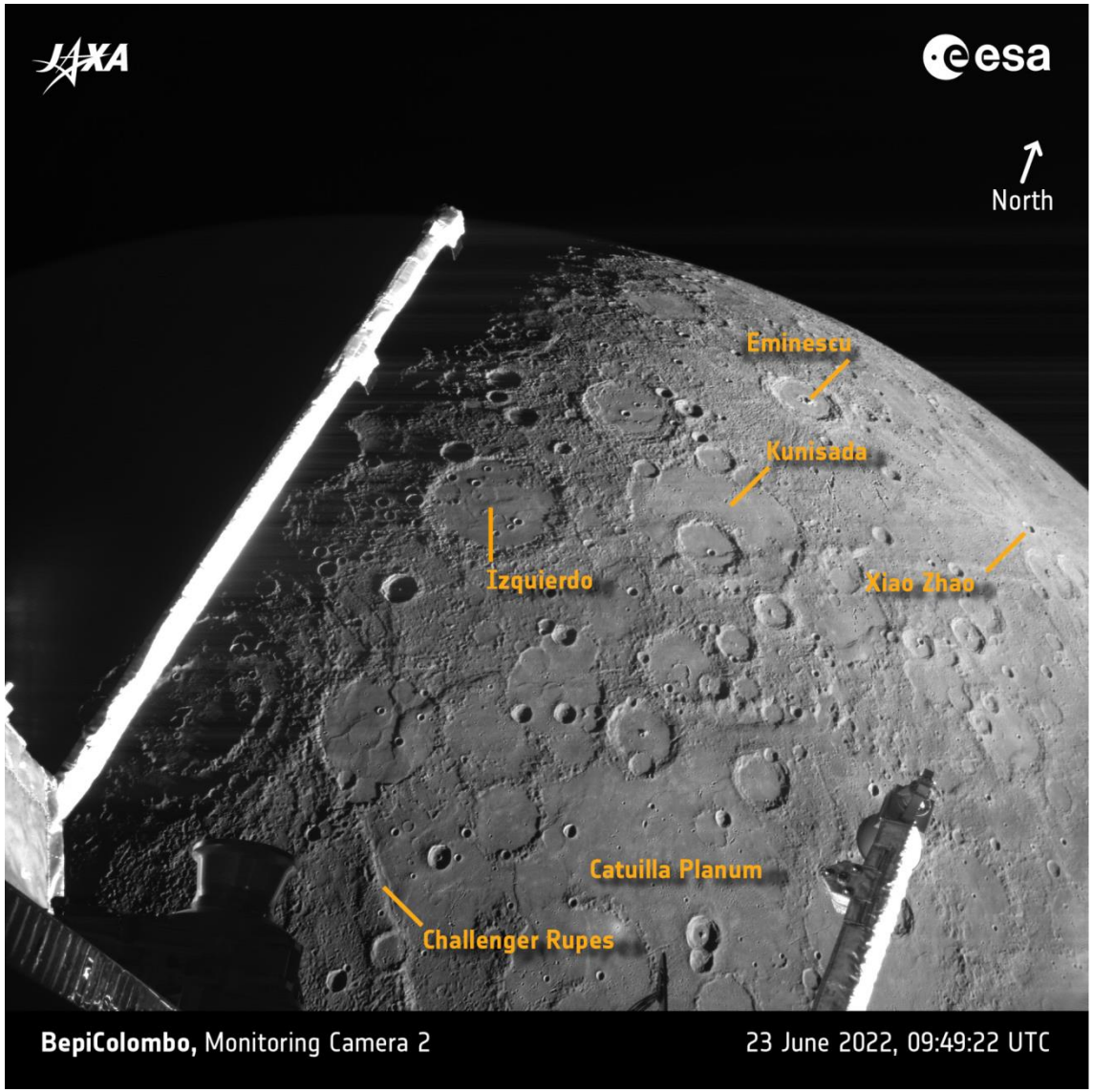
HTRB stress: 500 hours at 280ºC



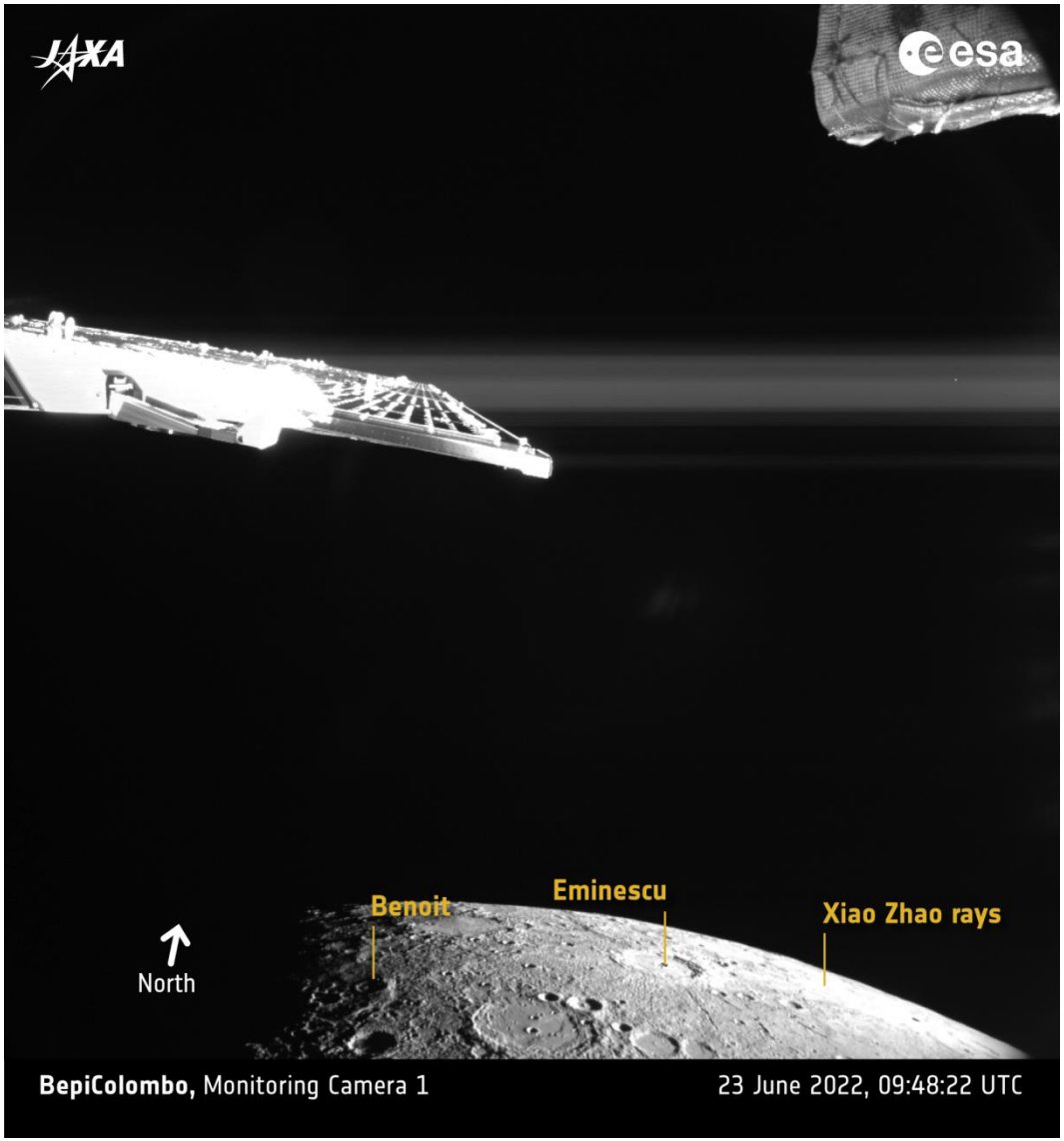
Drift after preconditioning. No extra drift after HTRB and DC bias stress



The search for volcanoes annotated pillars



BepiColombo surveys Mercury's rich geology annotated pillars



Sunrise and shadows annotated pillars

Solar Orbiter flyes within the orbit of Mercury

CONCLUZII

- S-a demonstrat ca dispozitivele realizate pe carbura de siliciu prezinta un mare potential pentru dezvoltarea aplicatiilor de putere si in conditii de functionare extreme.
- Carbura de siliciu permite realizarea atat a redresoarelor si comutatoarelor de putere cat si a unor circuite integrate sau referinte de tensiune stabile in temperatura.
- Comparativ cu dispozitivele realizate pe siliciu, dispozitivele pe carbura de siliciu pot functiona la temperaturi si la tensiuni mult mai ridicate precum si la frecvente inalte cu randamente superioare.
- Dispozitivele pe carbura de siliciu au contribuit la explorarea spatiului cosmic in zone cu variatii extreme de temperatura, intre -170ºC / +280ºC.

Va multumim pentru atentie

Institute of Microelectronics of Barcelona IMB-CNM

- Centre Nacional de Microelectrònica (CNM)- Institut de Microelectrònica de Barcelona (IMB

- D+T Microelectrònica A.I.E. Barcelona