

saes

Strategies to prevent gaseous contaminants issues in sealed electronic and optoelectronic devices

Alessio Corazza, Luca Mauri, Giovanni Zafarana, Enea Rizzi

Outline

- Hermetically sealed devices with getters
- Vacuum sealed devices with thin getter films
- Hermetically sealed devices with filling gas
- New Getter solutions and main features
- Takeaways

SAES: an Advanced Material Company

More than 80
Years of innovation

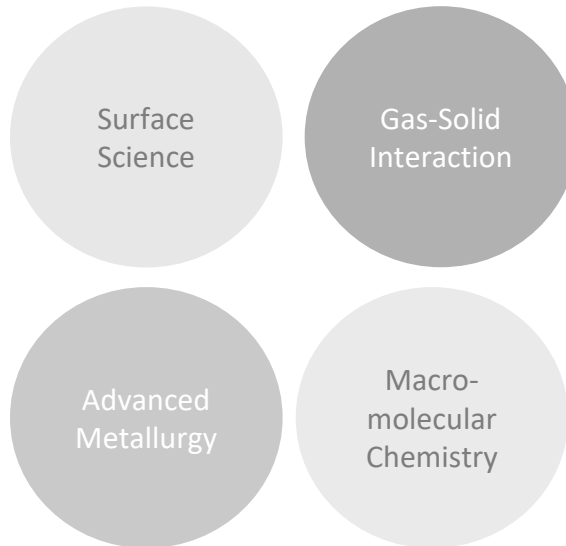
~650
Employees

8
production sites worldwide

>135 Mill €
total revenues of the Group

R&D-based Group:
our first values are Research & Innovation

Our key competences



Our Advanced Functional Materials



Functional Metals

- > Getter Alloys
- > Alkali Metal Dispensers
- > Sintered Heat Sink submounts
- > Shape Memory Alloys



Functional Chemicals

- > Inorganic & Organic Getters
- > Advanced Polymers
- > Advanced Composites



SAES Group: Industrial Applications

These applications deal with supplies of various components and systems :

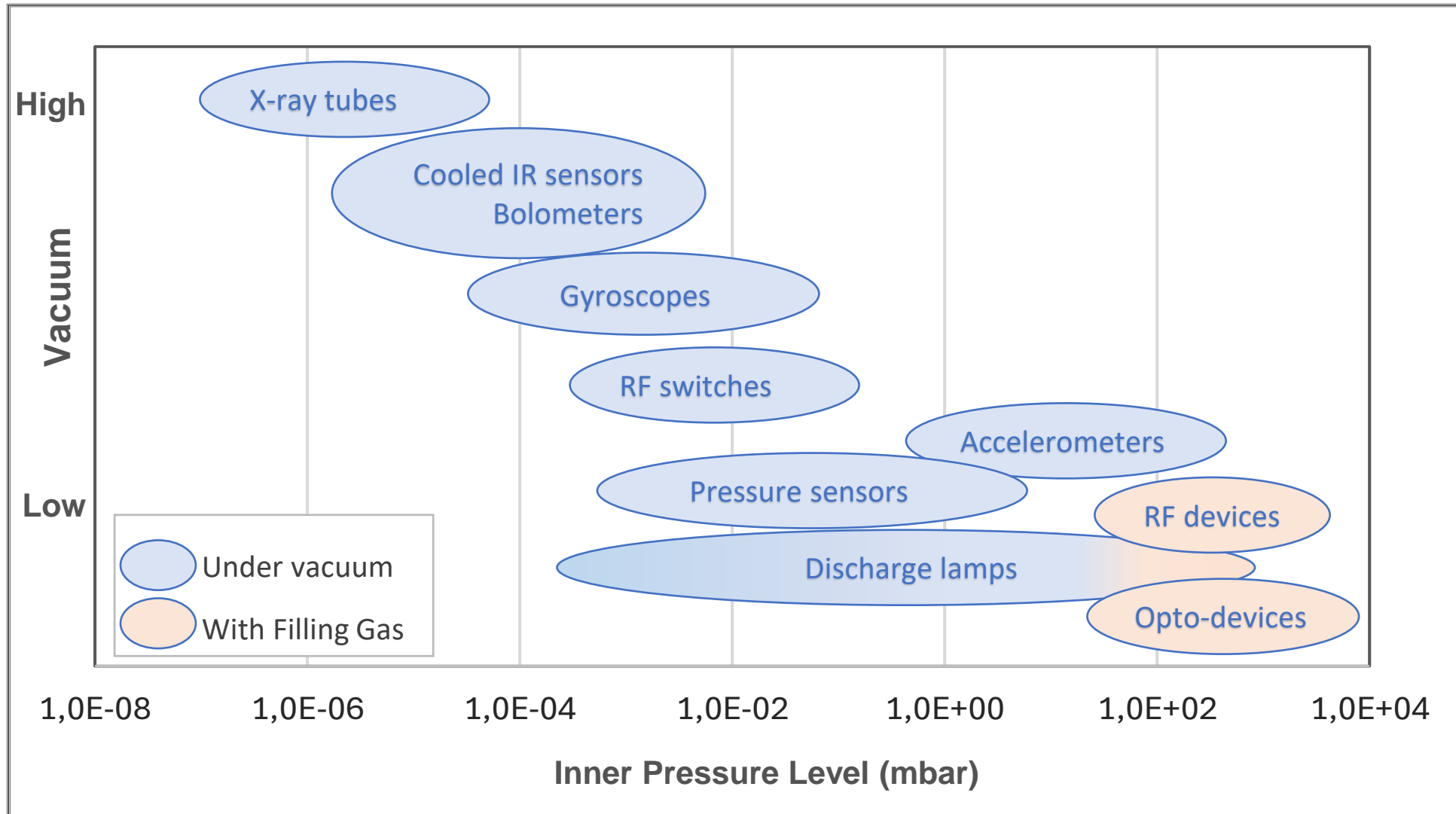
- Getters and dispensers for Electronic and photonic devices
- Getter Solutions for Sensors used in various market sectors: consumer electronics, security & defense, healthcare diagnostic, aerospace, industrial
- Solutions for Vacuum insulated systems in cryogenics, solar collectors, thermos and vacuum insulating panels for the white industry
- Solutions for vacuum systems utilized both in industrial and scientific applications, like: analytical instruments, vacuum systems for research and particle accelerators
- SMA wires and actuators for consumer electronics, automotive systems, white goods, medical systems, domotics, fluids management
- Gas barriers, high-capacity dispensable getters and active fillers for encapsulated organic electronics to ensure good performances during their entire lifetime
- Fully flexible encapsulating materials and Thin Film Encapsulation (TFE) inks for plastic electronics are also included in the functional chemical portfolio



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Hermetically Sealed Devices with different operational pressure levels

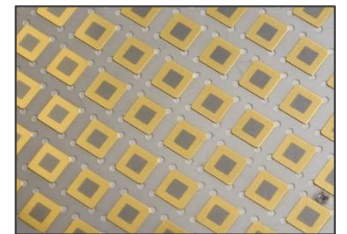


Getters: main characteristics

A Getter is a material or component able to sorb and remove undesired gases that could degrade performances and affect reliability of vacuum-sealed or gas-filled devices.

Main Characteristics of a Getter

- Gas sorption: getters remove active gases like H_2 , H_2O , O_2 , CO , CO_2 and Volatile Organic Compounds (VOCs); No sorption of inert gases.
- Material Composition: getters are often made from metallic alloys (Zr, Ti, V) or hybrid organic-inorganic materials.
- Activation: most of the getters require a thermal activation in vacuum or inert gas to become active.
- Long-Term action: getters ensure that vacuum levels or internal pure atmosphere remain stable for years.

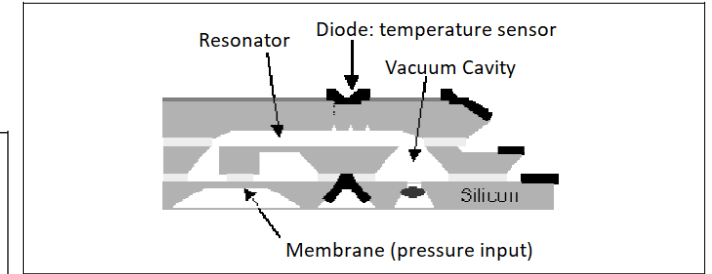
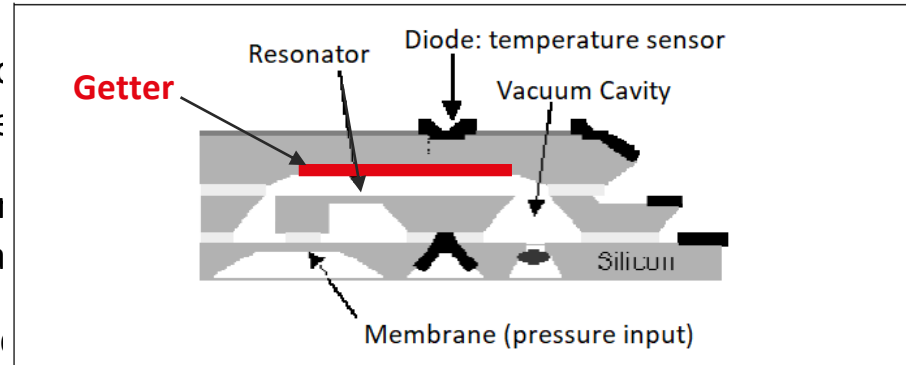


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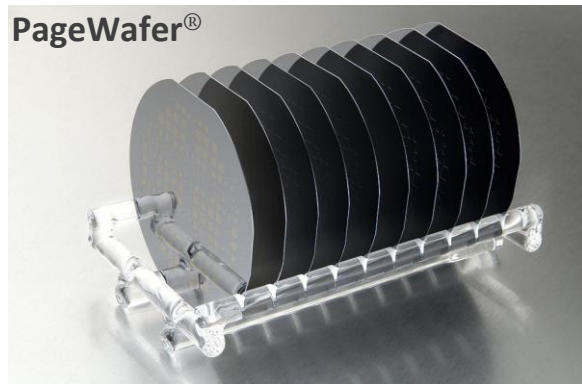
Getter Film in Resonant MEMs

- Resonant MEMs, such as inertial sensors, timing devices and energy harvesting systems
- Device performances depend on the underdamping parameter Quality factor (Q-factor) describing how underdamped an oscillator is. → Problem: Reduced Q-factor

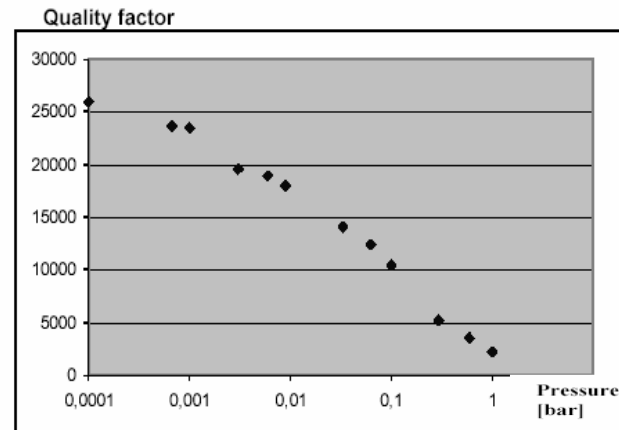


the parameter Quality factor (Q-factor) describing how underdamped an oscillator is. → Problem: Reduced Q-factor

Stable and Reliable Q-Factor of Pressure Sensors with Getter Film



Q-FACTOR AS FUNCTION OF INTERNAL PRESSURE



$$Q = \frac{\alpha}{\eta} \left(1 + \frac{\beta}{P^{1.159}} \right)$$

P=inner pressure
 η = gas viscosity
 α, β parameters dependent on resonance frequency and geometrical factors

RESIDUAL GAS ANALYSES ON GAS SENSORS

	Without Getter		With Getter	
	Pressure	%	Pressure	%
H ₂	5.7*10 ⁻³	26.2	< 1.0*10 ⁻⁴	0
CO	2.1*10 ⁻³	9.5	< 1.0*10 ⁻⁴	0
N ₂	1.2*10 ⁻²	57.6	< 1.0*10 ⁻⁵	0
CH ₄	9.3*10 ⁻⁴	4.3	< 1.0*10 ⁻⁵	0
H ₂ O	< 1.0*10 ⁻⁷	0	< 1.0*10 ⁻⁷	0
C ₂ H ₆	< 1.0*10 ⁻⁶	0	< 1.0*10 ⁻⁶	0
C ₃ H ₈	1.1*10 ⁻⁴	0.5	< 1.0*10 ⁻⁶	0
CO ₂	3.5*10 ⁻⁴	1.6	< 1.0*10 ⁻⁴	0
N.G.	7.6*10 ⁻⁵	0.3	8.3*10 ⁻⁴	100
Total	2.2*10⁻²	100	8.3*10⁻⁴	100

Q-FACTOR AFTER 7-month CYCLING TESTS -50°/ 90°C WITH GETTER

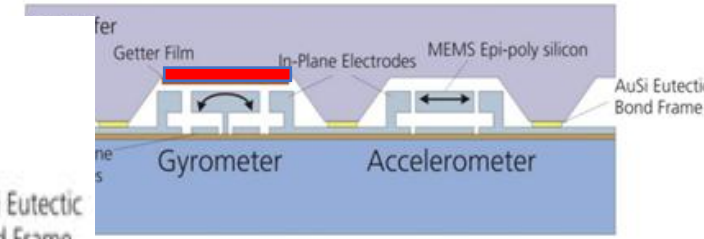
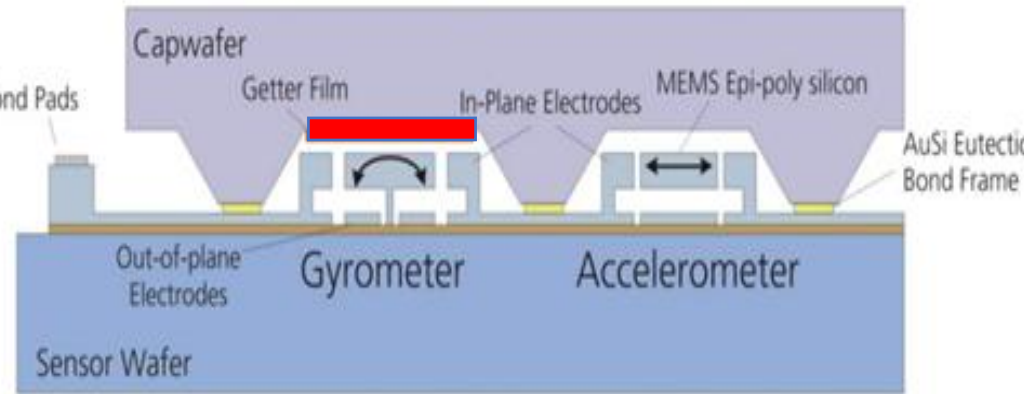
	Q factor at t ₀	Q factor at 7 months
Sensor 1	21328	21347
Sensor 2	23836	23460
Sensor 3	21046	20296
Sensor 4	22421	21362
Sensor 5	22689	23301
Sensor 6	22445	21608
Sensor 7	21027	20377
Sensor 8	20834	21506
Sensor 9	22663	23240
Sensor 10	19054	19789
Sensor 11	24566	24214
Average	21992	21864

G.Longoni, A.Conte, M.Moraja, (SAES) A.Fourrier (Thales) Proc. SPIE 6111, Reliability, Packaging, Testing, and Characterization of MEMS/MOEMS V, 61110N (2006); <https://doi.org/10.1117/12.647710>



Getter Film in MEMs inertial sensors

- MEMS inertial sensors are used in cars as for vehicle control, e.g. electronic stability control
- Single-chip full inertial measurement unit (IMU) angular-rate-type multi-axis sensor have different operational pressure requirements → SOLUTION

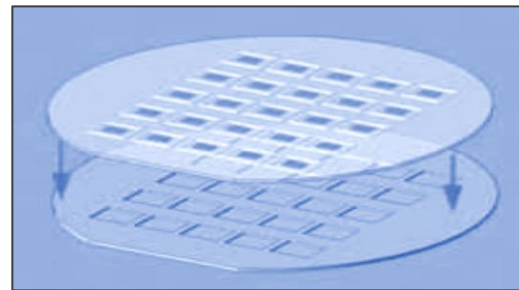


different operational pressure thanks to a getter

Combined MEMS Inertial Sensors with getter for IMU Applications

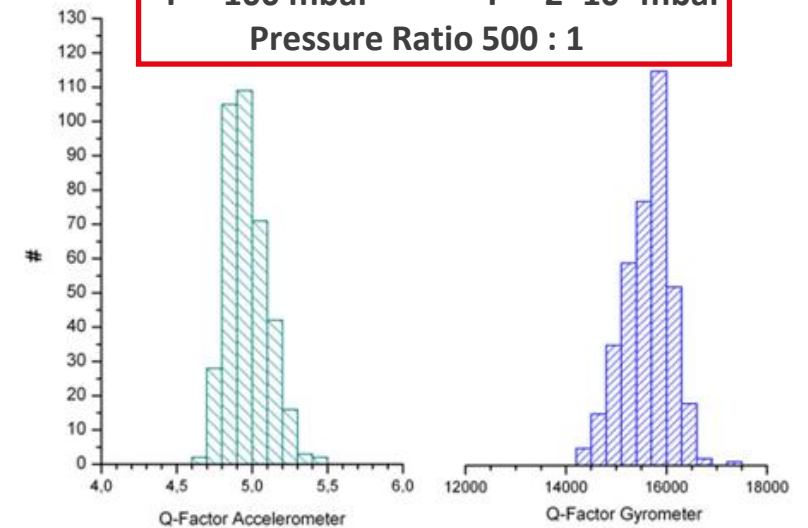
- Cavity volumes in the sensor $\sim 0.15 \text{ mm}^3$ and getter film with area of about 1 mm^2
- During wafer bonding, a gas mixture of noble gases (Ar, Kr or Ne) and getterable gases (like N_2 , O_2 , CO, CO_2) is backfilled into the cavities
- After bonding process, the getter is reactivated at 350°C to reduce pressure

PageWafer[®] for Wafer Level Packaging (WLP)



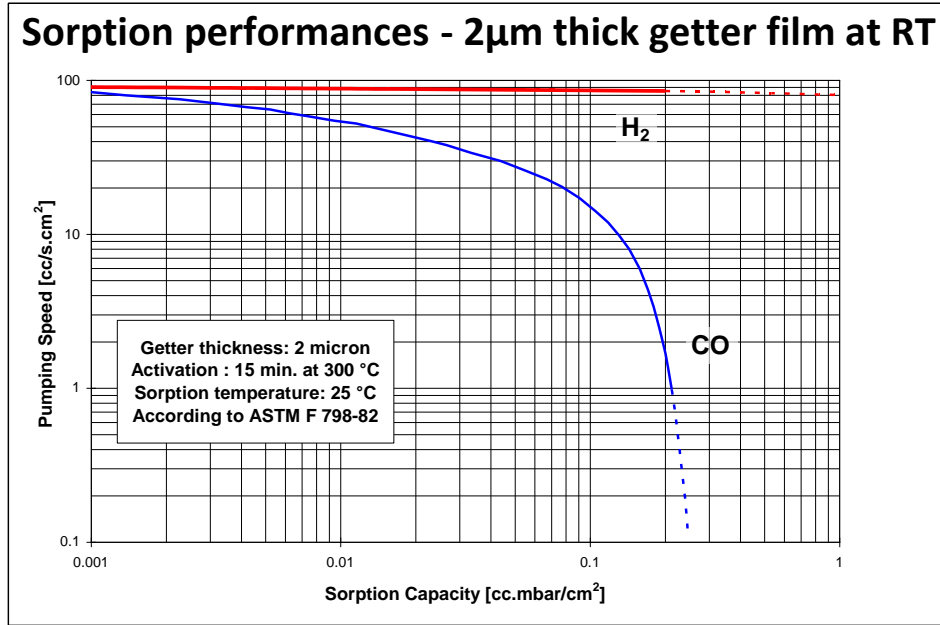
P.Merz, K.Reimer, M.Weiß, O.Schwarzalbach, C.Schröder (Fraunhofer Inst.-ISIT), A.Giambastiani, A. Rocchi, M.Heller (SensorDynamics AG) IEEE 23rd Int. Conference on Micro Electro Mechanical Systems (2010)

Accelerometer **Gyrometer**
P ~ 100 mbar **P ~ $2 \cdot 10^{-1}$ mbar**
Pressure Ratio 500 : 1



Characteristics of PaGe[®] Getter (for electronic and MEMs applications)

- ❑ The PaGe[®] getter film is obtained by a PVD process and can be deposited both on Wafers and on Lids used for device sealing.
- ❑ Good conditions for getter activation are 300°C for 15 minutes, usually achieved during the bonding/sealing process.



Typical Sorption Capacity for Different Gases at Room Temperature						
(cm ³ .mbar/cm ²)						
H ₂	CO	CO ₂	O ₂	H ₂ O	N ₂	Noble gases
> 15	0,25	0,20	0,75	0,75	0,15	No sorption

Typical Page Film Characteristics	
Getter activation	15 min. at 300 °C in vacuum or noble gas
Film density	~6·10 ³ kg/m ³
CTE (bulk)	~6·10 ⁻⁶ m/m/°C
Young's modulus (bulk)	67 GPa
Stress value at rupture	120 MPa
Electrical conductivity	>20 kS/m
Storage temperature / Shelf life	25 °C / 1 year in dry N ₂

PageWafer[®] is compatible with several wafer-to-wafer MEMS bonding techniques

Bonding type	Bonding/activation temperature	Typical bonding time	Page performance (a.u.)
Eutectic (AuSn)	300 °C	15'	1
Anodic	350 °C	30'	1.5
Eutectic (AuSi)	400 °C	30'	2
Glass frit	450-470 °C	30'	2.5
Low temperature direct	450-500 °C	30'	2.5



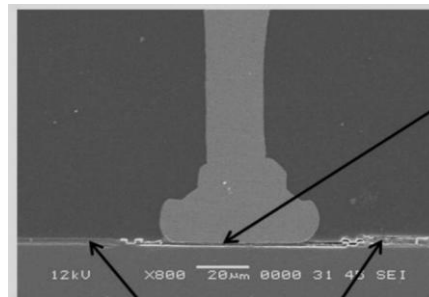
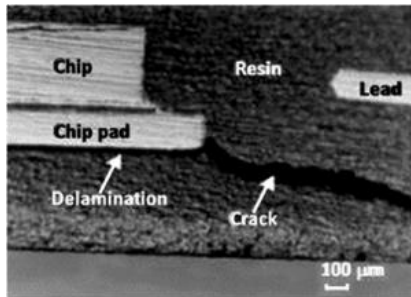
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Hermetically Sealed Electronic or Opto-electronic devices with filling gas

- ❑ Electronic and Optoelectronic devices used in high-reliability applications such as defense, aerospace, telecom and medical sectors, often require sealed packages with a filling gas to ensure optimal performance and long-term stability.
- ❑ Packaged devices may suffer problems related to outgassing and accumulation of gaseous contaminants

Devices	Gaseous Contaminants	Induced Problems
High Electron Mobility Transistors	Hydrogen	Gate poisoning and electric changes
Laser diodes	VOCs	Performance degradation
Laser modules, optical devices	Moisture	Condensation, oxidation, corrosion on contacts, shorting, swelling
Optical transmitters/receivers, Transceivers, Multiplexers, etc.	Moisture, Hydrogen	Oxidation, corrosion, swelling, dark current increase; Electric changes, Signal attenuat.
Optical fibers	Hydrogen	Signal attenuation, moisture formation



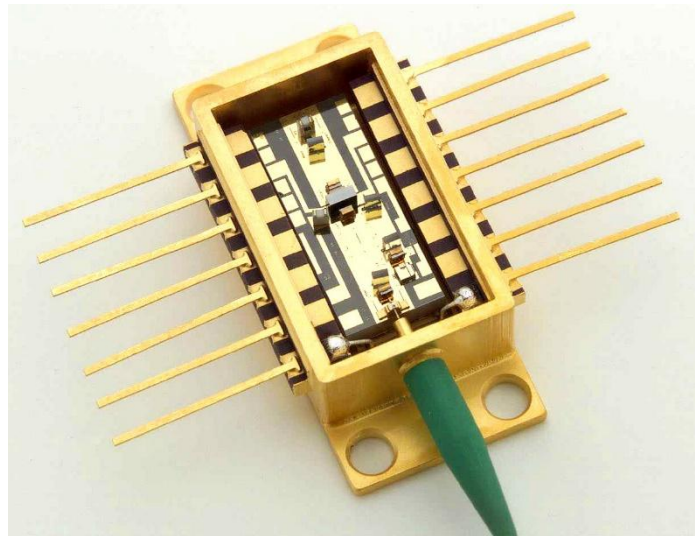
Critical levels of main contaminants:

- ✓ H₂O > 5000 ppmv
- ✓ H₂ > 1000 ppmv



Gas sources inside packages

Butterfly package for optoelectronic modules



<https://www.sandia.gov/media/NewsRel/NR2000/images/jpg/ocm.jpg>

Moisture

- > By product after die attach adhesive curing;
- > Desorption from porous or polymeric materials;
- > Reaction of H₂ with oxide layers;
- > Contamination of backfilling gases (N₂, air, He)

Hydrogen

- > Desorption from:
- > Metals;
- > Plating

Volatile Organic Compounds (VOCs)

- > Desorption from:
- > Glues;
- > Epoxies;
- > Contaminated surfaces

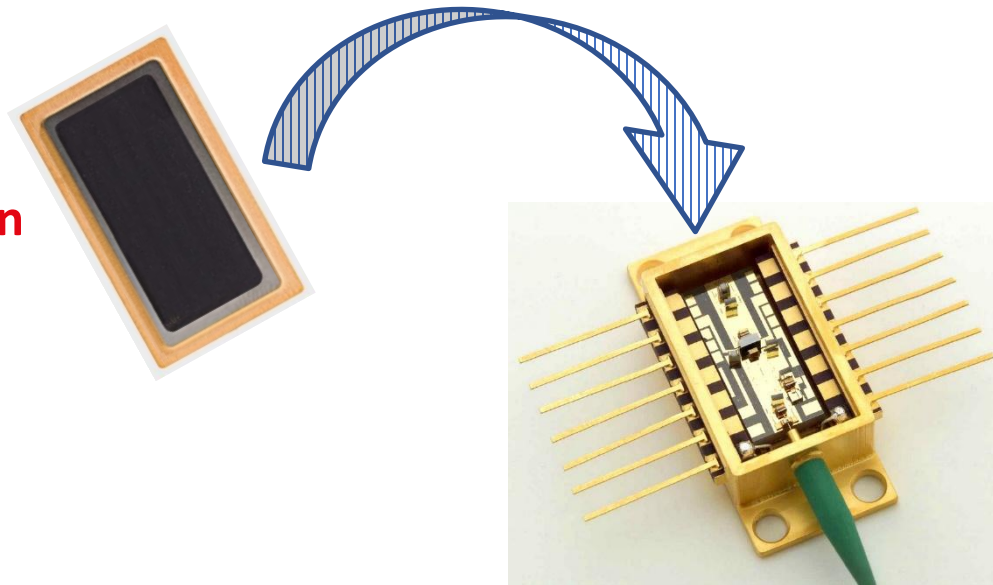
In order to keep the resulting gas load under the critical level,
high performance selective getters are needed

Getter coating integrated on the Lid

New solutions have been developed to solve the gas contamination issues in gas filled devices → ZeDry[®] getter family

- ❑ Integrated on metallic Lids to provide plug-in solutions for these devices
- ❑ Easy to handle and to be activated during standard baking of the devices

**ZeDry
Getter Film on
metallic Lid**



Outline

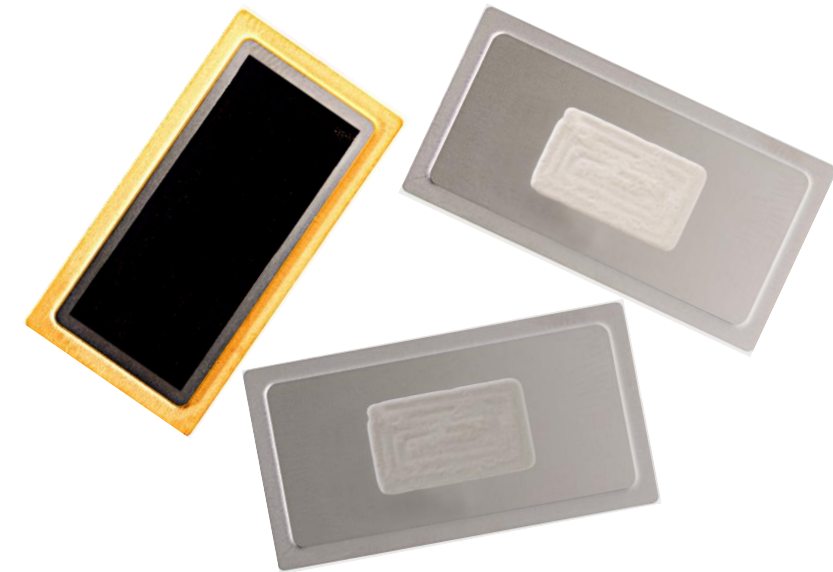
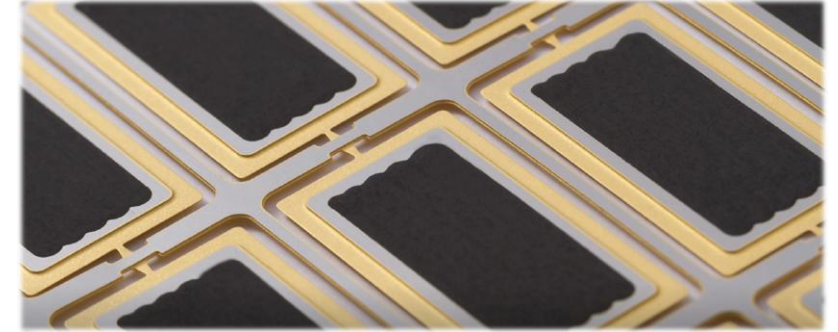
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ZeDry[®] GETTER LIDS FOR OPTOELECTRONIC DEVICES

Epoxy-based, solventless selective getters on lids (ZeDry[®] Lids) suitable for hermetically or semi-hermetically sealed devices.

Product	Sorbed Gases
ZeDry [®] /M Lid	H ₂ O (capacity 15%Wt)
ZeDry [®] /H ₂ Lid	H ₂ O + H ₂
ZeDry [®] /VOC Lid	H ₂ O + VOCs

- ✓ ZeDry getters are **reversible getters**. ZeDry Lids can be stored and handled in ambient air and activated in the range 100°-120°C for a few hours, just before device sealing.
- ✓ Lids available in a variety of base materials (Kovar, Steel, Aluminum,...) and platings (Gold, Nickel, ...).

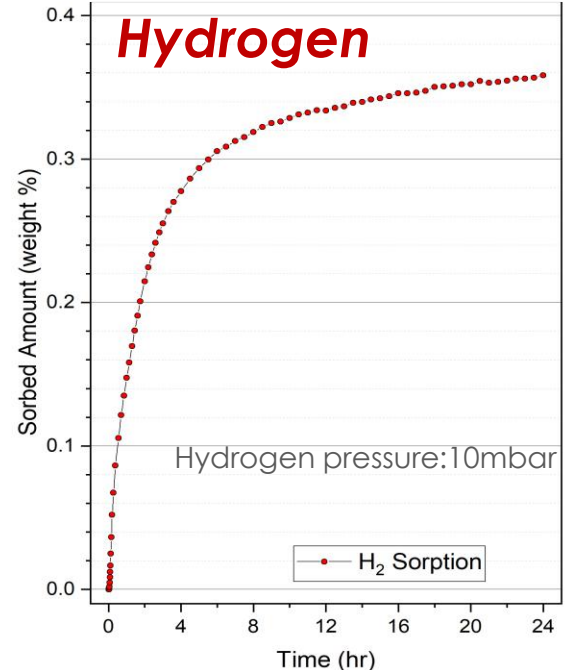
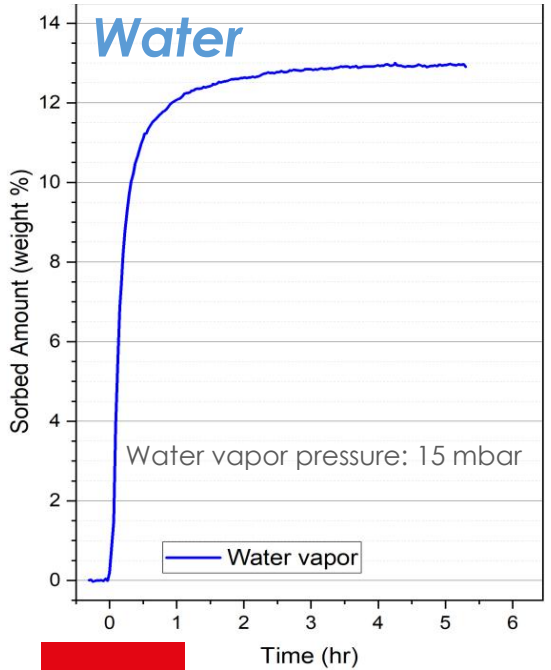
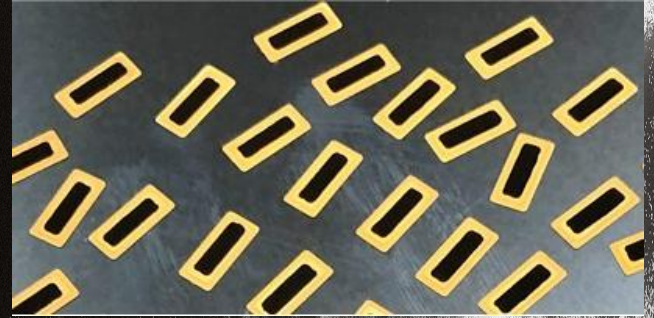


ZeDry[®]/H₂: Getter solution for H₂ and H₂O

Main characteristics:



- ✓ Nominal Moisture Capacity: 13%wt
- ✓ Nominal Hydrogen Capacity: 40 Ncm³/g
- ✓ Hydrogen and moisture adsorptions are not competitive processes
- ✓ Solventless formulation → no outgassing issues



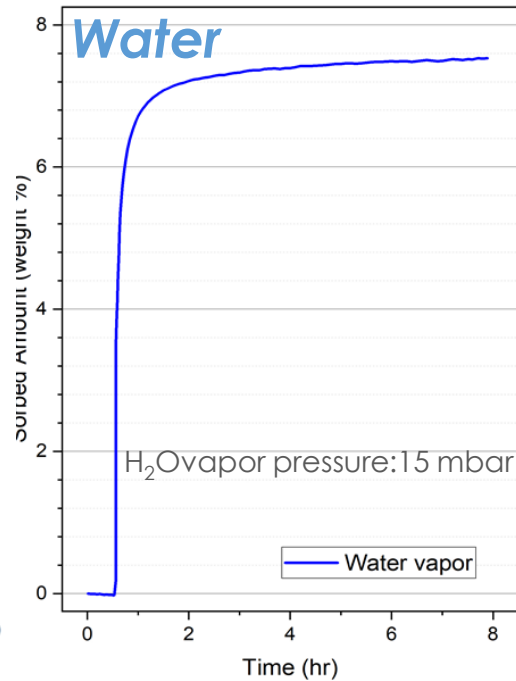
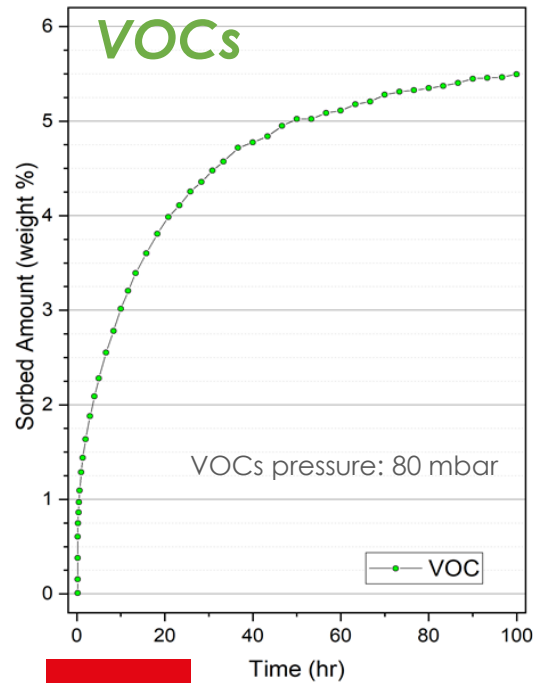
- ✓ Reversible getter adsorption for H₂O, irreversible getter for H₂
- ✓ Sorption measurements @ RT
- ✓ Activation at 120°C for 1 hour



ZeDry[®]/VOC: Getter solution for VOCs and H₂O

Main characteristics:

- ✓ Nominal Moisture Capacity: 8%wt
- ✓ Nominal Capacity for VOCs: 5%wt
- ✓ VOCs and moisture adsorptions are not competitive processes
- ✓ Solventless formulation → no outgassing issues



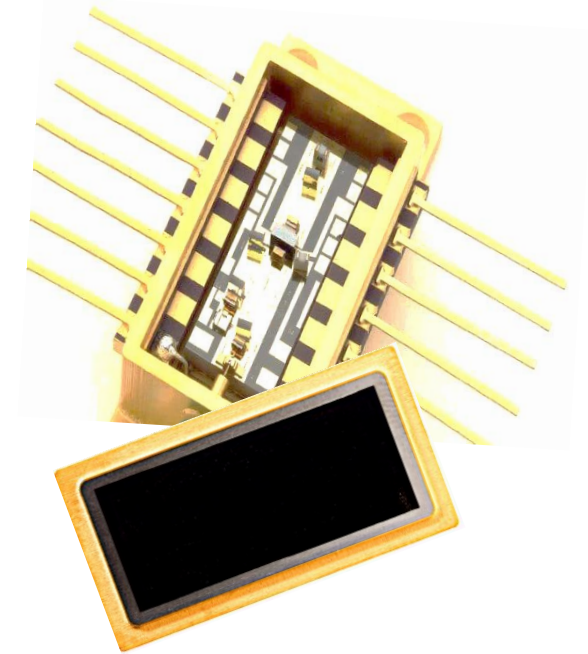
- ✓ Reversible getter adsorption for VOCs and H₂O
- ✓ Sorption measurements @ RT
- ✓ Activation at 120°C for 1 hour

Effectiveness of ZeDry® Getter Lids in Optoelectronic Devices

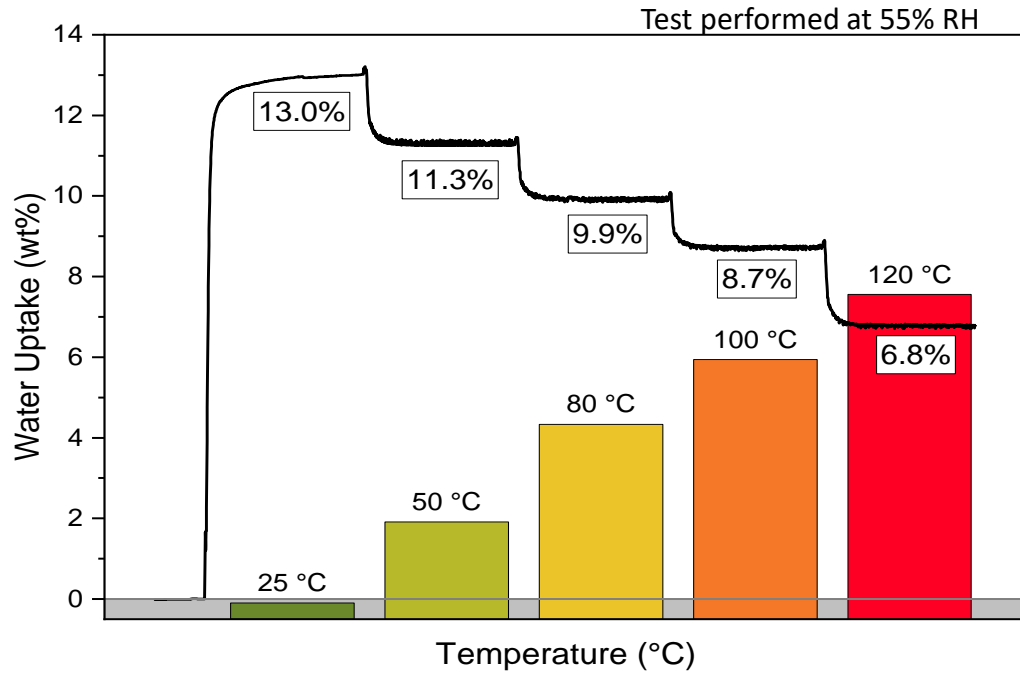
Results of Gas Analyses performed on optoelectronic modules sealed using Lids with ZeDry®/H₂ coatings have shown that the getter is able to drastically reduce the H₂ and H₂O levels in the packages

Ranges of H₂ and H₂O levels measured in optical devices

Device Without Getter		Device With ZeDry/H ₂ coating on Lid	
Gas contaminant	Concentration levels	Gas contaminant	Typical Concentration levels
H ₂	1000 – 5000 ppmv	H ₂	80 – 200 ppmv
H ₂ O	3000 – 10000 ppmv	H ₂ O	100 – 300 ppmv



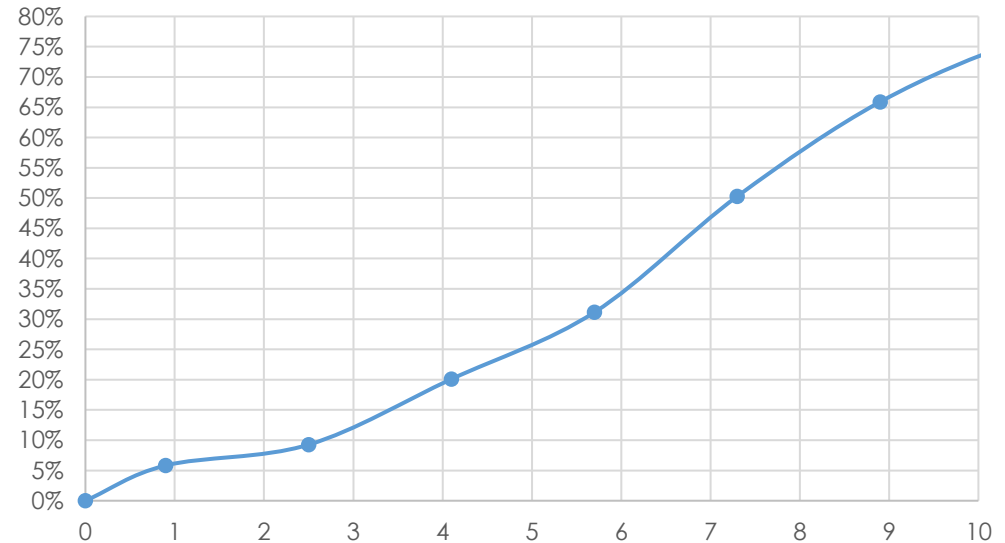
Water sorption as a function of working temperature and H₂O capacity Loss - ZeDry[®]/H2



Even if the H₂O sorption capacity decreases when the operation temperature increases, the getter still provides more than half of its full capacity at 120°C; this guarantees good performances even in severe working conditions.

After activation, ZeDry coating can be exposed to air, if necessary, but just for a short time otherwise a portion of its capacity is lost:
 exposure to air for maximum a few minutes

H₂O capacity loss in air

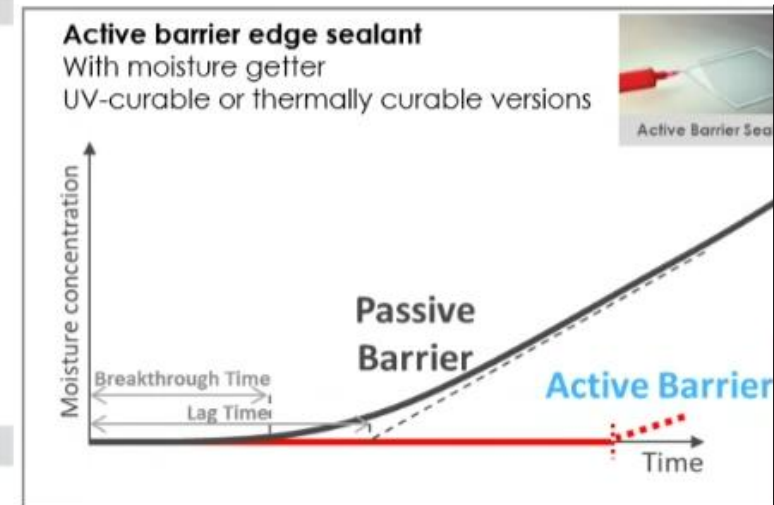
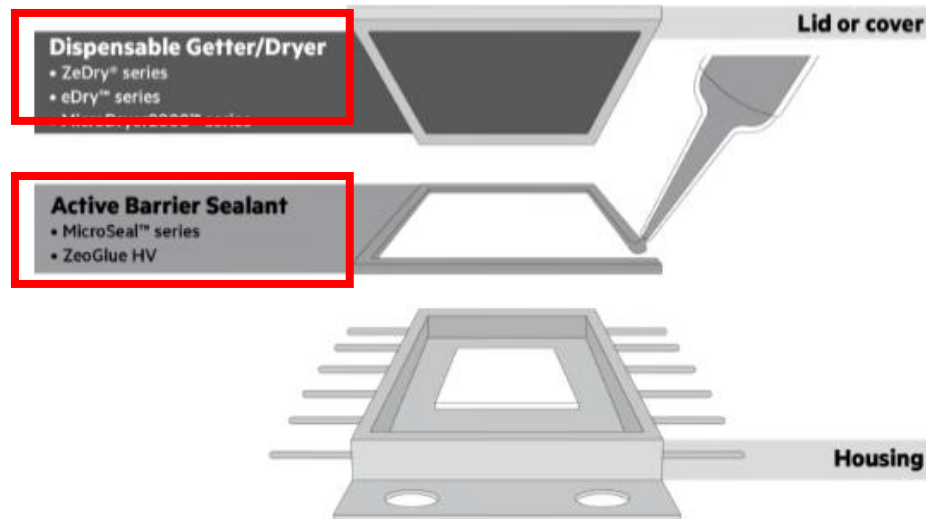


Solutions also for Semi-hermetic devices

For hermetic packaging



For Semi- or non-hermetic packaging



Key Takeaways

- ❑ Performances and operation life of electronic and optoelectronic sealed devices may be affected by detrimental gases inside the packages.
- ❑ Getter film integration is an effective and consolidated solution for managing pressure increase and presence of gaseous contaminants:
 - PaGe getter film is suitable for vacuum devices (Electron devices, Sensors and MEMs)
 - ZeDry[®] getter coatings on Lids are the solutions for gas filled modules (Optoelectr.devices)
- ❑ Different tailored getter materials can be integrated inside the devices in order to sorb different gas contaminants with high capacity and to assure proper device functionality over all the lifetime.

Thank you
for your attention

The logo consists of a solid red square with the word "saes" written in white, lowercase, sans-serif font.

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www.saesgetters.com