

# Enhancing Microelectronic Package Reliability through Getter Material Integration and Inner Gas Atmosphere Characterization



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making **innovation happen**, together

Luca Mauri, Giovanni Zafarana, Enea Rizzi, Alessio Corazza

Saes Getters, viale Italia 77 - 20045 Lainate (ITALY)

[luca\\_mauri@saes-group.com](mailto:luca_mauri@saes-group.com)

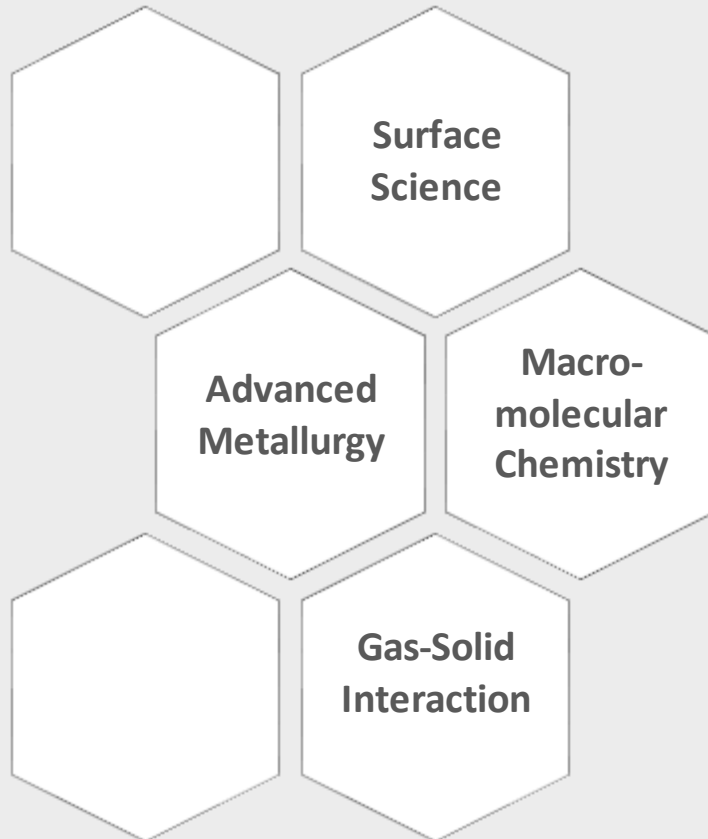
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# AGENDA

- ✓ Vacuum Hermetic Packaging: requirements and issues
- ✓ Evolution of getter technology with packaging
- ✓ Characterizations of vacuum sealed devices
- ✓ Hermetic packaging for Optoelectronics: requirements and issues
- ✓ Getter solutions for Optoelectronics and Photonics
- ✓ Takeaways

# SAES: an Advanced Material Company

FROM OUR KEY CORE COMPETENCES



Our

ADVANCED FUNCTIONAL MATERIALS



## Functional Metals

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



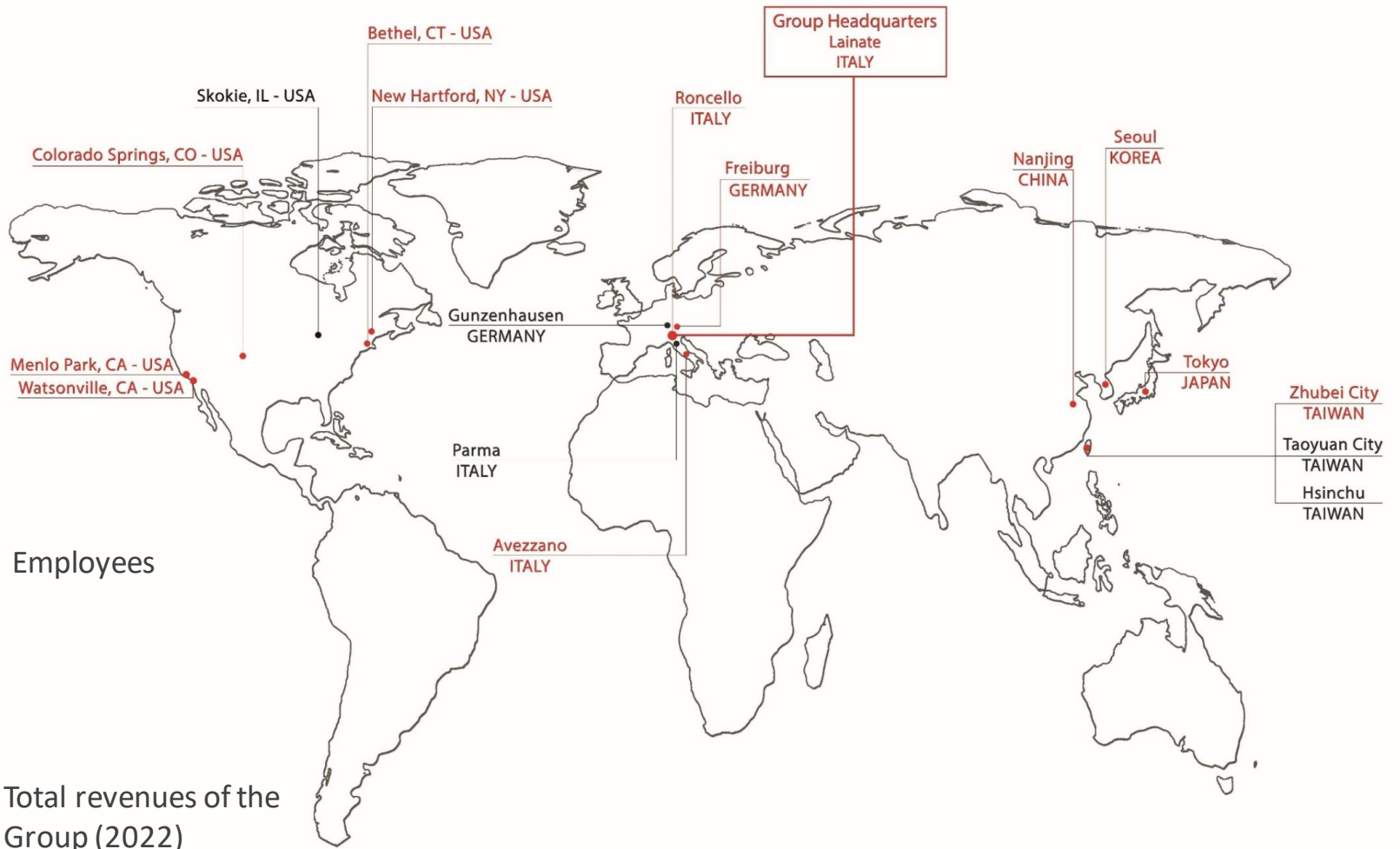
## Functional Chemicals

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

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# The Group at a glance

The parent Company SAES Getters S.p.A. is listed on the Italian Stock Exchange Market, STAR segment, since 1986.



80  
Years

A long history of innovation

  
~1,100

Employees

  
10

Production sites worldwide

  
> 250 M€

Total revenues of the Group (2022)

  
R&D

Our first values are Research & Innovation

  
Quality

All the Group factories are certified according to proper ISO/DIN standards related to their own business field

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# Requirements for Hermetic Vacuum Packaging

- ✓ Vacuum packaging is mandatory for some electronic and MEMS devices:
  - to improve stability and reliability over lifetime in High performance sensors
  - To preserve internal atmosphere and pressure in order to increase lifetime
- ✓ Contaminants like moisture, hydrogen, hydrocarbons and others may affect performances or even cause failures

## Device

Cryo-tanks, IR sensors, MEMS  $\mu$ bolometers

IMUs, gyroscopes

X-Ray tubes, vacuum interrupters, MW-RF modules

## Gaseous Contaminants

$H_2$ ,  $H_2O$ ,  $CO$ ,  $CO_2$ ,  $CH_4$ ,  $O_2$   
 $N_2$ ,

## Induced Problems

Thermal insulation degradation

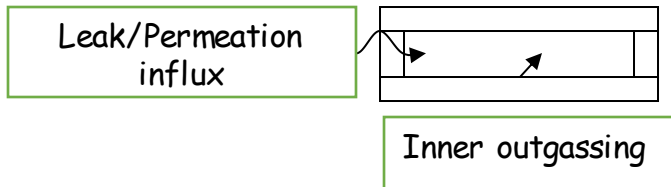
Low Q-factor

Operating failures

# How to preserve vacuum: getter integration

## No getter

Continuous pressure increase during lifetime

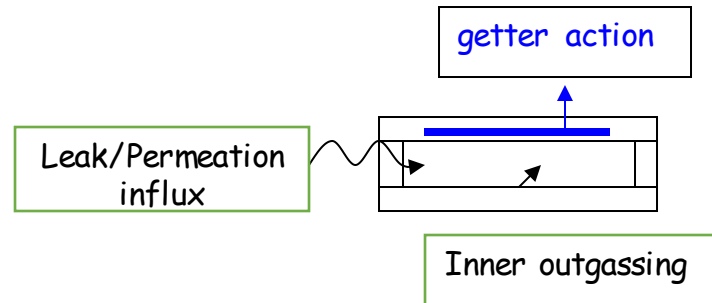


$$V \cdot \frac{dp}{dt} = InFlux(t)$$

## With getter

Quasi-stationary conditions at low pressure level

Balance between getter pumping and gas release from inner surfaces



$$InFlux(t) = S(Q) \cdot p$$

# Evolution of the getter technology vs hermetic packaging requirements

## Getters for electronic devices

- Pills, Porous, strips, films
- Powder pressing, sintering,
- Can sorb all reactive gases
- Thermally or electrically activated
- Activation Temperature: 350-900°C



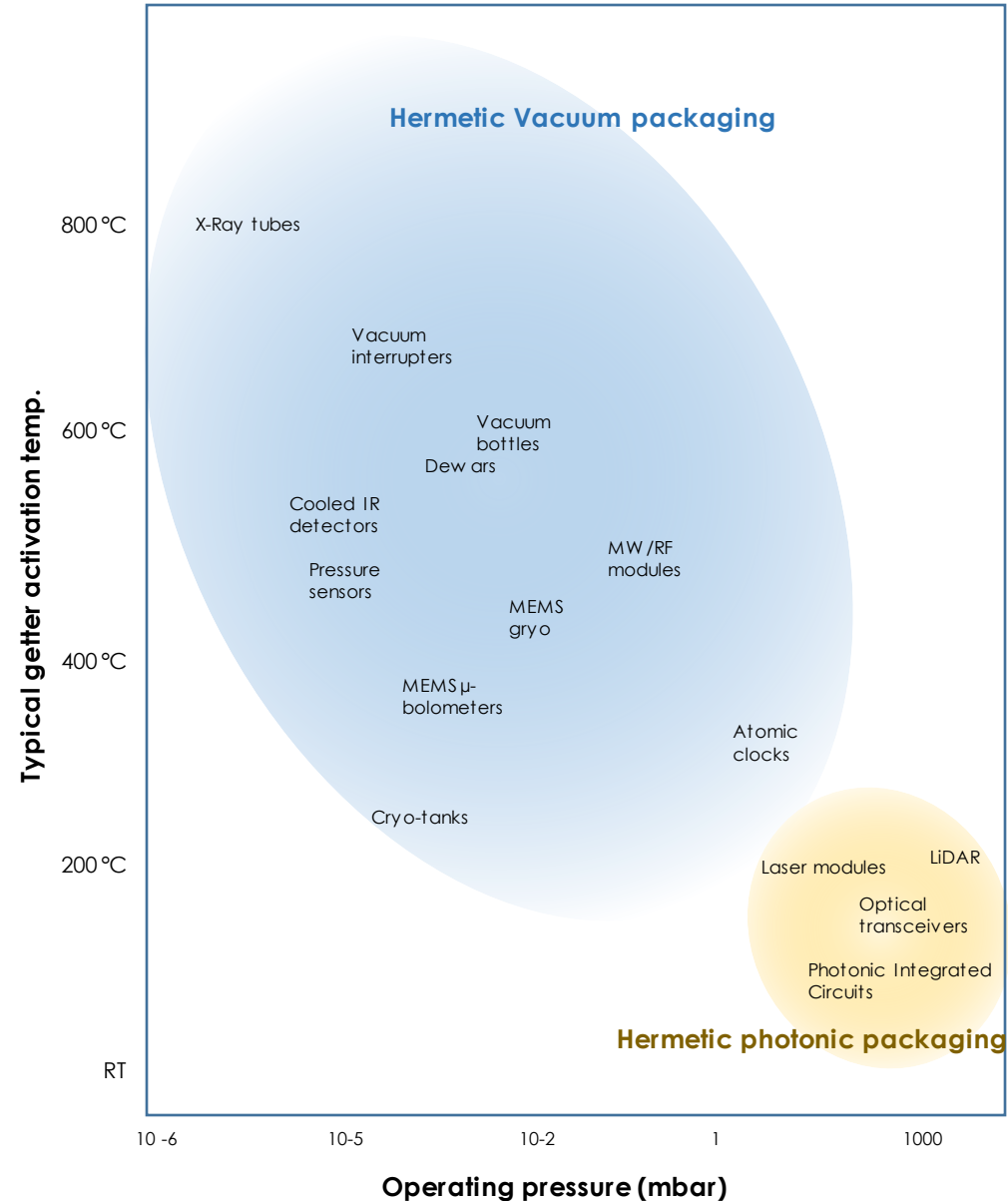
## Getters for MEMS

- Thin films
- Physical Vapour Deposition
- Can sorb all reactive gases
- Thermally activated
- Activation Temperature: 300-450 °C



## Getters for photonic and optoelectronic devices

- Dispensed and cured directly on parts/lids
- Components with getter function
- High selectivity (H<sub>2</sub>O, H<sub>2</sub>, VOCs)
- Thermally activated
- Activation Temperature: 100-150 °C



# Characterizations of vacuum sealed devices

## Residual Gas Analysis

- Measurement of total absolute pressure and Partial pressures of gases
- Composition of residual atmosphere inside the device
- Purpose:
  - To check the effect of an integrated getter on the atmosphere composition of the MEMS
  - To provide useful information for process optimization or troubleshooting
  - As an input for modelling

## Hermeticity Test

- To establish whether the device is affected by a leak or not
- Check and assess the hermetic level of the bonding frame
- Evaluation of the leak impact on lifetime can be extrapolated

## Outgassing

- Identification of desorbed species and total amount of released gas
- Outgassed amount for fixed temperature and time interval
- Purpose:
  - Provide indications for vacuum compatible materials
  - Assessment of generated gas load after specific manufacturing processes
  - Provide input data for modelling the pressure evolution inside sealed devices



# Case Study: Residual Gas Analysis and the role of getter

Gas	No getter film		Getter film	
	Absolute Pressure (mbar)	Relative Concentration (%)	Absolute Pressure (mbar)	Relative Concentration (%)
H <sub>2</sub>	4.9·10 <sup>-1</sup>	5.6	-	-
CO	5.9·10 <sup>-1</sup>	6.7	-	-
N <sub>2</sub>	-	-	-	-
CH <sub>4</sub>	2.8·10 <sup>-1</sup>	3.2	3.0·10 <sup>-4</sup>	27.7
H <sub>2</sub> O	-	-	-	-
O <sub>2</sub>	-	-	-	-
CO <sub>2</sub>	7.2	81.7	-	-
*HCs	2.6·10 <sup>-1</sup>	2.9	2.5·10 <sup>-6</sup>	0.2
**NGs	1.1·10 <sup>-4</sup>	<0.1	7.7·10 <sup>-4</sup>	72.1
<b>TOTAL</b>	<b>8.8</b>	<b>100.0</b>	<b>1.1·10<sup>-3</sup></b>	<b>100.0</b>

Comparison of RGAs of micro-bolometers with and without a getter film.

\*HCs: light hydrocarbons (ethane and propane)

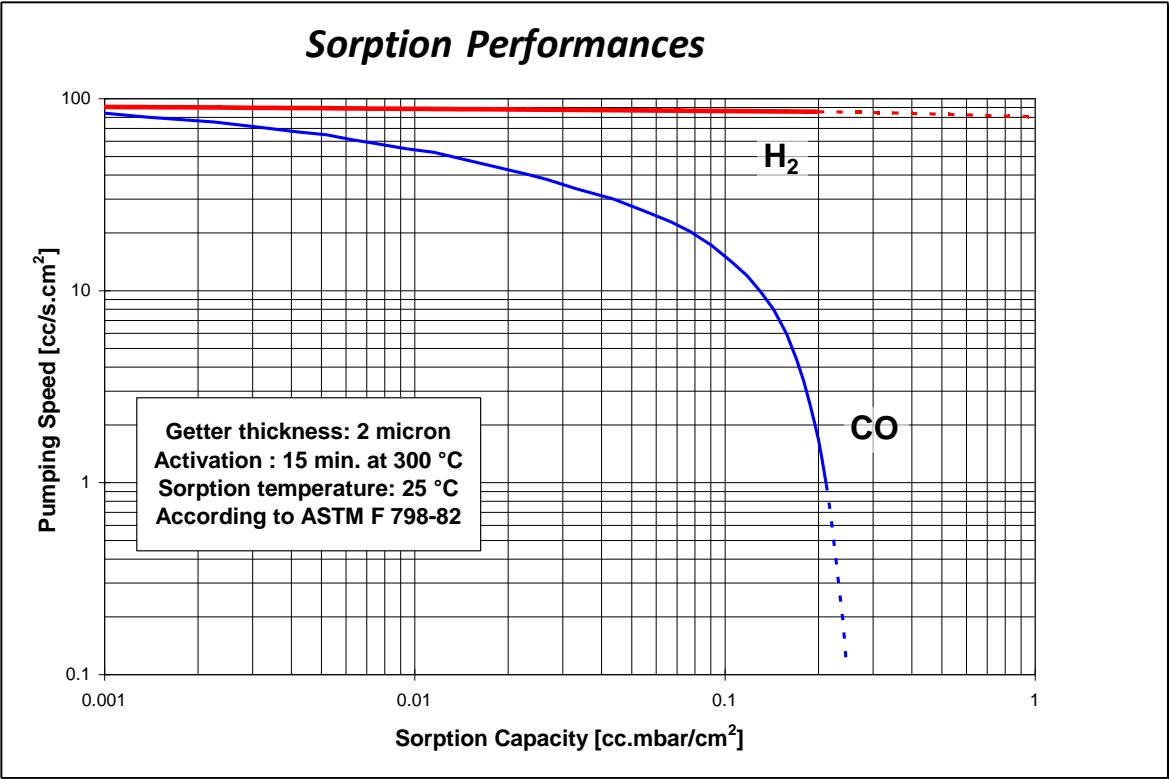
\*\*NGs: noble gases

- The getter effectively removes all the getterable gases, decreasing total pressure by three orders of magnitude.
- The residual pressure is mainly composed of noble gases, methane and traces hydrocarbons.

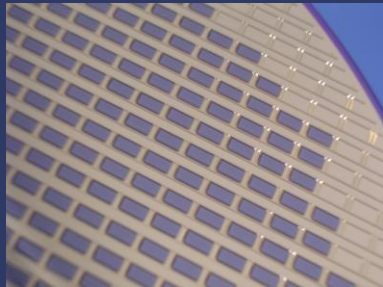
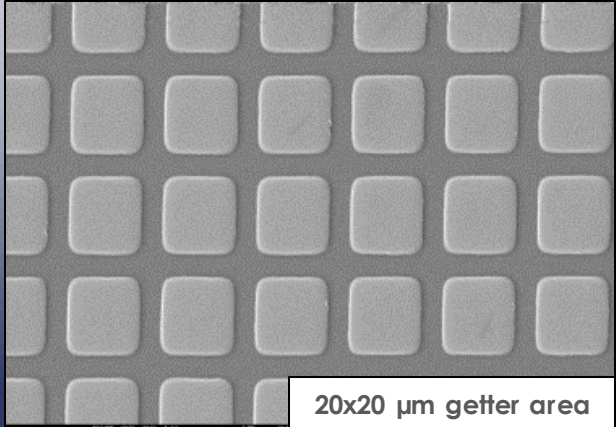
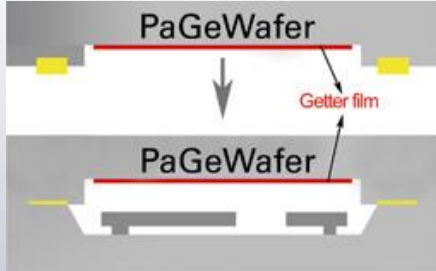


# New generation Getters for miniaturized devices: PaGeWafer®

PaGe (Patterned Getter) can be applied on Wafers or on Lids

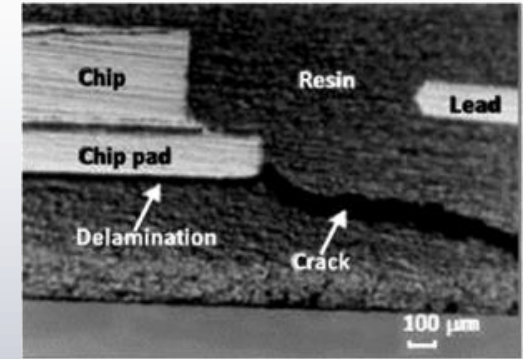


Relative Sorption Capacity for Different Gases at Room Temperature (a.u.)						
CO	CO <sub>2</sub>	O <sub>2</sub>	H <sub>2</sub> O	N <sub>2</sub>	H <sub>2</sub>	Noble gases
1	1	3	6	0.5	>50	N/A



# Requirements for Hermetic Optoelectronic Packaging

- ✓ Hermetic packaging of photonic devices is a key-step to obtain good quality, reliable, and stable performances (optical, electrical)
- ✓ Packaged photonic devices may suffer problems related to gaseous contaminants: moisture, hydrogen, volatile organic compounds (VOCs)



Device	Gaseous Contaminants	Induced Problems
Laser Diodes	VOCs	Performances 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 attenuation
Optical fibers	Hydrogen	Signal shift & attenuation, moisture formation

✓ **Critical levels of main contaminants in devices:**

- ✓ H<sub>2</sub>O < 5000 ppmv
- ✓ H<sub>2</sub> < 1000 ppmv



# Gas sources inside photonic packaging

## Moisture

- ✓ By product die attach adhesive curing
- ✓ Desorption from porous or polymeric materials
- ✓ Reaction of H<sub>2</sub> with oxide layers
- ✓ Contamination of backfilling gases (N<sub>2</sub>, air, He)

## VOCs

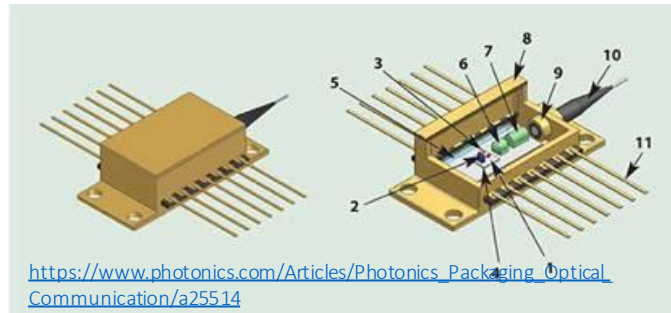
Desorption from:

- ✓ glues
- ✓ Epoxies
- ✓ Contaminated surfaces

## Hydrogen

Desorption from:

- ✓ Metals
- ✓ Plating



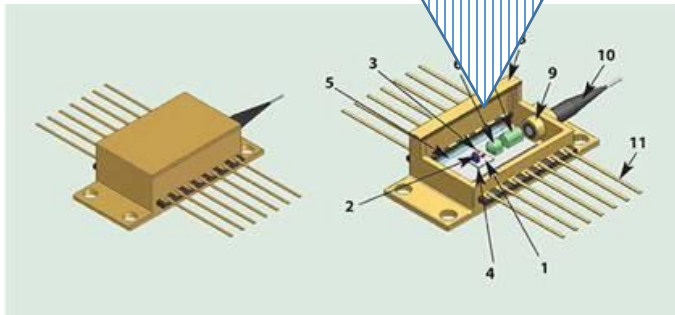
# Dispensable Getters: SAES solutions

## ZeDry<sup>®</sup> Family

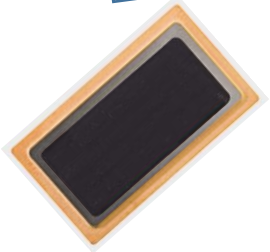
**ZeDry<sup>®</sup>-H<sub>2</sub>**  
Hydrogen & moisture

**ZeDry<sup>®</sup>-M**  
High level of moisture

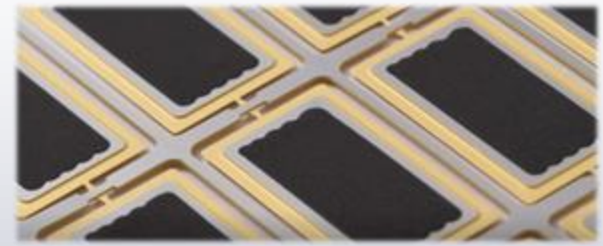
**ZeDry<sup>®</sup>-VOC**  
VOCs & moisture



[https://www.photonics.com/Articles/Photonics\\_Packaging\\_Optical\\_Communication/a25514](https://www.photonics.com/Articles/Photonics_Packaging_Optical_Communication/a25514)



**ZeDry<sup>®</sup>**  
Getter coating  
on metallic Lid



# ZeDry<sup>®</sup> Lids: general features

## BASE MATERIALS

- ✓ Lid substrate: kov ar, ceramic, glass, Ti, Al
- ✓ Lid plating: gold, nickel

## ZeDry GETTER CHARACTERISTICS

- ✓ Solventless formulation
- ✓ Compatible with laser/seam welding sealing processes because of high decomposition temperature matrix (> 300 °C)
- ✓ Reversible getter: lids can be handled in ambient air
- ✓ Water uptake is present up to 80 °C - 100 °C device operating temperature

## PROCESS STEPS

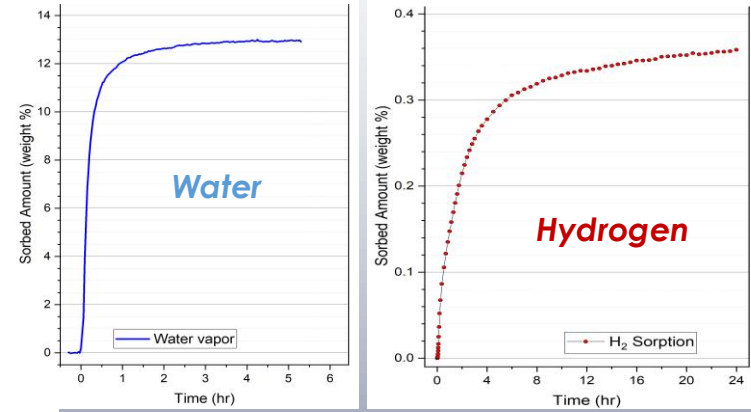
- ✓ ZeDry Getter activation: Vacuum – N<sub>2</sub> – dry air oven, 100 °C – 200 °C, few hours
- ✓ Lid assembly to the housing
  - ✓ Seam welding / Laser welding (Hermetic packages)



# ZeDry<sup>®</sup>-Family: performances

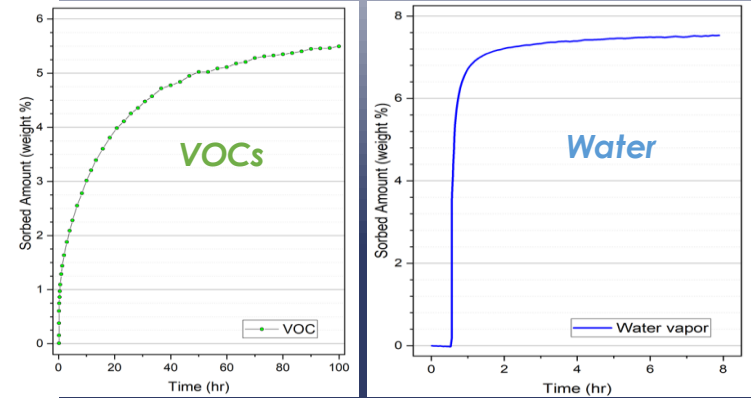
**ZeDry/H<sub>2</sub> :**  
Getter solution for H<sub>2</sub> and H<sub>2</sub>O

- ✓ Nominal Moisture Capacity: 13%wt
- ✓ Nominal Hydrogen Capacity: 40 Ncm<sup>3</sup>/g
- ✓ Hydrogen and moisture adsorptions are not competitive processes



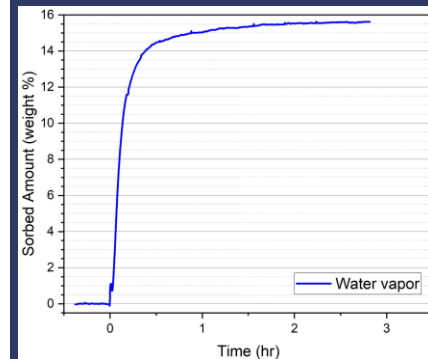
**ZeDry/VOC:**  
Getter solution for H<sub>2</sub>O and VOCs

- ✓ Nominal Moisture Capacity: 8%wt
- ✓ Nominal Capacity for VOCs: 5%wt
- ✓ VOCs and moisture adsorptions are not competitive processes



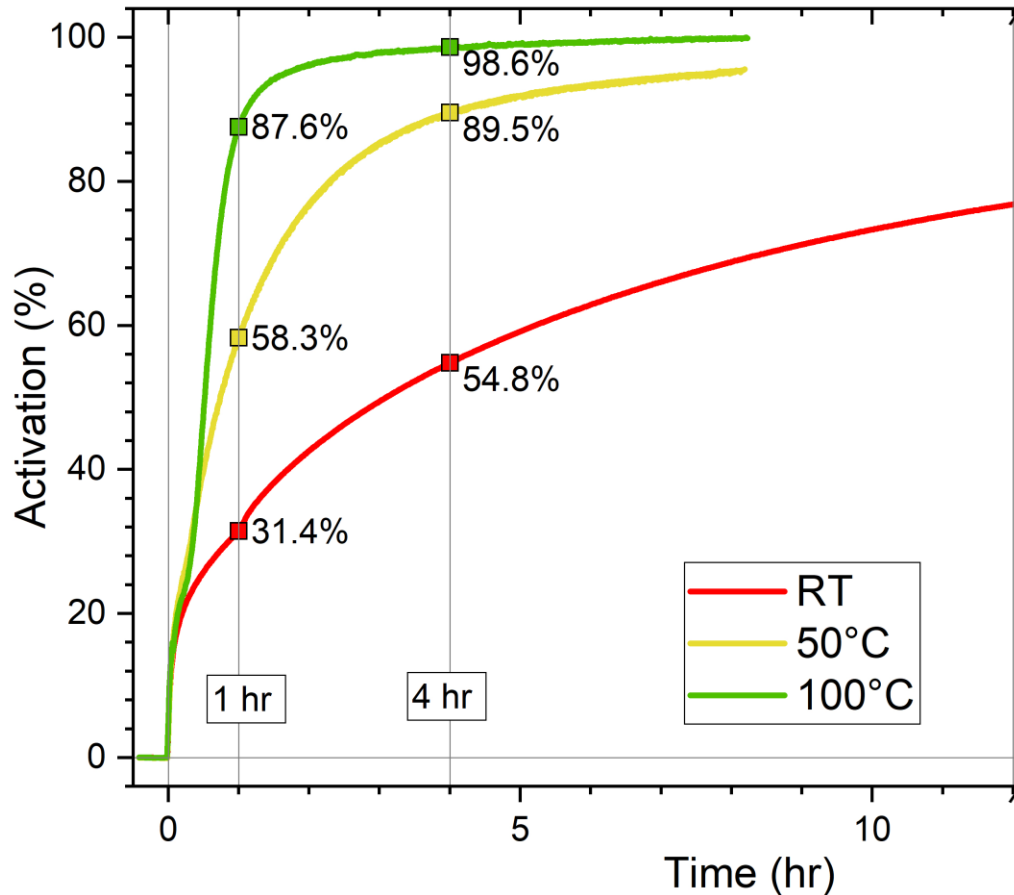
**ZeDry/M:**  
Getter solution for H<sub>2</sub>O

- ✓ High Capacity getter
- ✓ Nominal Moisture Capacity: 15%wt



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# ZEDRY<sup>®</sup>-H<sub>2</sub>: activation efficiency for H<sub>2</sub>O sorption



Vacuum Activation ( $< 1 \cdot 10^{-2}$  mbar)

For heating in vacuum at 100 °C the activation is complete to almost 90% after 1 hour and the getter is ready to operate in the device

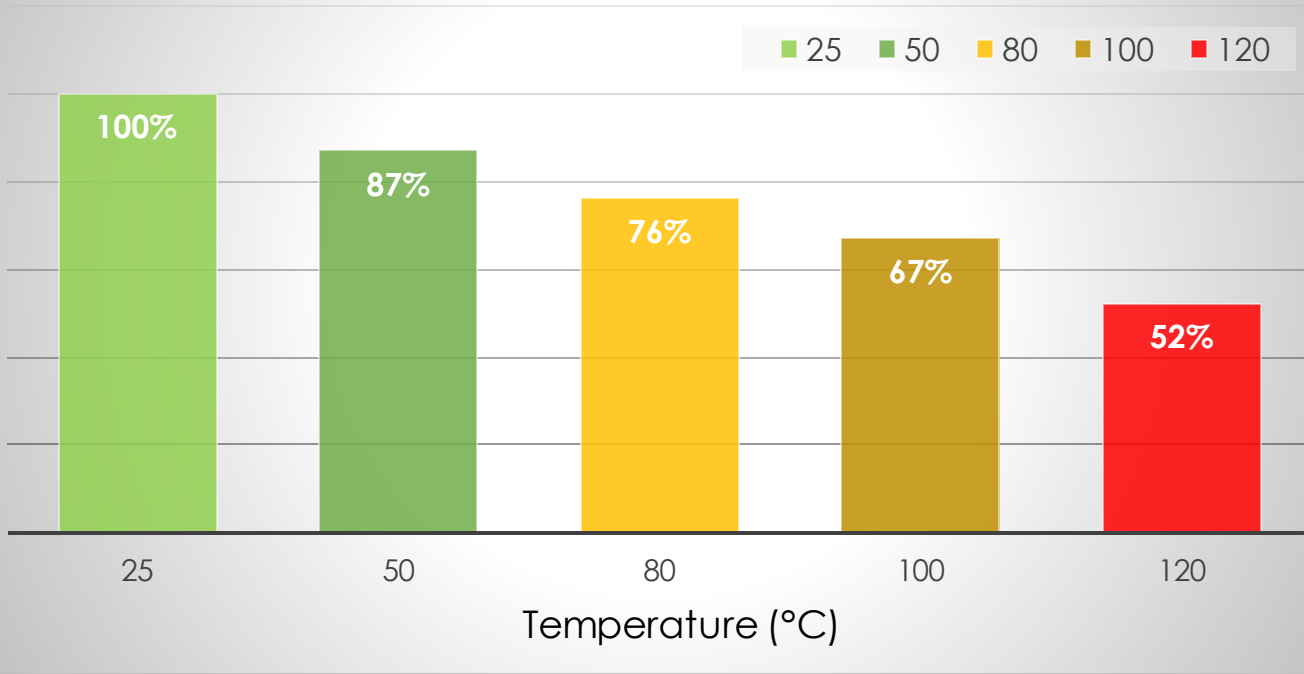
On the other side at RT after 4 hours, the material recovers up to 50% of the sorption performances



# ZEDRY<sup>®</sup>-H<sub>2</sub>: Moisture uptake at different temperatures



### Moisture Uptake Efficiency

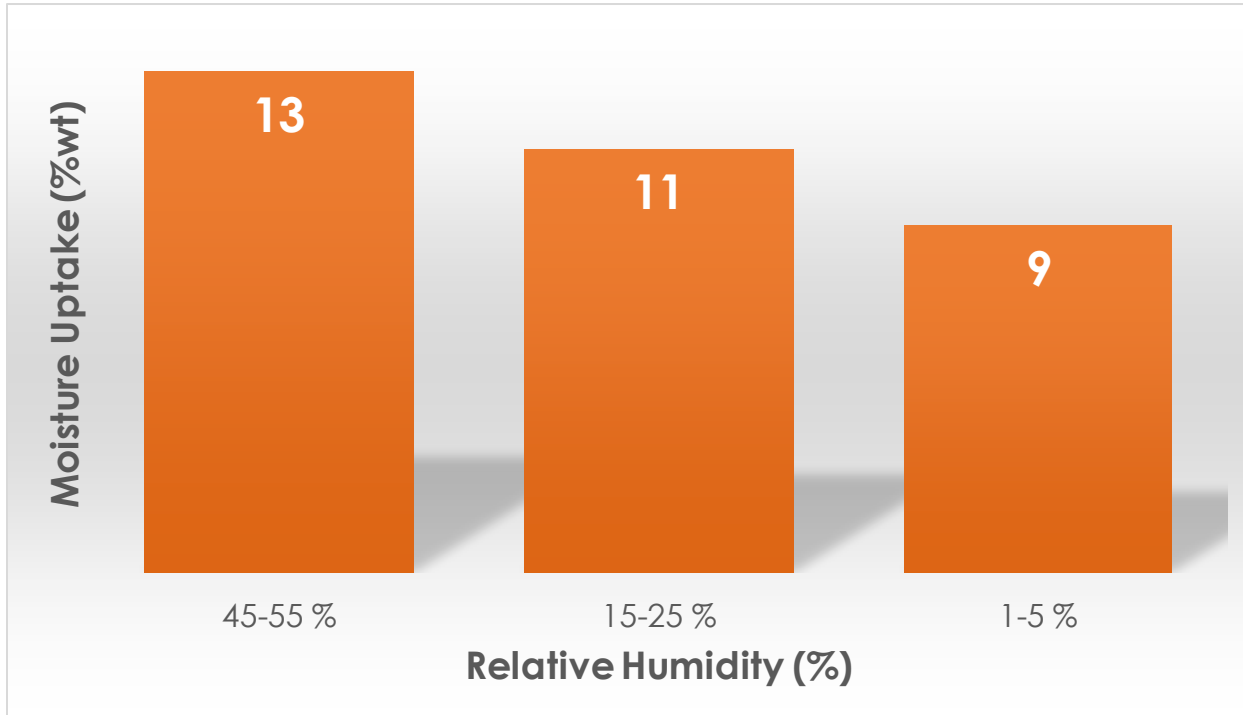


Relative Humidity: 50%

ZeDry<sup>®</sup>-H<sub>2</sub> can operate at high working device temperature. The getter still provides more than half (52.1%) of the full efficiency at 120 °C, ensuring good performances even in the most tough working conditions.



# ZEDRY<sup>®</sup>-H<sub>2</sub>: Moisture uptake at different RHs



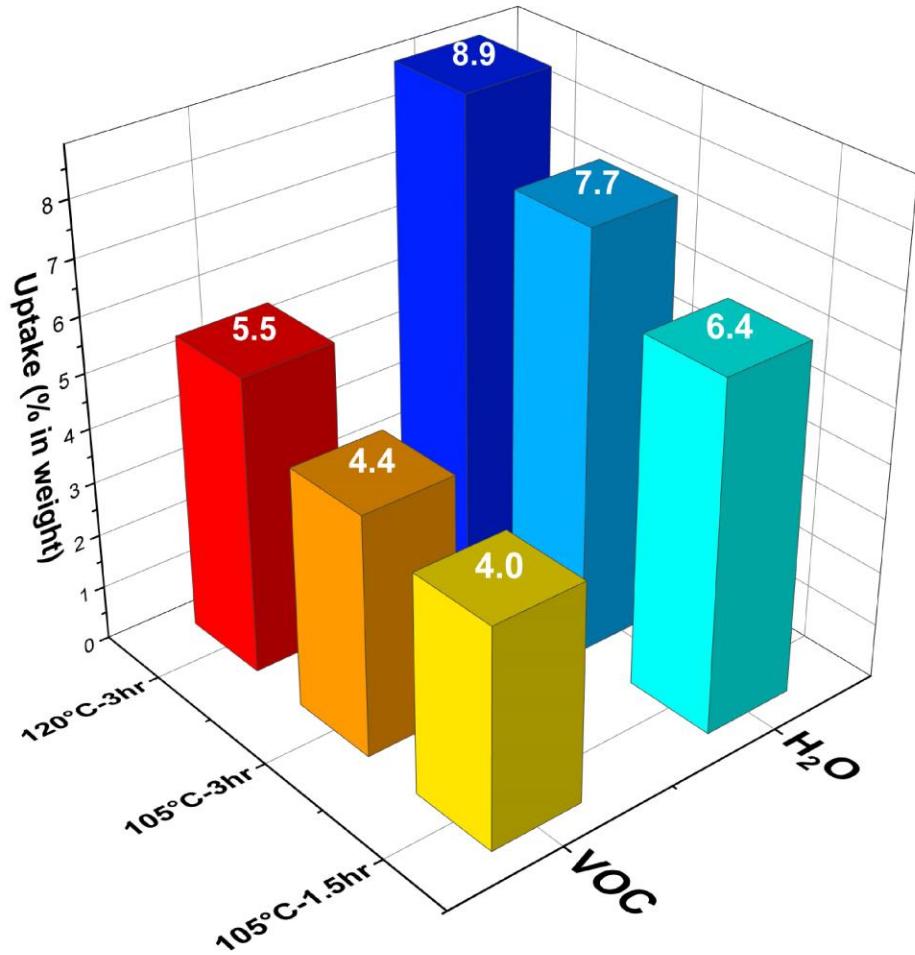
Temperature: 25 °C



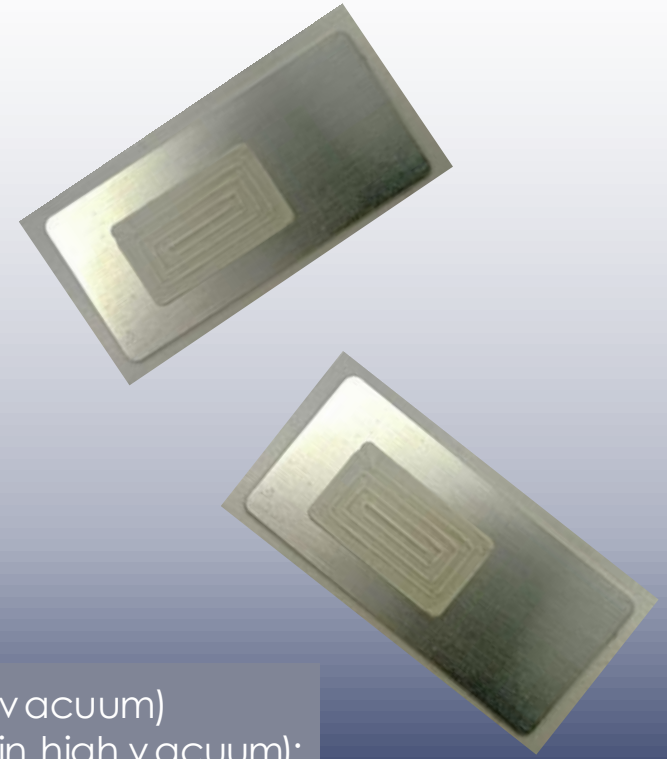
ZeDry<sup>®</sup>-H<sub>2</sub> can sorb high moisture quantities even at low RH. The water uptake efficiency at low RH levels is still 70% of that at ambient RH



# ZEDRY<sup>®</sup>-VOC: moisture and VOC performances



Mild activation conditions (105 °C and low vacuum) compared with optimal activation (120 °C in high vacuum): good performances in terms of both water and VOC uptake



# TAKEAWAYS

- ✓ Getter integration is an effective solution for devices requiring vacuum to operate.
- ✓ Analytical techniques, such as RGA and Outgassing Tests, are available to support continuous efforts in improving performance and reliability of devices.
- ✓ Photonic Devices may suffer issues from gaseous contaminants, like H<sub>2</sub>O, H<sub>2</sub>, VOCs, in the filling gas inside the package.
- ✓ Tailored getter materials can be integrated in order to absorb gases and assure proper device functionality over lifetime.

The background features a composite image. On the left, there is a dark, textured surface, possibly a cross-section of a material. On the right, a microscope slide is shown with a metal spring resting on it. A pipette tip is positioned above the slide, with a small droplet of liquid about to fall. The overall lighting is a mix of cool blue tones on the left and warm orange tones on the right.

# Thank you

for your attention

[www.saesgroup.com](http://www.saesgroup.com)

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