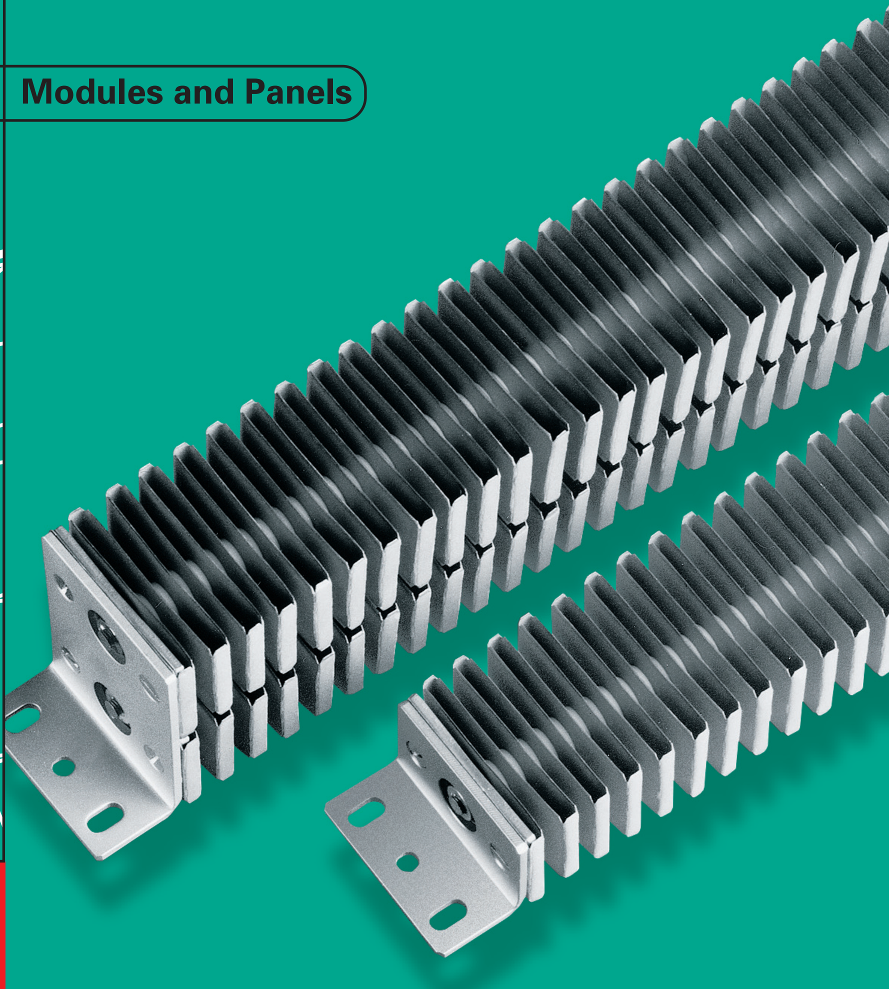
SORB-AC® Getter Wafer Modules and Panels



saes getters

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GENERAL INFORMATION

The volume getter pump known as the Wafer Module has been developed for use in plasma machines and associated equipment, in particle accelerators, and in general vacuum systems where large specific pumping speeds are required together with a simple non-magnetic and modular gettering solution.

GETTER MATERIALS

The gettering materials used in the Wafer Modules are a Zr-Al alloy with the trade name of St 101® or a Zr-V-Fe alloy having the trade name St 707® both manufactured by SAES Getters S.p.A. These alloys are suitable for pumping all active gases and especially H_2 (and its isotopes).

Active gases (such as O_2, CO and N_2) are permanently fixed by these Zr based getter materials with the exception of H_2 and its isotopes which form a solid solution in the alloy and can thus be reversibly sorbed, according to the «Sieverts' Law». During sorption of active gases at room temperature the surface of the getter material becomes progressively saturated and eventually the pumping speed falls to zero. If the sorption temperature is raised above room temperature, generally in the range 200-400°C the adsorbed gases diffuse into the bulk of the getter material. The surface will then remain sufficiently clean to maintain a constant pumping speed for a sufficient amount of time.

PUMPING CHARACTERISTICS

Dimensional Characteristics

The module structure consists of a pleated getter-coated metallic strip forming an array of parallel fins having an optimized ratio between their separation distance «d» and height «h». Figure 1 shows an example of these modules. The main dimensional parameters of the standard modules are summarized in Table 1.

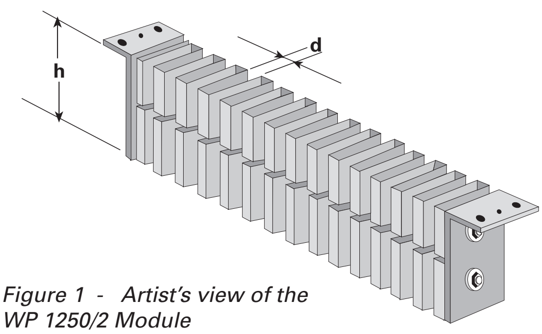

Figure 1 - Artist's view of the WP 1250/2 Module

Activation and Reactivation

These gettering materials develop their pumping characteristics after an **"activation"** process, i.e. after heating them to a suitably high temperature under dynamic vacuum for an appropriate time. Generally the heating is obtained by passing a suitable AC or DC current through the Wafer Module, however, under some circumstances indirect heating may also be applied. The maximum allowable heating temperature during activation is one of the main parameters to be considered in determining the alloy to be adopted in the specific application.

The heat treatment diffuses the thin protective layer (formed on the surface of the getter powder by air exposure during the manufacturing steps) into the bulk and makes the surface of the getter clean and able to sorb the residual gases of the vacuum environment in which it is operated.

"Reactivation" or a second heat treatment can be carried out on getter modules that have undergone a previous saturation cycle (i.e. have sorbed active gases until their pumping speed has fallen to unacceptably low values).

		WP 750	WP 38/950	WP 950	WP 1250	WP 1250/2	WP 1650
Surface of the strip (cm^2)		870	1375	1100	1750	3500	1950
Substrate thickness (mm)		0.2	0.4	0.4	0.2	0.2	0.4
Powder Coating thickness on each side (microns)		70	70	70	70	70	70
Total mass of St 101® alloy (g)		29	45	37	58	115	65
Total mass of St 707® alloy (g)		33	52	42	70	140	75
Electrical resistance (Ω)		0.16	0.10	0.10	0.2	0.1	0.19
Approximate total weight (g)	with St 101®	290	460	435	450	845	680
	with St 707®	295	465	440	460	870	690
Overall dimensions (mm):	total length	207	312	252	312	312	391
	active length	145	250	190	250	250	330
	width	50	38	50	50	50	50
	height	30	30	30	30	64	30

Table 1 - Dimensional parameters of Standard modules. Models with special dimensions can be produced on request

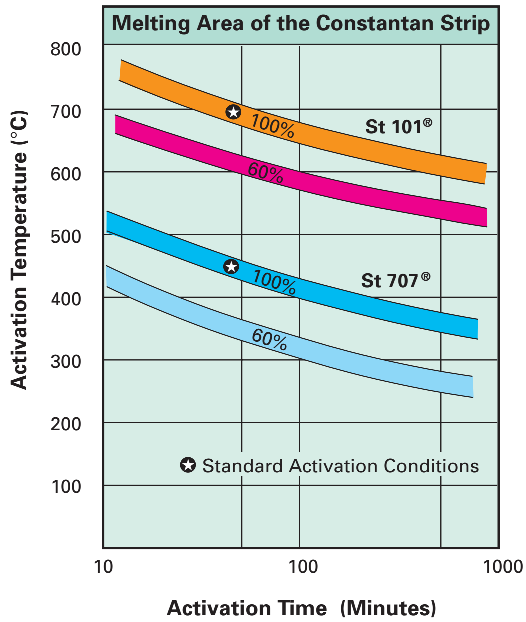

Figure 2 - Activation Curves for St 101 and St 707 Wafer Module

Through successive reactivations it is possible to exploit the pumping characteristics of the getter material up to a **maximum practical capacity**. Figure 2 gives the suggested temperature/time combinations for the best (100%) activation for both the St 101 and St 707 alloy based Wafer Modules. The curves show that in order to obtain the same final efficiency a shorter duration must be compensated with a higher temperature of the treatment and vice-versa. Both these parameters are limited by practical and physical reasons to the range of values indicated.

However, in practical cases it is not always possible to use the «ideal» temperature/time combinations. Suitable operation modes can be programmed where only a «partial» activation is considered sufficient. This results in a condition where the getter surface develops less than the full pumping speed. The conditions which give 60% of the optimum pumping speed are also shown in Figure 2.

The activation treatment should be carried out under a sufficiently good vacuum in order to avoid contamination of the gettering material, during the activation process. The total pressure under which activation is performed should not exceed 10^{-3} Torr. (A conversion table for pressure units is included at the end of the catalogue.)

Reversible Pumping of Hydrogen

Hydrogen does not form a stable combination with the getter alloy but diffuses rapidly into the bulk of the active material. A given concentration of hydrogen inside the getter alloy corresponds to an equilibrium pressure of hydrogen which is strongly dependent on temperature. This dependence is described by Sieverts' law given for St 101 and St 707 materials by the following expressions:

$$\log P = 4.82 + 2 \operatorname{Log} q - \frac{7280}{T} \quad \text{for St 101 alloy}$$

$$\log P = 4.8 + 2 \operatorname{Log} q - \frac{6116}{T} \quad \text{for St 707 alloy}$$

Where: **q** = is the concentration, in liter•Torr/gram of alloy
P = is the equilibrium pressure, in Torr
T = is the getter temperature, in K

The equilibrium curves for St 101 and St 707 alloys are reported in Figures 3 and 4. The corresponding curves for each individual module are obtained by simply multiplying the specific concentration by the mass of getter alloy (g) in the module given in Table 1.

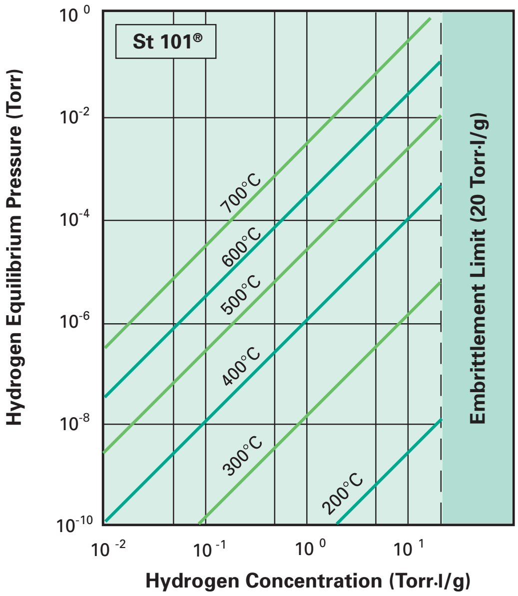

Figure 3 - Hydrogen Equilibrium Pressures of St 101 Alloy

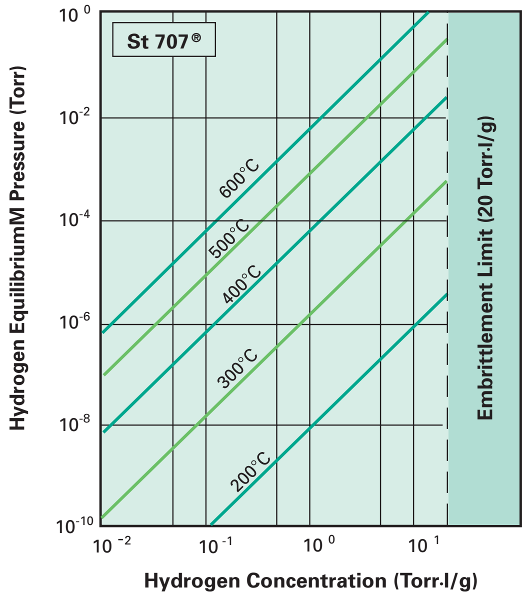

Figure 4 - Hydrogen Equilibrium Pressure of St 707 Alloy

Sorption Characteristics

The sorption characteristics (pumping speed and gettering capacity) are given for two gases (H_2 and CO) and for two operating modes in Table 2. Room temperature and 400°C are provided for St 101 Wafer Modules and room temperature and 280°C are provided for St 707 modules.

Oxygen and **Nitrogen** in the bulk diffusion regime are sorbed with pumping speeds of approximately: 65% (O_2) and 15% (N_2) with respect to that for H_2.

Water Vapour is pumped as hydrogen and oxygen and its pumping speed is limited by the rate of dissociation of the H_2O molecules. The pumping capacity is equal to the capacity for hydrogen under the prevailing conditions. However, if the released hydrogen is pumped away at each reactivation, the total capacity is only limited by the total capacity for oxygen, allowing as many as 20 or 30 pumping cycles.

Hydrocarbons are sorbed only at elevated temperatures and with a very low efficiency. A pumping speed for CH_4 of about 0.5% the speed for CO is observed at 500°C for Wafer Modules made with both St 101 and St 707 alloys.

Inert Gases are not pumped by the Wafer Modules. They can be used to purify rare gases containing active gas impurities.

Note: When the sorption temperature is not sufficiently high to efficiently diffuse the adsorbed gases into the bulk of the

	Pumping Characteristics	WP 750	WP 38/950	WP 950	WP 1250	WP 1250/2	WP 1650
St 101® alloy	Pumping Speed* (l/s)						
	H_2 Room Temperature	510	670	670	880	1000	1160
	H_2 400°C	640	840	840	1100	1250	1450
	CO Room Temperature	170	230	230	300	330	400
	CO 400°C	310	410	410	540	690	710
	Sorption Capacity (Torr·l)						
	H_2 Room Temperature	580	900	740	1160	2300	1300
	H_2 400°C	Depends on equilibrium pressure					
	CO 400°C**	65	100	80	130	255	145
St 707® alloy	Pumping Speed* (l/s)						
	H_2 Room Temperature	330	430	430	560	770	740
	H_2 280°C	400	530	530	690	950	910
	CO Room Temperature	130	170	170	220	240	290
	CO 280°C	190	250	250	330	420	440
	Sorption Capacity (Torr·l)						
	H_2 Room Temperature	660	1040	840	1400	2800	1500
	H_2 280°C	Depends on equilibrium pressure					
	CO 280°C**	75	115	95	151	310	165

Table 2 - Pumping speeds and sorption capacities

**Measured at a pressure of $3x10^{-6}$ Torr*

***When the indicated capacity has been exhausted (in several cycles) the pumping speed measured after a new activation is still at least 1/10 of the value given in Table 2* gettering material a continuous and sharp decrease of pumping speed versus sorbed quantity is observed. Sorption at room temperature falls in this category. The pumping speed values reported in Table 2 at room temperature are those of a clean, just activated gettering surface often referred to as «initial pumping speed».

Hydrogen Isotopes

The hydrogen isotopes deuterium and tritium, are sorbed with pumping speeds lowered by the following factors with respect to the values given in Table 2 for H_2:

$$D_2 : 1.41 \qquad T_2 : 1.73$$

Concerning the equilibrium law the following expressions hold for D_2*:

For St 101 based Wafer Modules

$$\text{Log P} = 4.9 + 2\ \text{Log q} - \frac{7220}{T}$$

For St 707 based Wafer Modules

$$\text{Log P} = 5.1 + 2\ \text{Log q} - \frac{6327}{T}$$

* *Theoretically the equilibrium pressure of tritium should be higher than that of deuterium by a factor of 1.2 for the same isotope concentration.*

INSTALLATION

Mounting

The wafer modules can be mounted on any suitable part of the vacuum system such as flanges, vacuum chamber walls and internal structures. No pre-assembly operation is required. Wiring must not be connected to the protruding central rods. These are insulated supporting rods and have no electrical function. The wires must be connected to the two terminals extending beyond the active portion of the module.

Each of these terminals has three holes suitable for bolts. Any type of feedthrough suitable for carrying the current necessary for activation can be used. The use of a thermocouple is advisable (although not mandatory) for a better regulation of the activation, regeneration and operating temperatures. The thermocouple should preferably be spot welded to the bare shoulder of the gettering strip (i.e. the 1.5 mm portion with no powder coating) and positioned in the central area of the module.

The getter module design allows it to be easily mounted adjacent to other modules (with electrical connections in series or in parallel) and within a support structure/heat shield assembly to form a pumping panel. Figure 5 illustrates this pumping panel concept.

Power Supply

The presence of insulating spacers between the fins of the module and the central rod allows Joule effect heating of the modules without short circuiting the strip. A simple AC or DC power supply is all that is necessary to activate and operate the wafer modules. A solution based on a variable transformer connected through an ammeter to the module allows correct adjustment of the current flowing in the circuit. An example of a suitable circuit diagram is shown in Figure 6.

Some typical values of the current required to heat the getter modules at various temperatures are shown in Table 3. These values refer to a single module mounted close to a reflecting surface (for example the wall of the system). If the modules are mounted far from the walls, the current values must be increased by about 30%. When several modules must be electrically operated at the same time both series and parallel connections are suitable. The choice depends on the maximum allowed values of the total current and voltage.

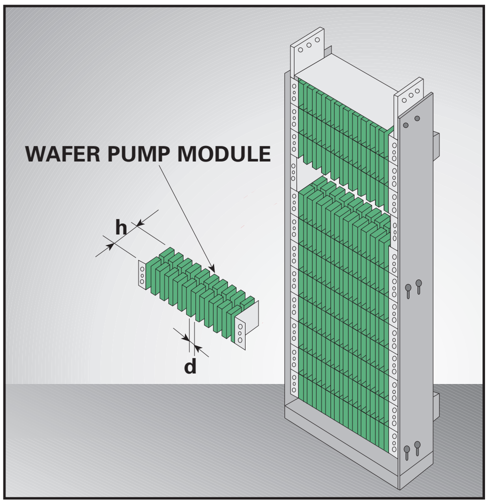

Figure 5 - Artist's view of the panel concept

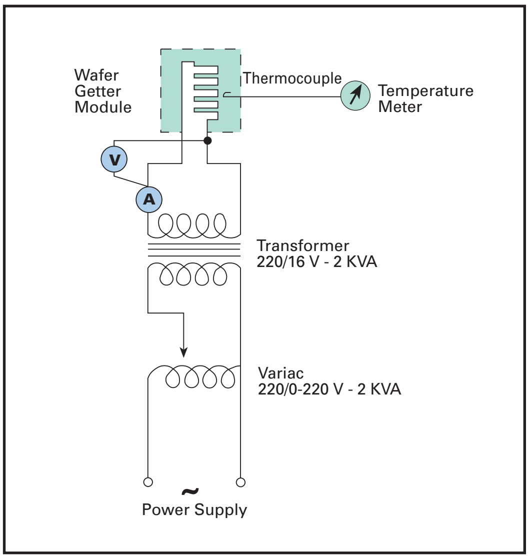

Figure 6 - Schematic diagram of a possible power supply for WP getter modules

Temperature °C	Type of module											
	WP 750		WP 38/950		WP 950		WP 1250		WP 1250/2		WP 1650	
	I(A)	P(W)	I(A)	P(W)	I(A)	P(W)	I(A)	P(W)	I(A)	P(W)	I(A)	P(W)
200	12	23	18	34	18	34	12	45	20	50	18	63
280	15	36	22	50	22	50	15	65	24	80	22	95
400	23	85	33	115	33	115	23	150	36	180	33	213
450	26	108	38	153	38	153	26	190	42	247	38	282
700	47	365	66	480	66	480	47	630	77	840	66	850

Table 3 - Typical current values required to heat the getter material

PRACTICAL OPERATING CONDITIONS

Optimum Operating Temperature

To maintain a sufficiently high pumping speed during the sorption cycle the operating temperature must be chosen according to the level of contaminants . The suggested sorption temperatures are indicated in Table 4.

Acceptable Operating Limits and Precaution

The recommended upper limit of H_2 concentration does not correspond to the solid solution limit but to the smaller value of 20 Torr·l/g of gettering alloy. This takes into account the necessity of avoiding loose particles due to embrittlement phenomena. It is normally advisable not to exceed 10 -12 Torr·l/g so as to keep a sufficiently large safety margin with respect to the embrittlement concentration.

The maximum suggested module temperature during thermal process such as activation, reactivation and regeneration should be 700°C. At higher temperatures the evaporation of Cu from the constantan support, (which is negligible up to 700°C) may start to take place.
The maximum pressure of 10^{-4} Torr during activation should not be exceeded by using a sufficiently high pumping speed of the backing pumps and by suitably arranging the getter temperature during the initial heating of the modules.

Outgassing under pumping at room temperature or at the same temperature at which baking is carried out is advisable in particular cases. In particular when the modules appear to be «gassy» from moisture or other gases picked-up during long exposures to the atmosphere.

Number of Reactivations Before Saturation

When the pumping speed of the gettering system based on modules has fallen below acceptable limits, due to sorption of active gases, the gettering efficiency can be restored by a new activation or reactivation. Of course this is also the case when the gettering system has been re-exposed to air. This treatment will at least partially recover the original gettering efficiency of the modules.

Through successive pumping and reactivation cycles the getter module will eventually accumulate an increasing quantity of irreversibly sorbed impurities (such as O_2 and CO) and a new activation will no longer be able to recover an acceptable gettering efficiency. At this time the modules must be substituted. The point at which this happens is a subjective judgement. Past manufacturer experience suggests using the following quantities of active gases sorbed (q is in Torr·l/g of the indicated gas species) to assess the module saturation point.

Conditions	St 101® module	St 707® module
Active gas mixtures such as CO, CO_2, N_2, O_2 to be pumped in the 10^{-5} Torr range	700°C	450°C
Active gas mixtures such as CO, CO_2, N_2, O_2 to be pumped with a total pressure less than 10^{-5} Torr	400-500°C	280-350°C
Hydrogen, when a high pumping speed is required and a heavy residual background of active gas impurities is present in the system (for example 1% to 10%)	400°C	280°C
Any condition when frequent re-activation treatments are possible or when in UHV conditions (10^{-9} Torr or better)	Room Temperature	
Hydrogen even at high pressures (up to 10^{-3} Torr) but with a very low (ppm range) gas impurity content	Room Temperature	

Table 4 - Suggested sorption temperatures

$$qCO + qCO_2 \frac{qO_2}{5} + \frac{qH_2O}{3} + \frac{qN_2}{4} = 2.2 \text{ Torr·l/g}$$

Regeneration

The hydrogen (hydrogen isotopes) sorbed by Wafer Modules can be released from the getter material through a regeneration treatment.

This regeneration is necessary when:

- the pumping speed for H_2 or hydrogen isotopes has fallen below acceptable limits because the equilibrium pressure is being reached
- the equilibrium is still far away but the H_2 or hydrogen isotope quantity pumped is approaching the embrittlement limit of 20 Torr·l/g.

The time necessary for the regeneration of a module is given by the expression:

$$t = \frac{M}{F}\left(\frac{1}{q_f} - \frac{1}{q_i}\right) 10^{-\left(A - \frac{B}{T}\right)}$$

Where: **t** = is the regeneration time, in seconds
M = is the mass of the getter material, in grams
F = is the pumping speed of the backing pumps in, liter/s
$\mathbf{q_f}$ = is the final H_2 concentration, in liter Torr/g
$\mathbf{q_i}$ = is the initial H_2 concentration, in liter Torr/g
A = 4.82 for St 101 modules; 4.8 for St 707 modules
B = 7280 for St 101 modules; 6116 for St 707 modules
T = is the regeneration temperature in K

Due to the exponential shape of the regeneration curve significant time saving is achieved when the regeneration is not programmed to be complete (100% of the sorbed H_2 released again) but only partial (for example 90%).

Thermal Fatigue

The regeneration process can be performed often but not for an indefinite number of times. This is due to the development of thermal fatigue effects in the getter coated strips causing peel-off of the getter powder. Peel-off mainly depends on temperature and duration of regeneration. Figure 7 shows the number of permissible thermal cycles, at 700°C, 600°C and 500°C as a function of the hold time, before peel-off starts to be observed.

Air Venting

Opening of the vacuum chamber when Wafer Modules are mounted should be carried out only when the gettering material is at room temperature or at least less than 50°C. After each air exposure a new reactivation of the getter module is required. A progressive reduction of pumping speed for H_2 and active gases is observed after successive exposures to the air. After about 40 air exposures at room temperature followed by reactivation the St 101 modules at 400°C and St 707 modules at 280°C still have a pumping speed of about 30% of the initial pumping speed for H_2. If dry N_2 is used instead of air, the pumping speed reduction after the same number of exposures appears to be smaller (residual pumping speed is still about 80% of the initial value). Use of pure Argon as a protective gas during maintenance operations obtains further improvements.

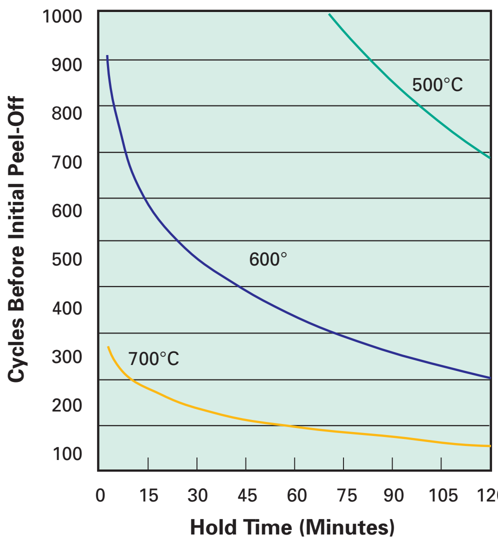

Figure 7 - Cycles to initial peel-off vs hold time

SPECIAL INSTRUCTIONS

Vacuum Failure During Activation or Regeneration

During activation or regeneration of getter modules air must not be allowed to suddenly enter the vacuum system to prevent burning of the coated strip. This occurs if the temperature of the module at the moment of vacuum failure is above 450°C in the case of St 101 modules and above 200°C in the case of St 707 modules.The burning is slow and progressive and not explosive.
Permanent damage, but not burning, could result should a serious vacuum failure take place when the temperature of the module is below the above indicated values. Automatic switch-off of the gettering system power supply may be required to prevent damage. In this case the pumping characteristics of the getter material will be affected to a greater or lesser extent depending on temperature and time of the exposure. For example only negligible damage would result in St 101 Wafer Modules if the air exposure occurs at 300°C for a maximum of 2-3 minutes. In this case, recovery of the gettering efficiency may be obtained by using a reactivation procedure at a temperature higher than the normally adopted value.

Mechanical Shocks

Due to the mechanical characteristics of the insulating elements of Wafer Modules (ceramic spacers), particular care must be observed in handling during assembly in (and removal) from the pumping system. Accidental dropping and similar mechanical shock could result in breakage of the insulating elements with possible electrical path short circuits.

UNPACKING

The getter modules are delivered individually packed in suitable cans. Each module is wrapped in an aluminium foil and is embedded in a foam material. The can, with slight modifications to the internal packaging, may contain two modules instead of one if required for delivery reasons. The can is filled with a dry nitrogen atmosphere slightly above atmospheric pressure to prevent any contamination of the module.

The can is easily opened by means of a normal can-opener. Even if the modules can stay in normal air without damage due to the stability of the getter alloy used, it is advisable not to open the can until use of the modules is foreseen within a short time. Long exposures to humid atmosphere or to dusty ambients are always to be avoided. The modules must be handled with the normal care adopted for all components of UHV systems. In particular they should be handled with plastic or rubber finger cots (or gloves) and never with bare hands.

Reference:

Conversion Table

To obtain	Multiply	By
Pa	Torr	133.3
Pa m^3	Torr liter	0.1333
Pa $m^3 \cdot m^{-2}$	cm^3 Torr $\cdot$ cm^{-2}	1.333
m^3 $sec^{-1} \cdot m^{-2}$	cm^3 $sec^{-1} \cdot cm^{-2}$	0.01
Torr	Pa	7.501×10^{-3}
Torr liter	Pa m^3	7.501
cm^3 Torr $\cdot$ cm^{-2}	Pa $m^3 \cdot m^{-2}$	0.7501
cm^3 $sec^{-1} \cdot cm^{-2}$	m^3 $sec^{-1} \cdot m^{-2}$	100

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SAES Getters S.p.A.
Group Headquarters:
Viale Italia,77
20020 Lainate (Milano), Italy
Tel.: +39 02 931 78 1
Fax: +39 02 931 78 320

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