3.3.2.2 NEG pumps

NEG materials are produced in industry by powder technology. Small grains of very reactive metals are sintered to form pellets, discs or plates. In addition, the grain can be pressed onto a metallic substrate to form ribbons.

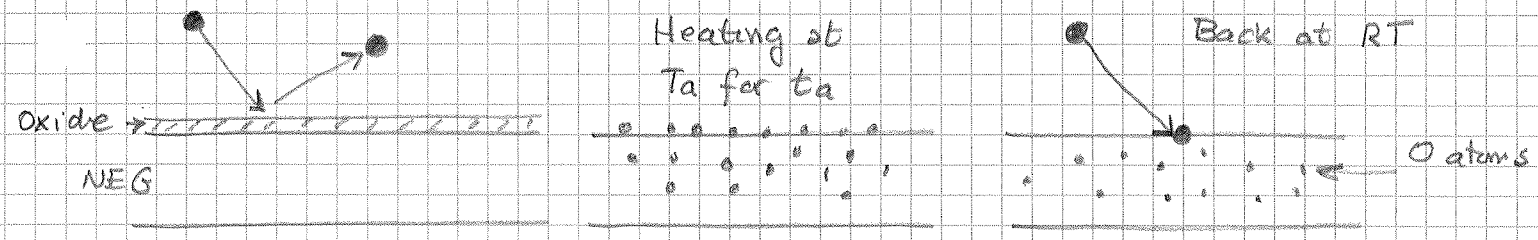
These pumps are based on the exception high oxygen solubility limit of the element of the 4th group :

Sc	Ti	V
Y	Zr	Nb
La	Hf	Ta
1-4%	20÷30%	1-2%

O solubility limit at RT in the 3rd, 4th, 5th groups

O solubility limit ⇒ in a oxygen-metal system, it is the concentration of oxygen in the solid solution in equilibrium with the oxide. It depends on temperature.

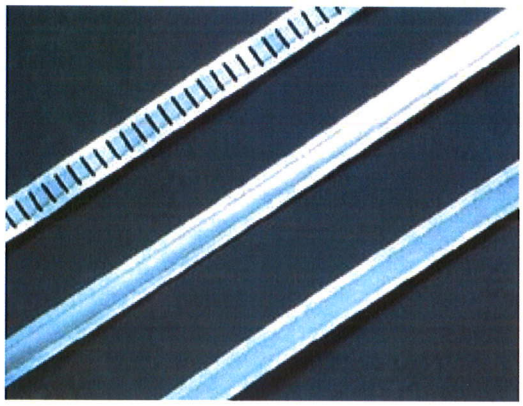
Zr is in general the metal of choice.

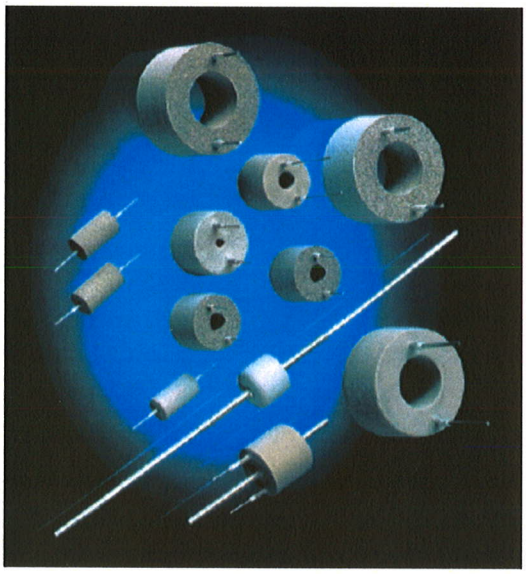


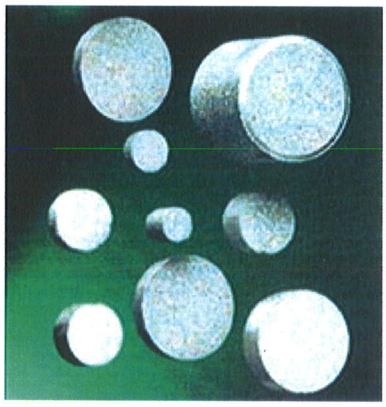
To reduce the activation temperature, other elements are added to increase the O diffusivity ⇒ faster O dissolution.

A typical alloy is St 707 (produced by SAES Getters, Milan, I)

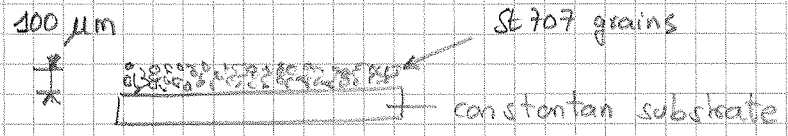
St 707 :
- Zr 70% wt. ← high solubility
- V 24,6% wt. ← increase diffusivity
- Fe 5,4% wt. ← reduce pyrophoricity





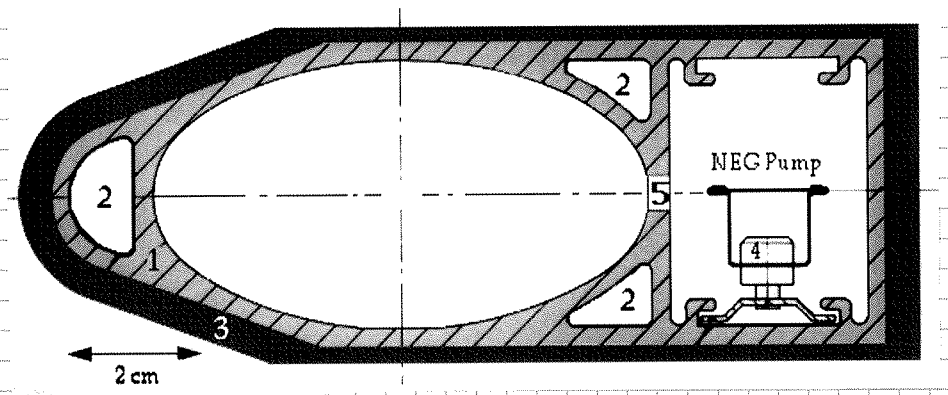


Typical activation temperatures: $400°C \times 45'$ min / $300°C \times 24$ h



If compared to Ti sublimation pumps, NEG pumps present the risk of powder peel-off due to excessive heating or H_2 embrittlement (excessive hydride formation). However NEG may provide distributed pumping in beam pipes. In the LEP, NEG ribbons provided more than 90% of the pumping speed. The alloy was Zr-Al (St 101) activated at 750°(45')

LEP vacuum chamber cross section



The pumping speeds for St 707 are shown in the next figures.

The general behaviour is the following:

- NEGs do not pump CH_4 + noble gases
- At room temperature, the adsorbed gas molecules progressively saturate the surface and reduce the pumping speed, except for H_2 that is dissolved in the NEG bulk
- CO inhibits the pumping of other gases
- N_2 has a small surface blocking for the other gases
- H_2 does not block the adsorption of the other gases

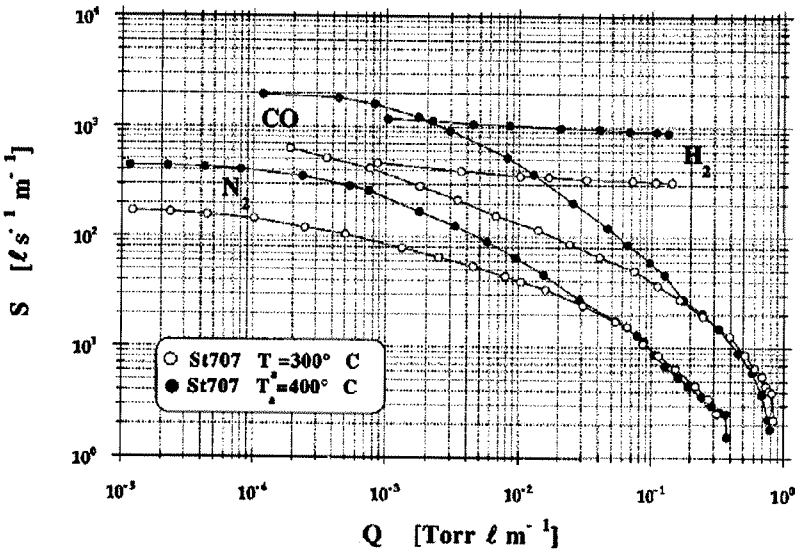


FIG. 1. Pumping speed of the St707 NEG after 45 min activation at 300 and 400 °C as a function of the pumped quantities of CO, N_2, and H_2.

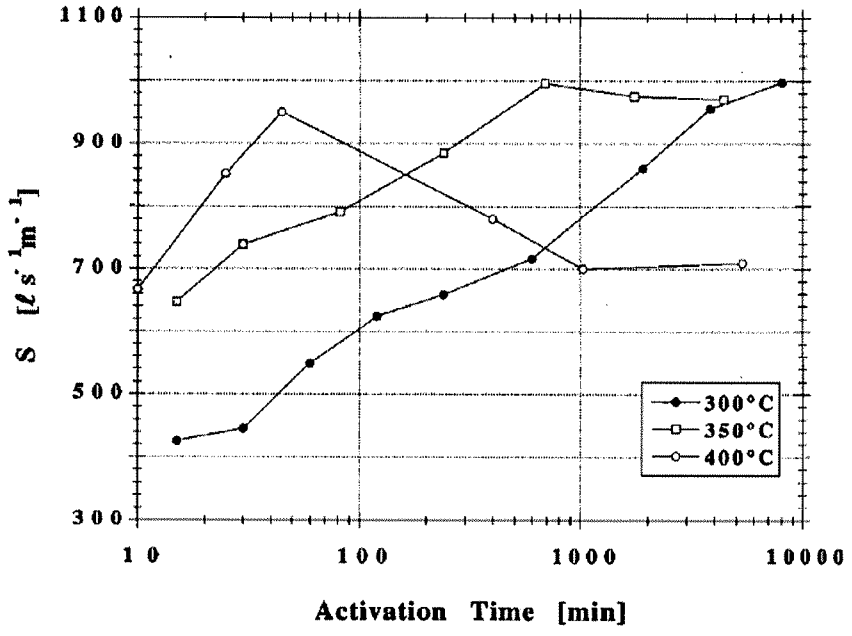


FIG. 7. Variation of the initial pumping speed for H_2 of a St707 NEG as a function of the heating time and for various heating temperatures.

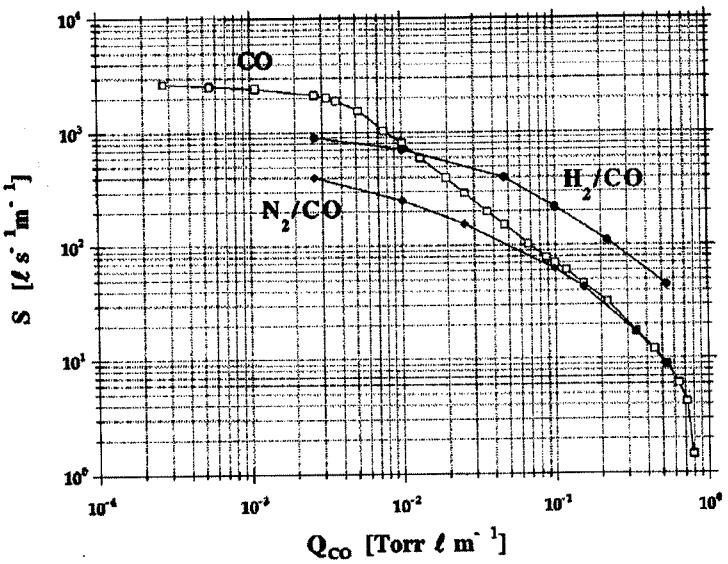


FIG. 8. Variation of the measured pumping speed for H_2, N_2, and CO as a function of the adsorbed quantity of CO.

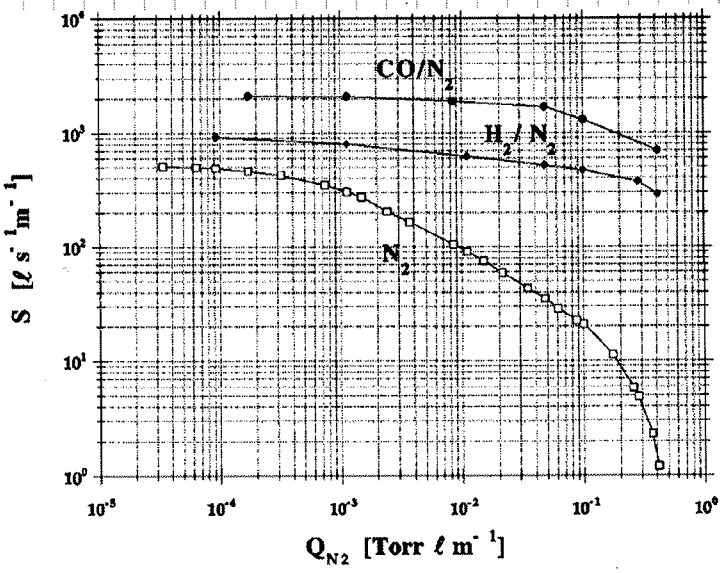
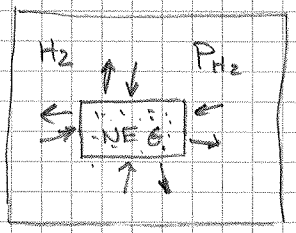


FIG. 9. Variation of the measured pumping speed for H_2, N_2, and CO as a function of the adsorbed quantity of N_2.

Active gases are pumped irreversibly, except for H_2.
This gas can enter and exit from the NEG material at a rate that depends on temperature and hydrogen concentration. An equilibrium condition is attained. The H_2 equilibrium pressure is also called dissociation pressure.



$$H_2 + Me \rightleftarrows 2H \text{ (in metal)} + Me$$

$$K_{eq} \propto \frac{P_{H_2}}{C_H^2} \rightarrow P_{H_2} = \tilde{K} \cdot C_H^2$$

$$\tilde{K} = \tilde{K}_0 \, e^{-E_s/RT}$$

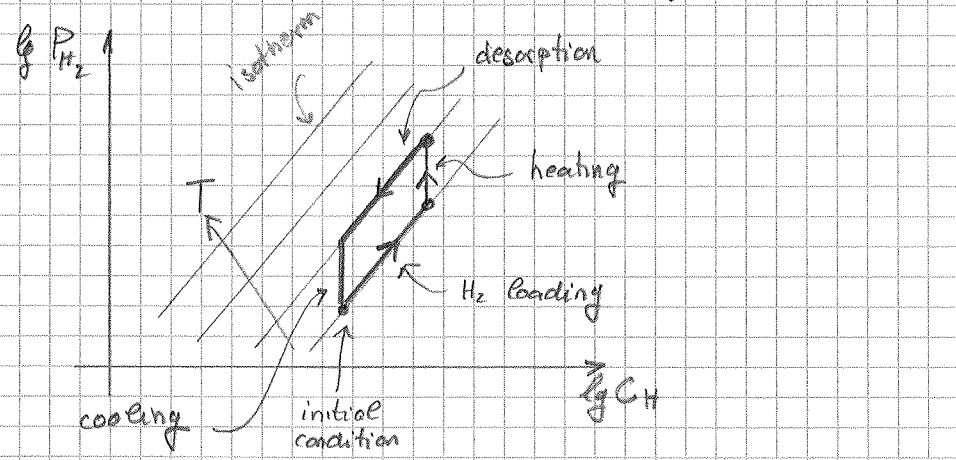
$$\rightarrow \quad \lg P_{H_2} = \lg \tilde{K}_0 - \frac{E_s}{RT} + 2 \lg C_H$$

For St 707:

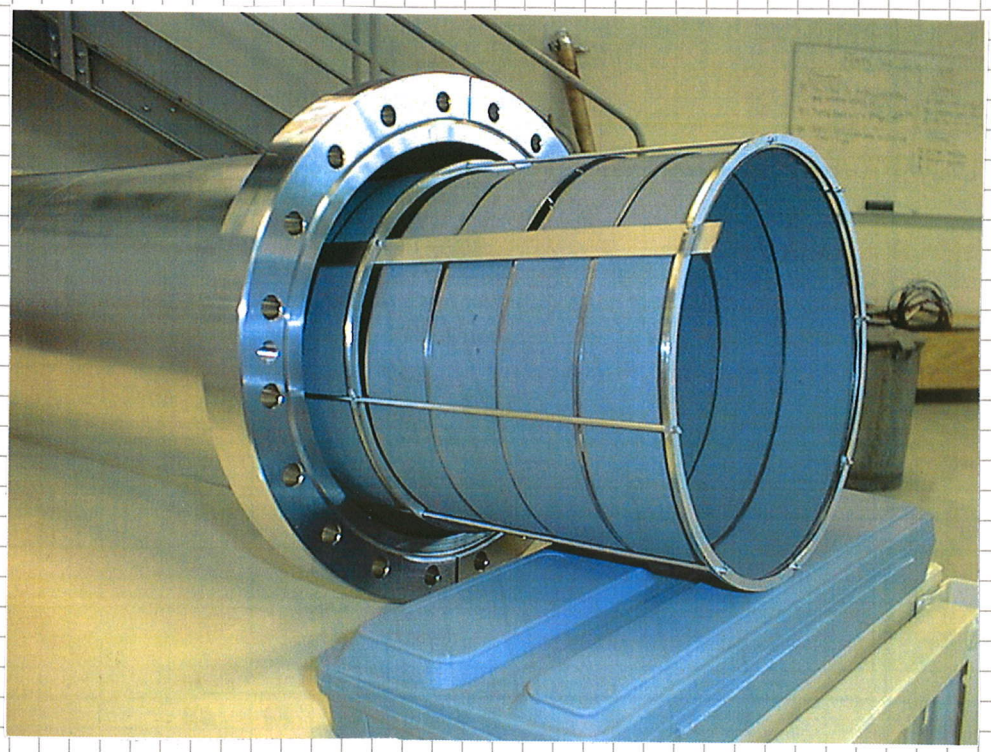
$$\lg P_{H_2} = 5{,}14 - \frac{6250}{T} + 2 \lg C_H$$

P [mbar] C_H [mbar ℓ/g]
T [K]

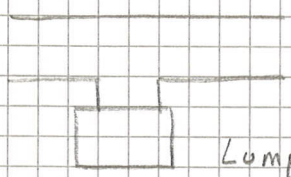
The H_2 equilibrium pressure increases when increasing T. If a NEG has been charged with H_2, it can always come back to the initial condition by stopping the external gas load, increasing the temperature to accelerate hydrogen desorption and then cooling down to room temperature.



The inner walls of a vacuum pipe can be covered by NEG St 707 ribbon, activated during the bakeout at a temperature $T \geq 300°C$.
Very low pressures are achieved coupling the NEG with sputter ion pumps for the pumping of CH_4 and rare gases.



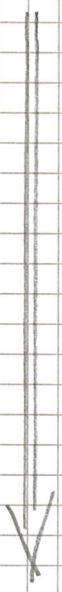
PUMP EVOLUTION



Lumped pump

Linear pump

Integrated pump



The pump has moved closer to the gas source.

NEXT STEP ⇒ COATING THE WALLS OF THE BEAM PIPE BY NEG THIN FILMS.

(see ppt presentation)

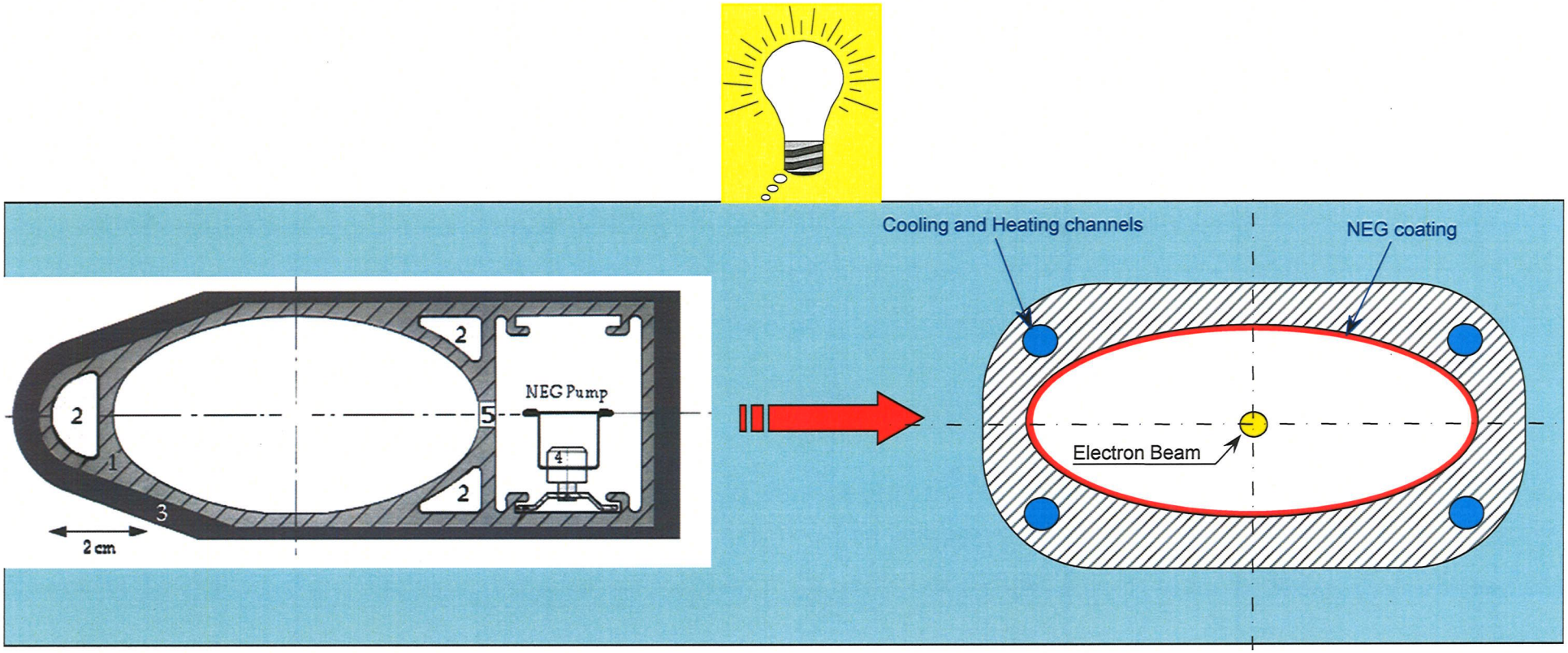
... where the NEG film was born in 1996!

NEG thin film coatings

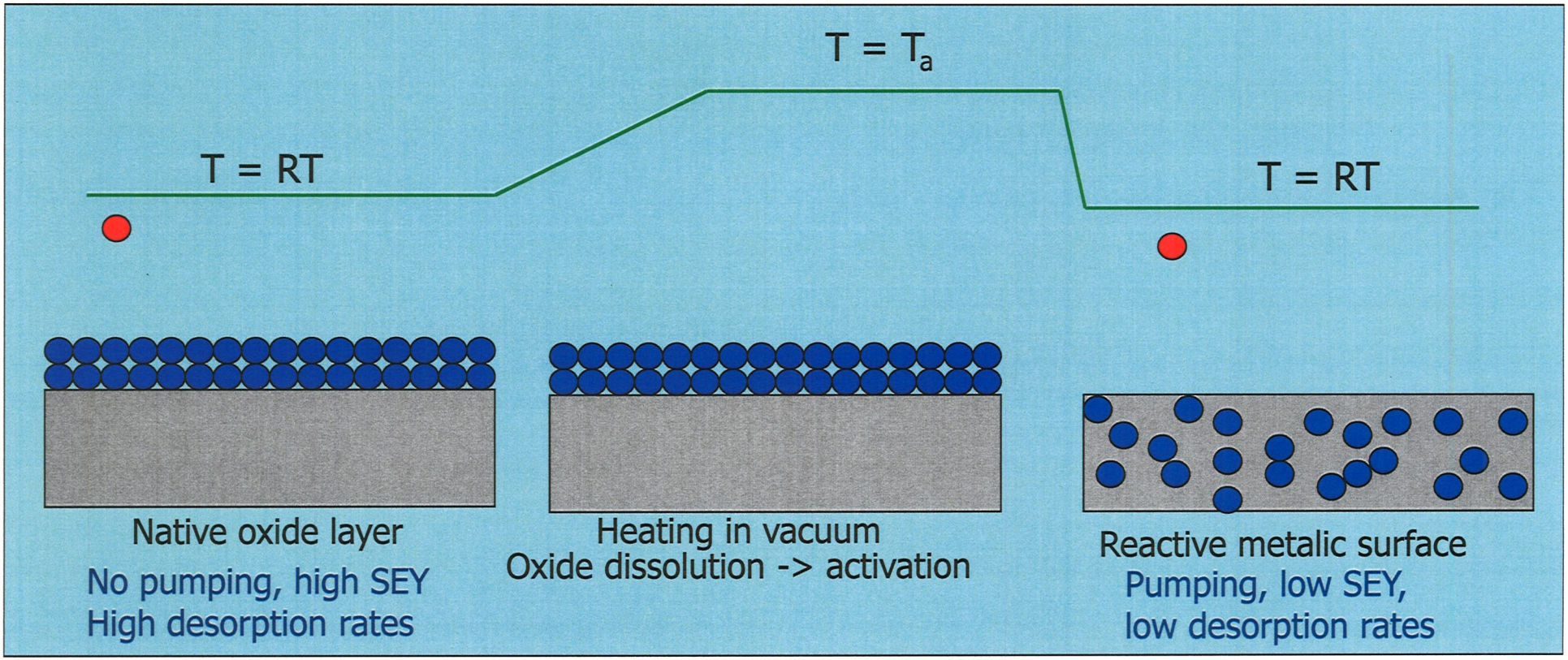
Paolo Chiggiato

How a pumping vacuum chamber can be obtained:

…by sputter coating its inner wall with a non-evaporable getter film before the installation in the accelerator.



Getters are materials capable of chemically adsorbing gas molecules. To do so they need to be activated



NEGs pump most of the gas except rare gases and methane at room temperature

The activation temperature has to be compatible with the substrate materials:

St. steel < 400 °C

Copper alloys < 250°C

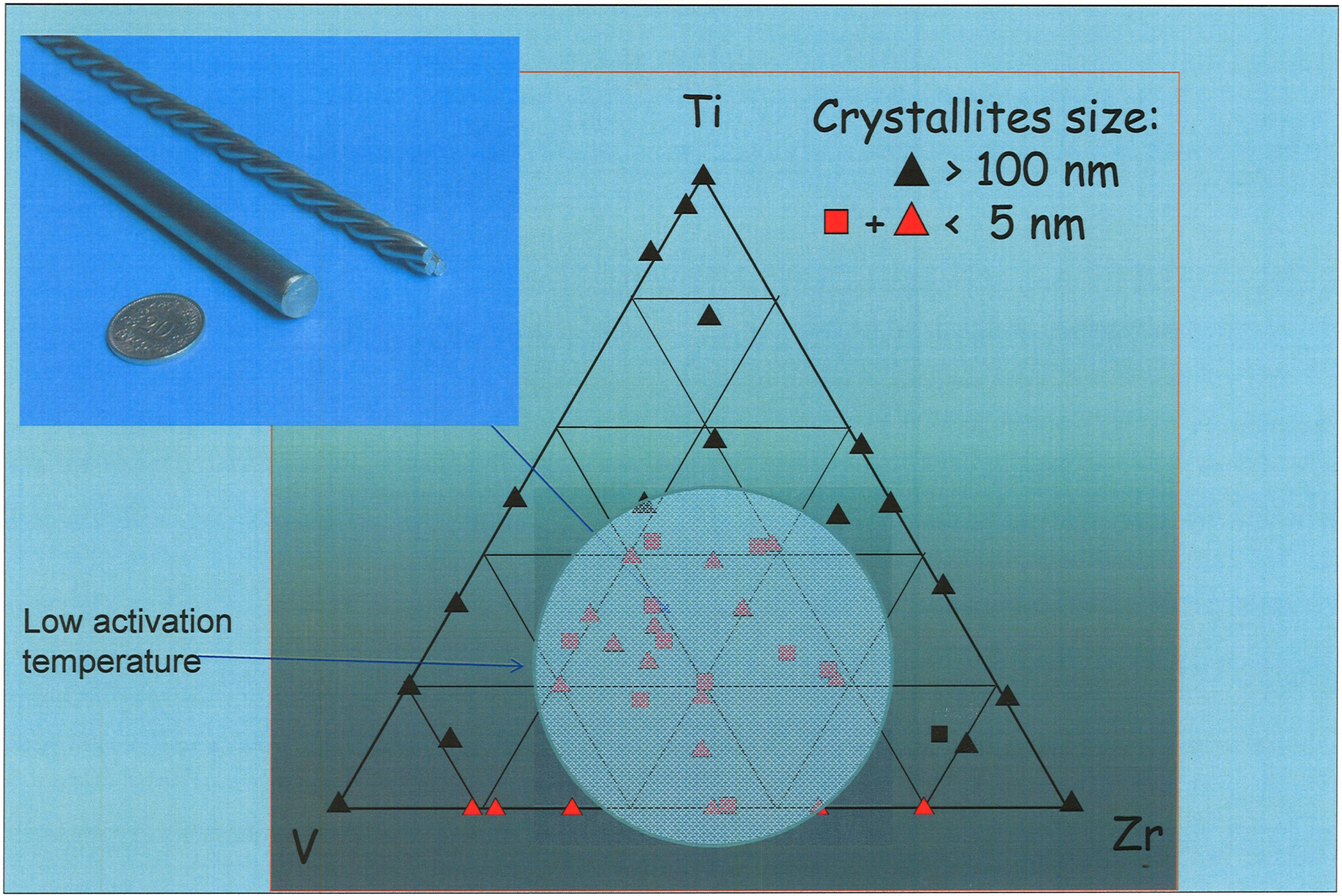
Aluminum alloys < 200 °C

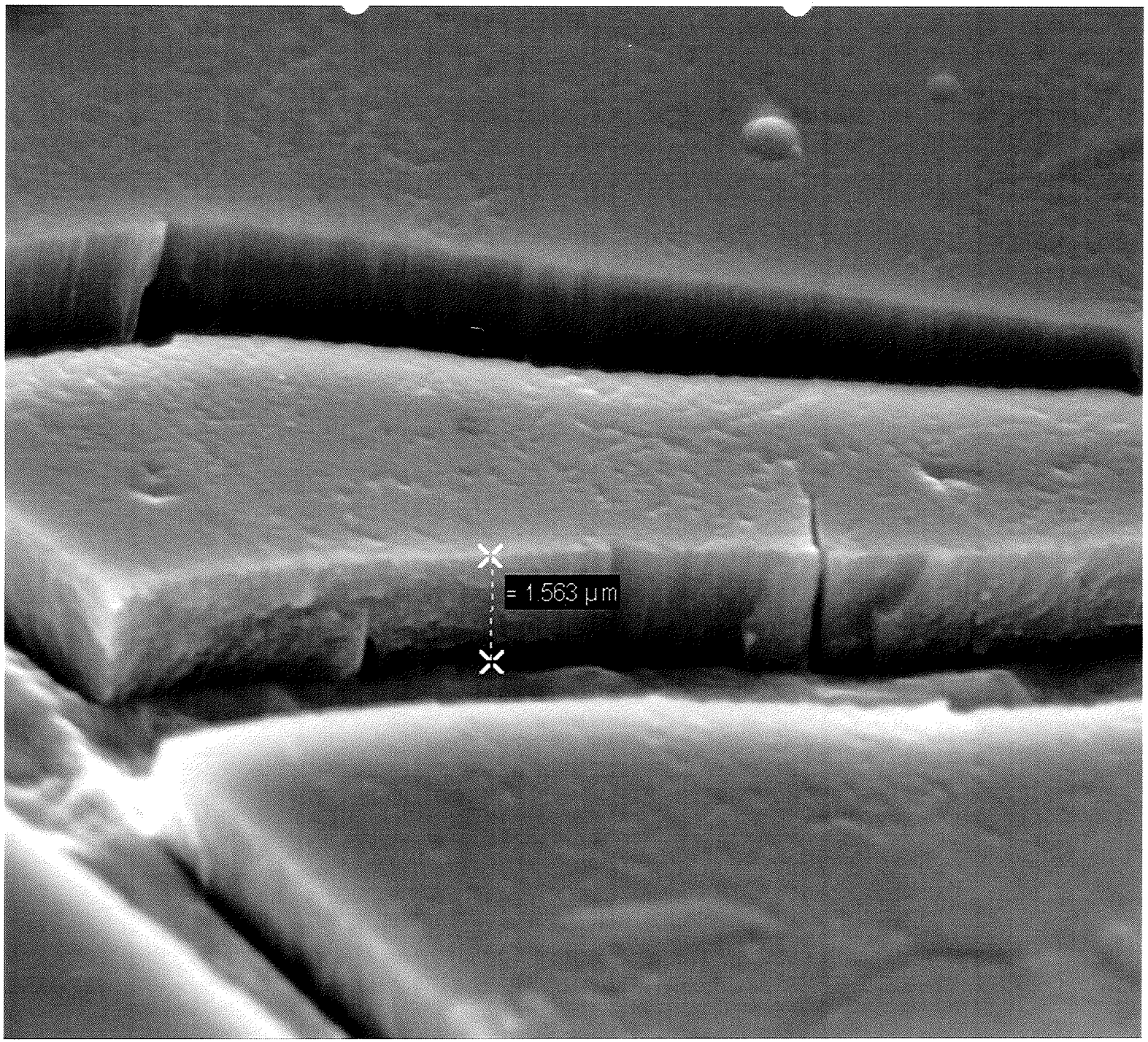
Lowest activation temperature obtained by sputtering Ti-Zr-V alloys!

180 °C

(24 hours heating in vacuum)

in a large range of composition in the Ti-Zr-V system


Ti
Crystallites size:
> 100 nm
+ < 5 nm
Low activation temperature
V
Zr


= 1.563 µm