

# HEAVY ION INDUCED DESORPTION MEASUREMENTS ON CRYOGENIC TARGETS\*

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## Abstract

Heavy-ion impact induced gas desorption is the key process that drives beam intensity limiting dynamic vacuum losses. Minimizing this effect, by providing low desorption yield surfaces, is an important issue for maintaining a stable ultra high vacuum during operation with medium charge state heavy ions. For room temperature targets, investigation shows a scaling of the desorption yield with the beam's near-surface electronic energy loss, i.e. a decrease with increasing energy [1, 2]. An optimized material for a room temperature ion-catcher has been found. But for the planned superconducting heavy-ion synchrotron SIS100 at the FAIR accelerator complex, the ion catcher system has to work in a cryogenic environment. Desorption measurements with the prototype cryocatcher for SIS100 showed an unexpected energy scaling [3], which needs to be explained. Understanding this scaling might lead to a better suited choice of material, resulting in a lower desorption yield. An experimental setup for systematic examination of this scaling is presented. The cryogenic beam-induced desorption yield of several materials at different temperatures is examined.

## EXPERIMENTAL SETUP

The experiment described in this article has been set up at the SIS18 at GSI. Its approach is rather straightforward: a cold target is hit by a (heavy) ion beam pulse of approx. 1  $\mu$ s length, while the resulting pressure peak is recorded. The setup consists of UHV-equipment, the target assembly including a coldhead, and beam- as well as vacuum-diagnostics.

### UHV-System

The primary goal in this campaign is to measure small ion impact induced pressure peaks. A sufficiently low vacuum background is required to achieve an adequate signal-to-noise ratio. The resulting pressure peak, however, should be contained in a chamber of defined volume (i.e. target and diagnostic chamber) to enable a meaningful analysis.

A differential pumping line is required, in order to connect the UHV system of the test setup to the beam transport line. To reach a suitably low pressure, the target region needs to be baked out. Limitations of the coldhead allow only moderate bakeout-temperatures.

### Target Assembly

The target is connected to the second stage of a coldhead (shown in Fig. 1), while its first stage is used to cool down a

thermal shield. This shield absorbs thermal radiation from the room temperature environment. Thus the heat load onto the second stage is minimized to reach sufficiently low temperatures for the measurements. A resistive heater is used to accelerate the warmup process.

During the design of the target assembly great care was taken to allow a reproduction of the measurements in [3]. This means including an insulating tile necessary for measuring the electrical current caused by the impacting ions. Such a current measurement is in operation in the ion catcher system of SIS18 [4]. The gold-plated copper target shown in Fig. 1 is the reused one from the cryocatcher prototype [3]. In a future measurement campaign, a second target, made of uncoated stainless steel will be used. This material has a comparable thermal capacity as copper, but a much lower thermal conductivity at cryogenic temperatures.

### Diagnostics

The cluster flange labeled "warm UHV diagnostics" in Fig. 2 carries an extractor-type vacuum gauge as well as a fast and triggerable residual gas analyzer, which is used to investigate the desorbent's composition. The number of particles hitting the cryogenic target is recorded by a beam current transformer right in front of the target. Temperature sensors on target and support structure are used to measure the thermal reaction during beam impact.

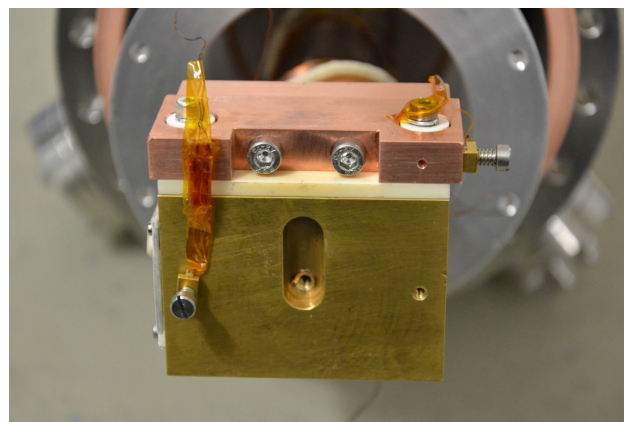


Figure 1: Photography of the target assembly without thermal shield. It consists of the target itself (gold), the insulation ceramic (white), and the target support (copper). Two temperature sensors are fixed by screws onto target and support. Beam direction is from bottom to top.

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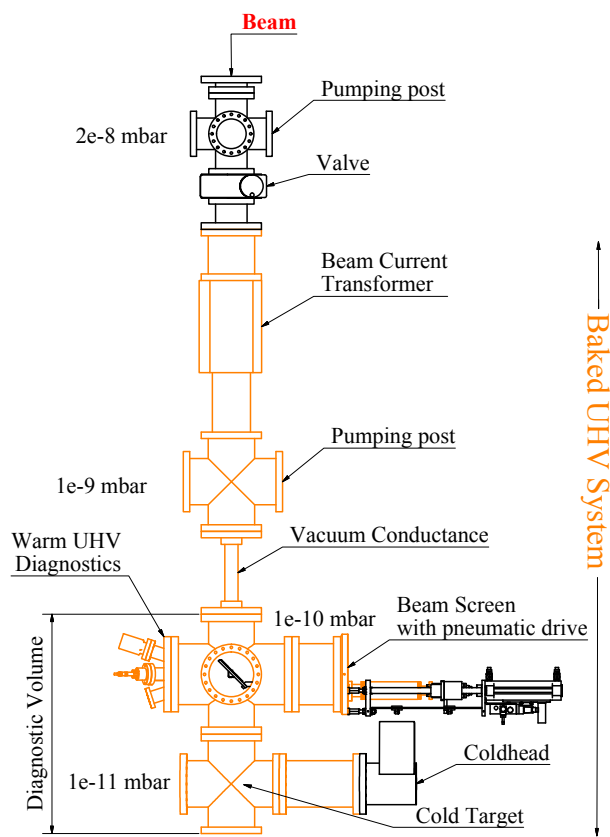


Figure 2: Sketch of the experimental setup. The beam comes from the top, The baked vacuum components are shown in orange.

## METHODOLOGY

The temperature dependence of the desorption is measured during warmups and cooldowns of the target. The minimum reachable temperature (here:  $T_{\min} \approx 38$  K) is determined by the equilibrium between heat load and the coldhead's cooling power while taking into account the thermal conductivity between desorbing surface and coldhead. In order to have a sufficient pressure relaxation time, the maximum repetition rate for beam impacts is about one shot per minute.

The beam screen right in front of the target is used to control the alignment of the beam. After a correct alignment without losses at the vacuum chamber is ensured, a fast electrometer, connected to an extractor in the diagnostic chamber is used to conduct the main measurement. When triggered by the accelerator, this electrometer records the pressure (through the extractor ion gauge current as proxy) with a rate of approx. 10 Hz to resolve the desorption peak as well as the relaxation process. Figure 3 shows a typical result of this measurement.

A wide range of parameters can be probed: Two targets have been prepared. Measurements have been taken at  $T_{\min}$ , the temperature ramps and room temperature. The projectile used in this campaign is  $U^{73+}$ , with energies between 50 and

350 MeV. To avoid a systematic error, energies were changed in random order.

## ANALYSIS AND FIRST RESULTS

When heating/cooling a surface in a sufficiently high vacuum, residual gas molecules will be desorbed/adsorbed at certain key temperatures. This means, the pressure time curve taken after beam impact can have a temperature dependent background slope that must be considered when calculating the desorption peak's amplitude. To account for that, a first degree polynomial is fitted to the relaxed ( $t > 4$  s) section of the curve. This fit is used as baseline for calculating the desorption peak's amplitude  $\Delta p$  (shown as a green line in Fig. 3).

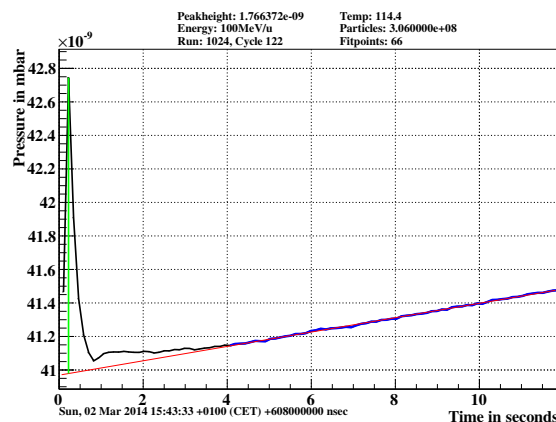


Figure 3: A typical measurement of the pressure evolution in the target region after beam impact. The desorption peak at the beginning is clearly visible. The thin red line constitutes the background fit, the bold green line shows height and position of the desorption peak. Only data points on the blue line have been used for calculating the background polynomial.

The number of desorbed particles per impacting beam ion  $\eta$  can be calculated using the ideal gas law:

$$\eta = \frac{N_{\text{des}}}{N_{\text{beam}}} = \frac{\Delta p \cdot V}{N_{\text{Beam}} k_B T},$$

where  $V$  is the diagnostic volume as shown in Fig. 2,  $k_B$  is Boltzmann's constant and  $T$  is the temperature. First results can be found in Fig. 4.

Two patterns can be identified: In the falling- $T$ -pattern,  $\eta$  rises steadily with  $T$ . The rising- $T$ -pattern features a large peak in the temperature range between 40 and 50 K. In this temperature range, a certain gas species gets released from the cold surfaces. A possible explanation of this peak is the target's inhomogeneous heating: The beam's energy deposition suddenly heats a fraction of the surface above a critical gas release temperature. With falling temperature and active coldhead, the deposited energy might dissipate easier into the coldhead because the temperature gradient between the desorbing surface and the inside of the target is greater. The region between  $T_{\min}$  and  $T \approx 45$  K is almost devoid of data.

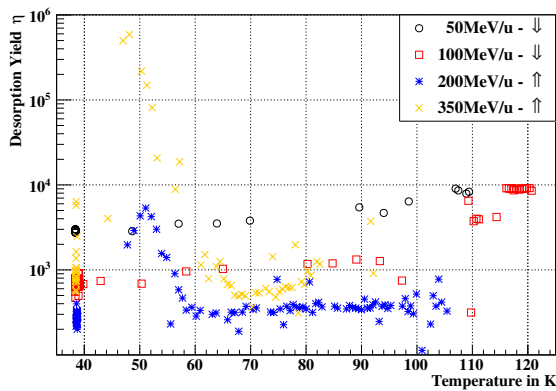


Figure 4: First result of the beamtime with  $U^{73+}$ . The arrow in the legend denotes a falling ( $\Downarrow$ ) or rising ( $\Uparrow$ ) temperature slope. Two distinct patterns, specific to this slope direction are clearly visible.

This is due to an unavoidable delay between deactivating the coldhead and resuming accelerator operation.

At  $T_{\min}$ , a lot of data can be taken in a small temperature range to probe the experiment's accuracy. It is remarkable, that  $\eta(T = T_{\min})$  spreads more with higher energies. Further analysis will show, if this is reproducible. However, the clearly visible patterns are already proof for the experiment's feasibility.

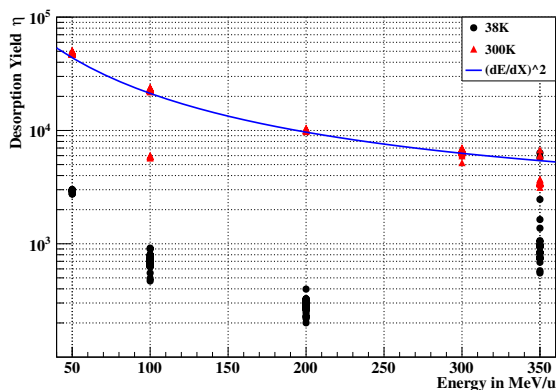


Figure 5: Comparison between the energy dependance of  $\eta$  at cryogenic and room temperature. At room temperature  $\eta \propto (dE/dx)^2$  is closely observed, but in the cryogenic environment,  $\eta$  again rises at higher energies.

Figure 5 shows the energy dependence of  $\eta$  at room temperature and at cryogenic temperatures. At room temperature the scaling of  $\eta$  with the electronic energy loss at the surface,

( $dE/dx$ ), known from [1], can be reproduced, proving the principally correct operation of the test setup. However at cryogenic temperatures,  $\eta$  is no longer found to scale with  $dE/dx$ . Instead, a different scaling seems to take over at higher energies.

Comparing  $\eta$  with the values from [3], a higher desorption yield is found. This is a consequence of the temperature distribution inside the chamber: In this experiment, the target is by far the coldest object in the setup while in [3], great care was taken to always keep the target at a higher temperature than the environment. This means, that the number of particles adsorbed to the target after cooldown is much higher in the present work, yielding in a higher amount of desorption.

## CONCLUSION AND OUTLOOK

An experimental test setup to systematically investigate heavy ion impact induced gas desorption from cryogenic surfaces has been built. The setup has been successfully taken into operation and first measurements with beam have been conducted. The fast pressure measurement allows to resolve ion beam impact desorption, even at the presence of comparably high static pressure or noise. An algorithm has been developed to determine the beam impact induced pressure rise, even if the vacuum system is not in equilibrium. The direction of the slope of the target temperature has been found to be very important for temperature evolution of  $\eta$ . The principally correct operation of the test setup could be shown by reproducing the known energy scaling at room temperature.

Further work will be done examining a stainless steel target and different ion species. In a second measurement campaign, a sapphire will be used instead of the ceramic insulating tile, enabling a higher thermal conductance. It will be investigated, if this conductance is of prime importance for the desorption yield.

## REFERENCES

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