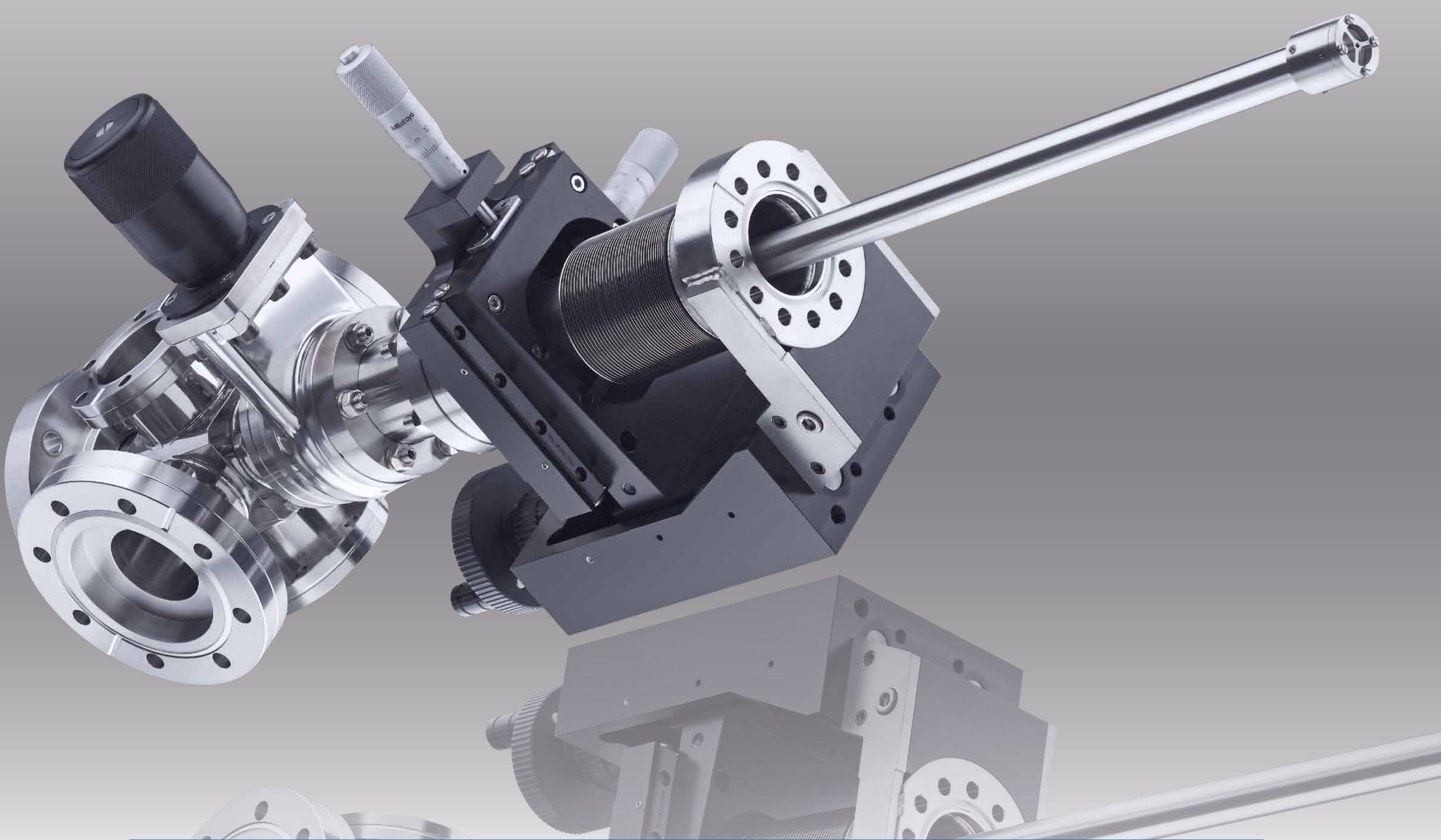
Components for Surface Analysis

RHD-NAP

Near Ambient Pressure RHEED System

Key Features
- RHEED at up to 1 mbar
- Works with any RHEED Gun
- Mini-RHEED Screen for Easy Alignment
- Compact Double Differential Pumping Stage

Applications
- PLD
- DC and RF Sputter Deposition
- ALD
- All Elevated Pressure Deposition Techniques



Motivation

Elevated Pressure Thin Film Deposition Techniques, like Pulsed Layer Deposition (PLD), Atomic Layer Deposition (ALD), DC and RF Sputter Deposition are of growing importance in research and development. The RHD-NAP system is an option for the SPECS RHEED gun RHD-30 or any other RHEED gun, which allows RHEED measurements to be made in systems with working pressures up to 1 mbar.

NAP-RHEED Overview

Two technical challenges must be addressed when attempting to perform RHEED measurements in high pressures. The first is to isolate the high voltage parts of the RHEED gun from excess pressure to prevent arcing and discharges. The second is to minimise the electron path through the high pressure region in order to reduce the inevitable inelastic scattering and intensity loss.

SPECS solves these problems through the use of (i) a double differential pumping stage (DDPS) (ii) a pumped beam-tube which allows the beam to travel in low pressure all the way to the sample and (iii) a special re-entrant RHEED screen on which the electron diffraction is imaged (Figure 1).

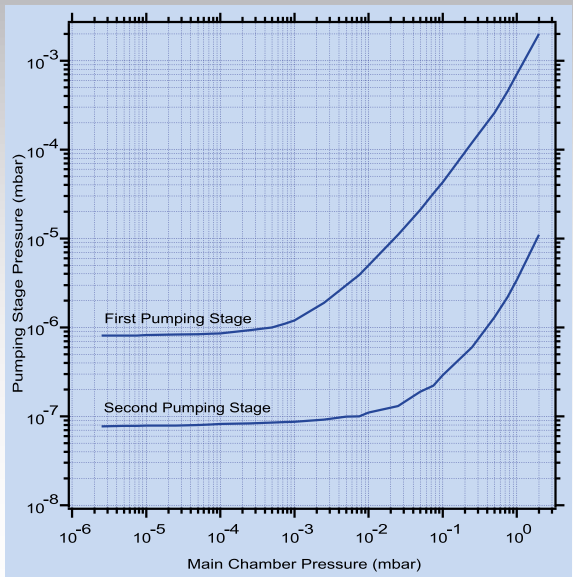


Figure 2: Pressures in first and second pumping stage as function of chamber pressure (non-baked)

On exiting the DDPS, the beam passes along the beam tube through an intermediate pressure zone of typically 10^{-3} mbar or less at which electron scattering is minimal. The end of the beam tube is closed with an aperture comprising two unique features – (i) a capillary aperture and (ii) a mini-RHEED screen which both contribute to making this system particularly simple to set up.

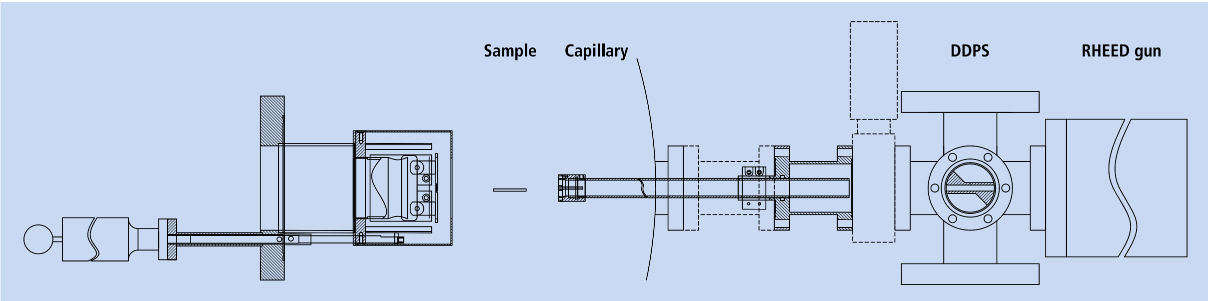


Figure 1: RHD-NAP Screen assembly (left) and RHD-NAP pumping stage assembly (right)

In the optimal configuration, the electron beam first travels from the RHEED gun in the lowest pressure region to the DDPS. The DDPS typically provides more than five orders of magnitude drop in pressure between the 1mbar region and the RHEED gun, ensuring that the gun operates safely and stably in pressures below 1 x 10^{-5} mbar.

The beam emerges through the capillary aperture into the high pressure region and is diffracted from the sample before striking the specially constructed RHEED screen. This screen is positioned close to the sample on a re-entrant tube, to minimise total electron path length through the high pressure region.

The distance between the end of the beam tube and the RHEED screen should ideally be kept as short as possible when operating at 1mbar. However 10cm is a perfectly usable distance at this pressure with 20cm considered as a maximum. Where the pressure to be used is lower, these distances can be increased considerably.

Features

Capillary Aperture

The RHD-NAP uniquely uses a capillary aperture to close the end of the beam tube. The use of a short length of capillary as the conductance restriction between the chambers of the RHD-NAP system, allows a lower conductance to be achieved than with a simple hole while the actual clear diameter of the aperture can be three times greater (1.5 mm). The increased aperture diameter greatly facilitates beam alignment and makes the electron beam less susceptible to blanking due to vibration of the beam tube than in competing systems.

Mini-RHEED Screen Capillary Aperture

In fact the capillary aperture is combined with a further unique feature which is a miniature phosphor screen. The phosphor faces the RHEED gun while the viewing side of the screen faces out into the chamber. This allows the beam to be focused on the mini-screen before the X and Y deflection controls of the RHEED gun are used to place the focused beam into the capillary aperture, allowing the beam to exit into the chamber. This dramatically simplifies alignment of the system.

Wide beam tube

The beam tube is designed with a large internal diameter to maximise gas conductance and minimise the pressure in this critical region of the electron path. Increased diameter also improves stiffness of the beam tube which is typically between 100 mm and 500 mm in length.

User-interchangeable beam tube ends

The beam tube is supplied as standard with the Mini RHEED Screen Capillary Aperture described above. This may however be exchanged (by the user) for a simpler version of the aperture without the integral RHEED screen which is recommended for applications where large samples are heated to very high temperatures and the radiated heat load on the beam tube is expected to be particularly high.

User-adjustable beam tube length

The beam tube is delivered with a user-specified length, typically 100 mm-500 mm long, but can be adjusted by the user by a further +/-25 mm to allow for fine-tuning while installing the system on the chamber or to accommodate alternative sample sizes or other configuration changes.

Double differential pumping stage

The Double Differential Pumping Stage (DDPS) part of the RHD-NAP system is unique in that it provides two stages of differential pumping, achieving over 5 orders of magnitude pressure drop, within the footprint of a standard 6-way DN40CF (2¾") cross.

This stage comprises a 6-way DN40CF (2¾") cross which is effectively divided diagonally into two chambers. One pump is connected to the RHEED gun while a second pump is connected to the beam tube. Separating these pumped regions is a tube in the middle of the cross, through which the beam passes, which provides the necessary conductance restriction between the two chambers.

Easy upgrade

The double-differential pump stage provides enough pressure drop between the main chamber and the RHEED gun to allow any RHEED gun to be used, whether or not it has its own internal differential pumping. As this differential pumping stage simply bolts on in front of the RHEED gun, no changes or modifications to the RHEED gun are required.

In case a RHEED gun is to be used that already has integral differential pumping, only a single further stage of differential pumping is required for near ambient pressure RHEED operation. This can be achieved by substituting a standard 4-way DN40CF (2 ¾") cross for the DDPS. As these two stages (single and double) are the same length, no overall change to the system length results.

Figure 3: RHD-NAP screen assembly

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Compact RHEED screen

The RHEED screen in the RHD-NAP system is of a re-entrant design and mounted on a DN100CF (6") flange. With a suitable adaptor it can therefore also be used on a DN150CF (8") or larger flange size. The screen is fully enclosed in a stainless steel shield with a double-bladed shutter to protect the phosphor as far as possible from the harsh environment typical of high pressure systems. The whole shutter mechanism can operate within the diameter of a standard DN100CF (6") port. The insertion length of the screen into the chamber is fixed and is specified by the customer.

Option Guide

Pressure

For operation above 1 x 10^{-2} mbar two stages of differential pumping are required.
This can be achieved with either

- DDPS and an un-pumped RHEED gun

Or

- Single differential pumping stage (4-way cross) with a differentially pumped RHEED gun.

Screen

The special re-entrant RHEED screen is recommended for operation above 1 x 10^{-2} mbar to help to minimise the electron path length.

At pressures below 1 x 10^{-2} mbar the increased electron path length which is possible without excessive scattering means that a standard port-mounted RHEED screen can be used. A camera for recording the RHEED images can be mounted on the RHEED screen/shutter flange.

Other

An X, Y, Z stage is recommended where a port, angled at grazing incidence to the sample, is already provided.

A gate valve can be inserted between the beam tube and differential pumping stage which allows the RHEED gun filament to be exchanged without venting the chamber. It also permits particularly high pressure operations (>1 mbar) such as annealing to be carried out in the chamber without exposing the RHEED gun to these gases.

A special support stand is available which will carry the weight of the pumps and RHEED gun when mounted on an X, Y, and Z stage and still allow X, Y, Z movement. The stand has pre-settable weight compensation up to 50 kg.

Pressure	DP in RHEED gun only	Single DP stage	Double DP stage
<1 mbar	n/a	n/a	✓
1 x <5 x 10^{-2} mbar	n/a	n/a	✓
<10^{-2} mbar	n/a	✓	n/n
<10^{-3} mbar	✓	n/n	n/n
<10^{-5} mbar	n/n	n/n	n/n

Pressure	Special Screen	Standard Screen
<1 mbar	✓	n/a
1 x <5 x 10^{-2} mbar	n/n	✓
<10^{-2} mbar	n/n	✓
<10^{-3} mbar	n/n	✓
<10^{-5} mbar	n/n	✓

DP = Differential Pumping, n/a = not applicable, n/n = not necessary

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