A CLEANING FACILITY TO PREPARE PARTICLE FREE UHV-COMPONENTS

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Abstract

To prepare UHV components both hydrocarbon and particle free a new cleaning facility has been installed at DESY/Hamburg. Both requirements are important for accelerators using superconducting accelerating structures of high gradients as well as for synchrotron radiation beamlines connected to an accelerator using optical components like mirrors for the photon beam transport. The cleaning facility is located inside a clean room which fulfils class 10.000 and partly class 100 specification†. Following standard UHV-cleaning the final cleaning process consists of a fine degreasing of the components in an ultrasonic bath and rinsing with ultra pure water‡. Thereafter the components are dried using up to 110° C hot filtered air or nitrogen gas according to clean room class 100 requirements. Vacuum chambers of up to 4.8 m length can be handled. Small components are cleaned using a lab washer, which is loaded from outside the clean room. A small assembly area equipped with an oil free pump station, leak detector and residual gas analyser completes the facility.

INTRODUCTION

Within the framework of the proposed superconducting e^+e^- linear collider TESLA with integrated X-ray laser laboratory [1] the TESLA test facility (TTF) has been set up at DESY/Hamburg. It comprises the complete infrastructure for treatment, assembly and test of superconducting accelerating structures, so called cavities. In addition a 250 m long superconducting linear accelerator serves for development and test of machine components and produces soft X-rays by self amplification of spontaneous emission from a free electron laser (FEL).

During the past decade the maximum achievable gradient for superconducting cavities has been improved substantially. One major contribution to this improvement is the consequent treatment and preparation of the cavities in clean rooms with procedures similar to standards in semiconductor industry [2]. Dust particles can act as field emitters and thus limit the performance of the superconducting cavities. Therefore particles on the inner surface of the cavities need to be absolutely avoided.

The few K cold cavities are an integral part of the accelerator beam pipe. Thus the risk to contaminate the superconducting cavities with particles from the warm vacuum sections during assembly and operation must be minimized. As a consequence all vacuum components for the superconducting TTF linac are prepared using procedures similar to those applied to the superconducting cavities.

Key components in synchrotron radiation (SR) beamlines are mirrors which are used to deflect and tailor the photon beam for experimental needs. In this process there is a strong interaction with the beam. Hydrocarbons in the residual gas surrounding the mirror interact with the SR beam. This will create SR cracked carbon deposition on the mirror surface, changing drastically the optical properties of the mirror. To avoid this, the hydrocarbon residual gas pressure of cleaned UHV parts has to be in the order of 10^{-3} of the achieved total pressure.

SR beamlines on free electron lasers as at the TTF linac or third generation SR sources like storage rings will have a large output of coherent photons. Especially in the X-ray regime dust on the mirrors will destroy partly the coherence properties of the beam. To which extent particles on reflecting surfaces have to be avoided is still under investigation.

So far all vacuum components for the superconducting TTF linac were prepared using the same clean room facilities as for the superconducting cavities. In order to separate the extremely critical treatment of the cavities including assembly in clean room class 10 areas and the cleaning and preassembly of vacuum components for the warm vacuum sections a new cleaning facility was built. It combines standard cleaning procedures [3], [4] according to environmental concerns with state of the art clean room technology and procedures developed for the treatment of superconducting cavities.

LAYOUT

The new cleaning facility has been constructed in an existing hall using an in-house clean room system comprising 90 m^2. About 22 m^2 of this area fulfils class 10.000 and 25 m^2 class 100 specifications. In addition the facility has a preparation and storage area and special locks from the preparation to the clean room area for personal and material to enter. An overview of the whole facility is given in Fig. 1.

Two ultrasonic (US) baths are available in the class 10.000 area – one bath for chambers up to 4.8 m length and 280 mm diameter, the other one for more compact components (up to 2.3 m length with max. 550 mm diameter). The US sound penetrates the baths from two sides under an angle of 45°. The baths are filled with ultra pure water and an added detergent according to the material to be cleaned. The baths can be heated and stabilized at up to 65° C. In order to keep the water clean,

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† clean room classification according US Fed. Standard 209E
‡ specifications according to semiconductor industry

it is continuously pumped in a circle through particulate filters at a rate of 1000 l/h.

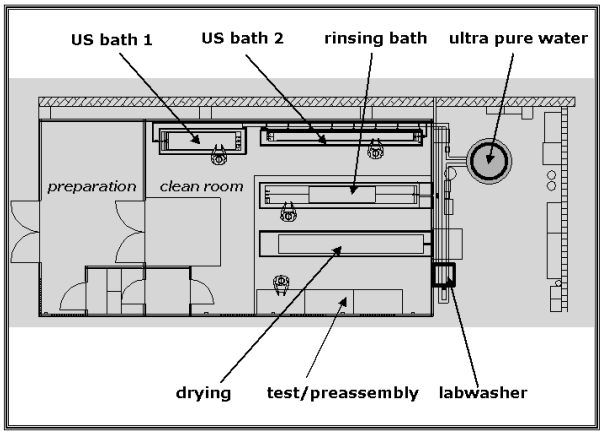

Figure 1: Floor plan of the cleaning facility.

Rinsing is done in a separate bath (5.0×0.55×0.55 m^3) located in the class 100 area. Ultra pure water is continuously flushed along the bath at a rate of about 1.500 litres per hour. Resistivity sensors are located at the overflow of the bath to monitor and control the change of the resistivity during the rinsing process.

The experience from the cleaning facility for the TESLA cavities showed, that rinsing should be done till a resistivity of 12 MΩcm is reached. It has been shown experimentally that at this value no remaining particles or drying spots could be found on cleaned objects [5]. This usually takes less than 30 min at the infrastructure used for the cavities. However when applying this procedure to the new rinsing bath a much longer time is needed to reach 12 MΩcm resistivity. This behaviour can be explained by the different bath geometries with a much larger water surface in contact with the surrounding air for the new facility. The resistivity of the water is strongly influenced by ions related to CO_2 impact from air. To counteract this effect nitrogen is continuously flushed into the water to act as a buffer and to replace the CO_2 in and on top of the water. This is supported by a gas tight cover on top of the rinsing bath. Nevertheless whenever the rinsing bath is loaded or unloaded a significant amount of CO_2 is introduced. Therefore it is difficult to transfer experiences from similar procedures [5]. Further studies to define reliable parameters for successful rinsing are ongoing.

After rinsing the pieces are loaded into a dryer of the same inner dimensions as the rinsing bath also located in the class 100 area. Up to 110° C hot filtered air according to class 100 specification is blown through longitudinally to dry the components. The air flow (~10.000 m^3/h) is operated in a nearly closed loop with 10% air exchange from the clean room. Alternatively vacuum chambers could be flanged to a gas line to blow ultra pure nitrogen gas through the inside while hot air is circulating at the outside.

An industrial lab washer operated with ultra pure water and appropriate detergent is used to treat small components. While loading of this machine with parts is done from outside of the clean room, the cleaned and dried components are unloaded in the class 100 area. Various programs for adequate cleaning of the different materials are available.

Ultra pure water of 18 MΩcm is produced at a rate of 500 l/h next to the clean room. As the consumption during operation of the facility is substantially higher, usually up to 4.000 l are produced and stored in a tank over night, where the water can be heated up to 50° C.

A particle counter as well as an oil free pump station equipped with leak detector and residual gas analyser allows testing of cleaned components with respect to particles, UHV cleanliness and UHV leak tightness. A table for preassembly and wrapping of the components completes the facility. Fig. 2 shows a photograph of the inside of the cleaning facility.

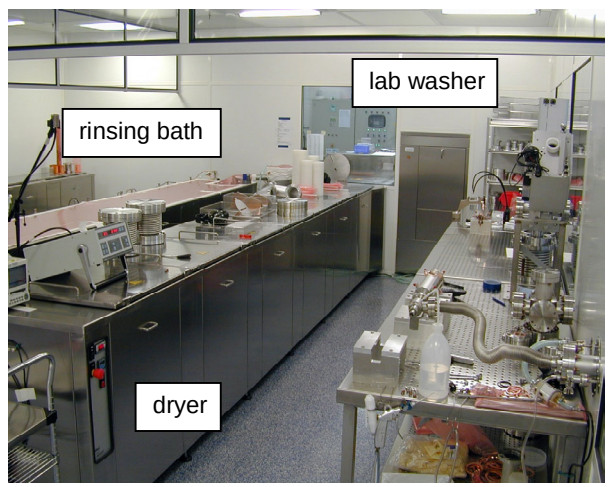

Figure 2: Inside the cleaning facility: rinsing bath and dryer on the left, access to the dish washer in the middle and preassembly bench on the right.

PROCESSES

All components to be made particle free are usually precleaned using standard UHV cleaning procedures for degreasing e.g. high pressure cleaning systems or lab washers using standard detergents. The following cleaning procedure in the clean room is shown schematically in Fig. 3.

Standard Cleaning Process

The following procedure is applied to stainless steel and copper components when the application of these parts does not care for surface oxidation.

The cleaning process starts with a fine degreasing of the components in the US bath using ultra pure water with 1% Tickopur R33 [6] at 50°C. At least for copper components this is followed by 1.5% Elma Clean 115C [7] at 65°C to remove oxide layers. Typical process time

is 18 min which consists of alternating 5 min long periods with and 1 min without US operation. The circulation and filtering of the bath is all the time running.

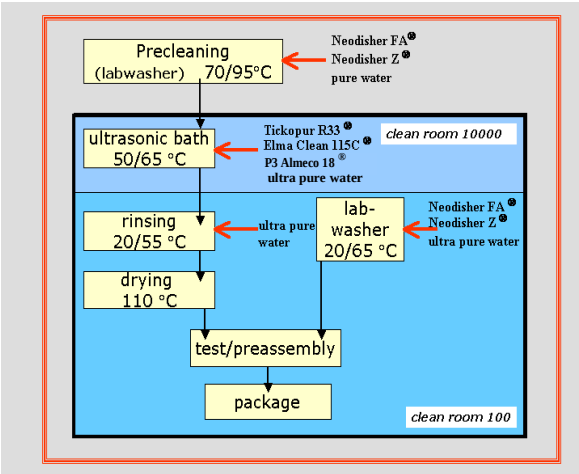

Figure 3: Process chart of the cleaning process.

After manual ultra pure water rinsing using a hand spray above the US bath, the component is transferred to the rinsing bath. Using the nitrogen buffer and minimizing the filling time of the bath, the rinsing in ultra pure water at a temperature of 50°C with a flow rate of 1.500 l/h takes about 30 min. The water resistivity is permanently monitored. The rinsing process is automatically finished when reaching 12 MΩcm. As explained above, experience [5] showed that at this value the cleaned parts are particle free.

The following drying process with air lasts about 1 h at 110°C. After cooling down the components are leak checked and a residual gas spectrum is taken. Fig. 4 shows a typical residual gas spectrum showing the cleanliness of a mirror chamber. The sum of the masses above mass 45 is less than 10^{-3} of the total pressure. This complies to the vacuum specifications of SR beamline components [8].

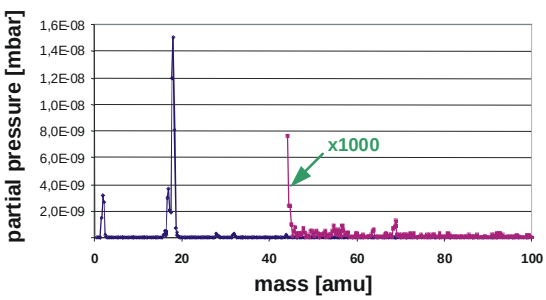

Figure 4: Residual gas spectrum of a cleaned mirror chamber. The intensities for masses larger 44 are enlarged by a factor of 1000.

Alternatively for small parts a lab washer is used. There are special washing programs for the different materials. As detergents neodisher® FA and neodisher® Z [9] are used. Drying in the labwasher is also possible. Typical process times are in the order of 1.5 h. Testing of these parts is done as previously described.

Finally the components are vented with dry nitrogen from a dewar vessel or ultra pure gas line, the flanges are closed off using plastic flanges (PTFE), and the complete units are wrapped and sealed in two layers of antistatic plastic foil for storage and transport to the final assembly place.

Cleaning of critical Cu and Cu coated Components

Using the superconducting TTF linac as driving source of a free electron laser, it turned out that a high electrical conductivity of the beam pipe surfaces is vital for the operation of this machine with very short bunches. Therefore the beampipe surface has to be made from Cu with ideally no oxide layer on top. Thus cleaning of Cu surfaces becomes crucial as the thickness of the oxide layer has to stay at values below 40 nm.

At present the following cleaning procedure gives the best results in showing only slight visible oxide layers:

- Precleaning using standard procedures.
- US cleaning with 1 % Tickopur R33 at 50°C for 3 times 5 min with and 1 min intervals without US operation followed by hand rinsing with ultra pure water.
- US cleaning with 1.5% Elma Clean 115C at 65°C for 3 times 5 min with and 1 min intervals without US operation followed by hand rinsing with ultra pure water.
- Rinsing at 1.500 l/h at 20°C for 30 min.
- Drying with hot air (60°C) for at least 30 min.

Important is the Elma Clean step which reduces the visible oxide layer totally with the following cold (20°C) rinsing step.

First measurements using the galvanostatic reduction method and x-ray photoelectron spectroscopy indicate, that the oxide layers caused by the procedures described above are well below 10 nm [10]. Further studies on the influence of different cleaning procedures on the oxide layer thickness are ongoing.

Cleaning of critical Al Components

The vacuum chambers for the undulators of the free electron laser of the superconducting TTF linac are made from aluminium with an inner bore of 10 mm. Also for these components thin oxide layers are required.

The cleaning procedure applied so far follows the experience at the Advanced Photon Source at Argonne National Laboratory [4]:

- Precleaning using standard procedures.
- US cleaning with 2 % P3 Almeco 18 [11] at 65°C for 6 times 5 min with and 1 min intervals without US operation followed by manual rinsing with ultra pure water.
- Rinsing at 1.500 l/h at 20°C for a few minutes.

- Drying with nitrogen inside the chambers and hot air (50°C) outside for at least 1h.

CONCLUSION

A cleaning facility to prepare particle free UHV components for superconducting accelerators and synchrotron radiation beamlines has been set up and is now under operation at DESY. The facility gives access to all needed cleaning procedures. First cleaning results for stainless steel, copper and aluminium components show satisfying results. The criteria for a standard rinsing procedure as well as the cleaning of oxide layer critical components needs further investigations.

ACKNOWLEDGEMENT

The authors want to thank D. Ahrendt, T. Hans, K. Harries, M. Schwalger, and E. Untiedt for their active support of the project at DESY. We want also to thank Dr. C. Jung from Elma for his technical advice.

REFERENCES

[1] TESLA TDR, TESLA-01-23 (2001).
[2] D. Reschke, Final cleaning and assembly; Proceedings of the tenth Workshop on RF Superconductivity, Tsukuba, 2001, http://conference.kek.jp/srf2001/.
[3] Y. T. Sasaki, J. Vac. Sci. Technol. A 9 (1991) 2025.
[4] R. A. Rosenberg, M. W. McDowell and J. R. Noonan, J. Vac. Sci. Technol. A 12 (1994) 1755.
[5] A. Matheisen, DESY, private communication (2003).
[6] Dr. H. Stamm, Chemische Fabrik GmbH, Berlin.
[7] ELMA – Hans Schmidtbauer GmbH, Singen.
[8] Vacuum Guidelines for Experiments at the VUV FEL, HASYLAB vacuum group, DESY (2001).
[9] Chemische Fabrik DR. WEIGERT GmbH & Co. KG, Hamburg.
[10] Universität Düsseldorf, Institut für physikalische Chemie und Elektrochemie 2, Arbeitsgruppe Prof. Strehblow, private communication (2003).
[11] Henkel KGaA, Düsseldorf.