INTRODUCING THE VERTICAL HIGH-TEMPERATURE UHV FURNACE OF THE S-DALINAC FOR FUTURE CAVITY MATERIAL STUDIES

R. Grewe[1,#], L. Alff[1], M. Arnold[1], J. Conrad[1], S. Flege[1], F. Hug[2], M. Major[1], N. Pietralla[1]
[1]Institut für Kernphysik, TU Darmstadt, Germany [2]Institut für Kernphysik, JGU Mainz, Germany

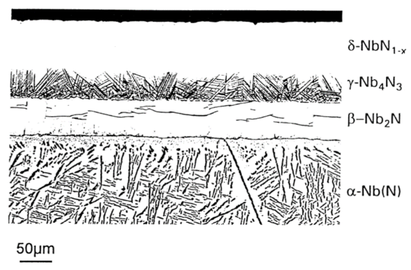
TECHNISCHE UNIVERSITÄT DARMSTADT

THPB066

Abstract

Since 2005 the Institute for Nuclear Physics in Darmstadt operates a high temperature UHV furnace for temperatures of up to 1750°C. It has been used several times for hydrogen bake-out of the SRF cavities of the S-DALINAC with proven success. In 2013, studies at FNAL have shown that cavities treated with nitrogen reached an up to four times higher q-factor. The cavities are exposed to N_2 at 850°C at the end of the H_2 bake-out. A thin layer of normal conducting (nc) hexagonal niobium nitride (NbN) forms at the surface which is removed by electropolishing while the higher quality factors are attributed to the N_2 diffusion into the bulk Nb. At temperatures from 1300°C to 1700°C a thin layer of the superconducting (sc) cubic phase of NbN can be observed, e.g. δ-phase NbN, which has a higher critical field and higher critical temperature and thus is very interesting for applications for SRF cavities. The UHV furnace has been prepared for future treatments of Nb samples and cavities in an N_2 atmosphere at high temperatures for research on cubic NbN. The material properties of the samples will be analyzed at the ATFT group at the Department for Material Sciences of TU Darmstadt.

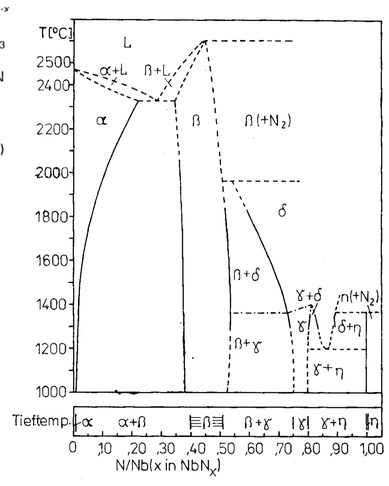
Niobium Nitride



M. Joguet *et al.*, *J. Alloys Compd.*, vol. 269, p.233, 1998.

	Phase	T_c in K
Nb-N	α	9.2
Nb_4N_3	γ	12.2-7.8
NbN	**δ**	**16.5**
Nb_2N	β	9.5-<1.2

W. Martienssen, H. Warlimont (Eds.), *Handbook of Condensed Matter and Materials Data*, 2005

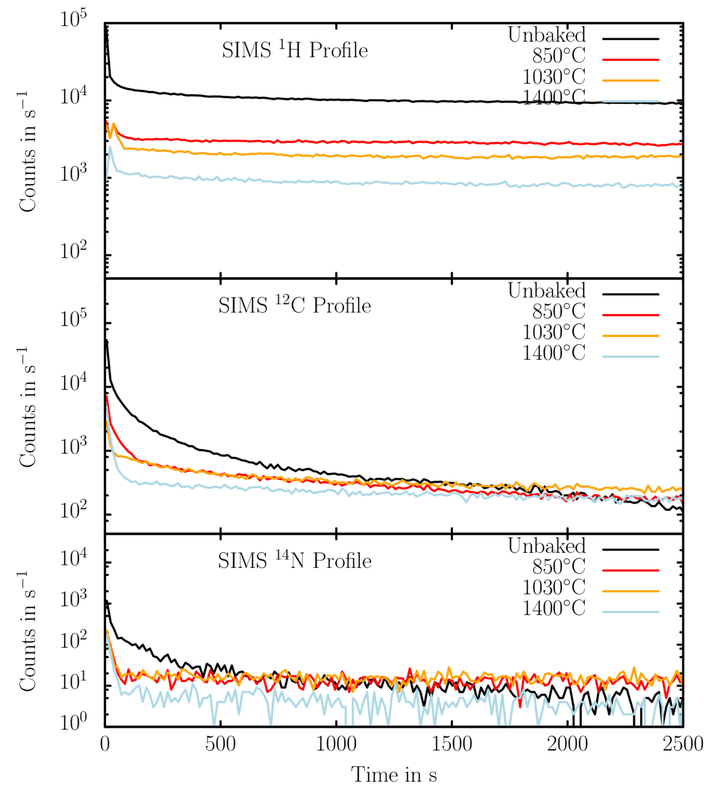


G. Brauer, W. Kern, *Z. anorg. allg. Chem.*, vol. 507, 1983

Samples

- samples size of 5x5 mm²
- thickness of 2 mm
- RRR 300
- 150 µm BCP
- Water jet cutted

SIMS ANALYSIS

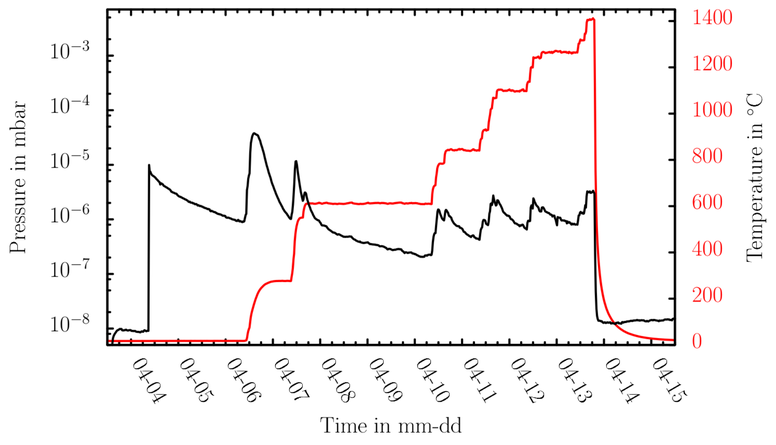


Secondary ion mass spectrometry (SIMS) of samples processed at different temperatures compared to an unprocessed sample.

- Impurities are pushed out of the surface.
- Further analysis can be done with X-ray diffraction and scanning electron microscopy.

Analysis of surface properties is done at the department of Materials Science at TU Darmstadt.

Sample Processing

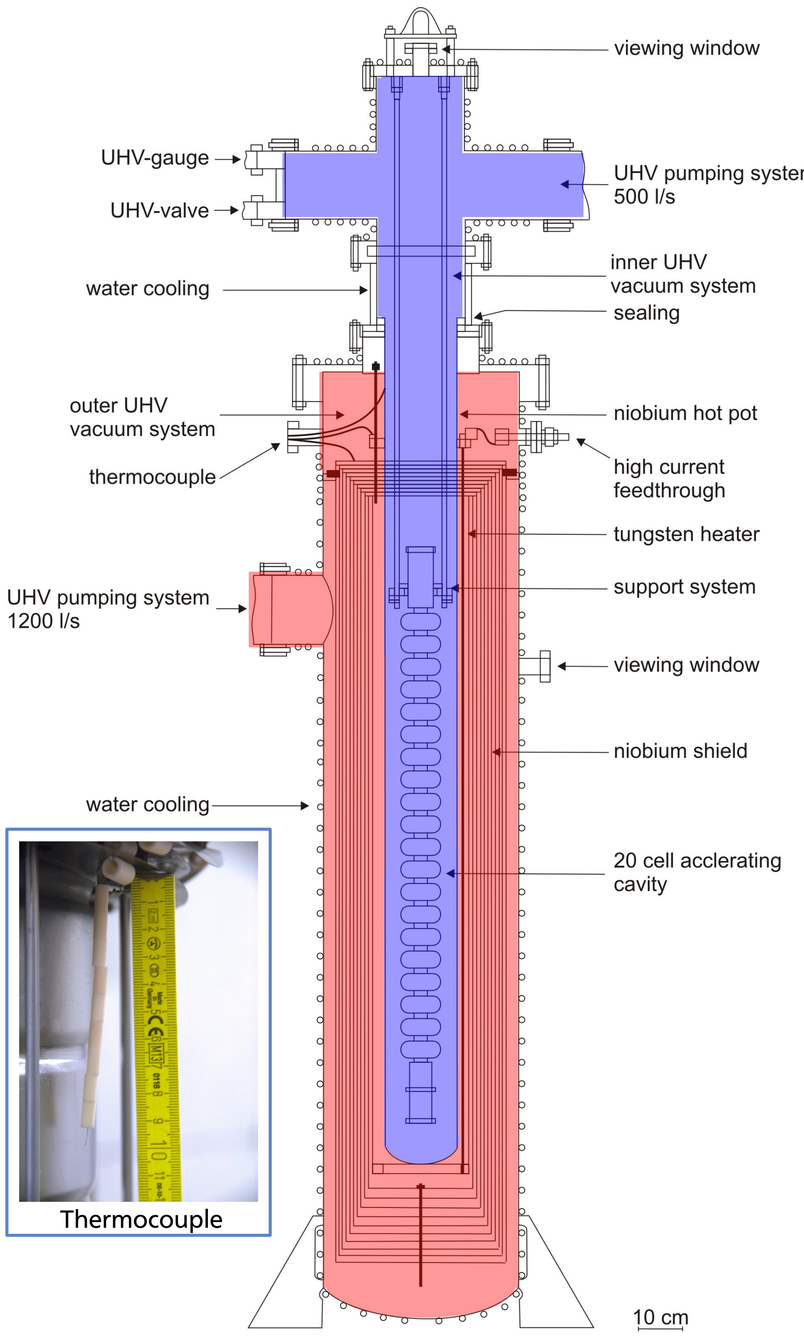


Example of a sample processing w/o N_2 at a temperature of 1400°C.

- First samples are processed without nitrogen.
- Temperature is raised slowly to keep the hot-pot pressure low.
- The desired temperature is kept for 4 hours.

These samples are used for comparison against nitrogen processed samples. Impurities induced by the furnace itself can be identified.

UHV-Furnace



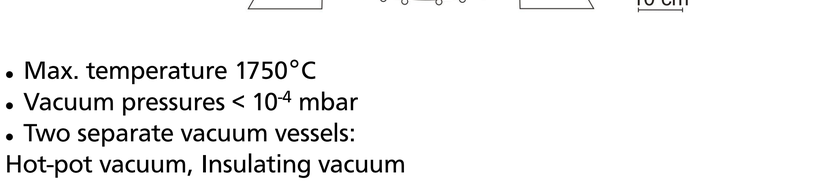
Thermocouple

- Max. temperature 1750°C
- Vacuum pressures < 10^{-4} mbar
- Two separate vacuum vessels:

Hot-pot vacuum, Insulating vacuum

- Everything inside the hot-zone of the hot-pot is made of niobium
- Materials used outside of the hot-pot: Al_2O_3, Niobium, Tungsten

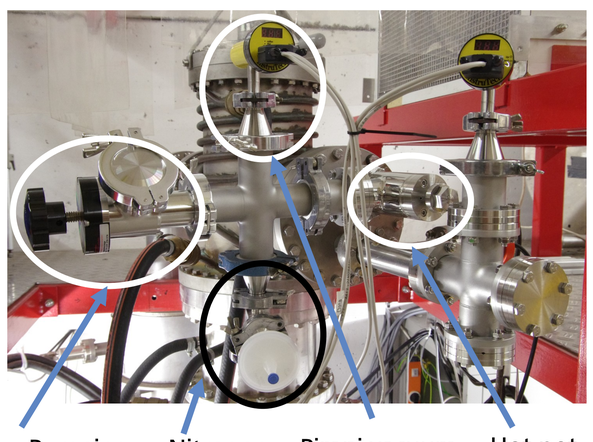
- 1983 built at University of Wuppertal
- 2002 moved to TU Darmstadt
- Since 2005 used for cavity bake-out at 850°C with proven success
- Technical constrains limited temperature to 850°C
- Beginning in 2015 upgrade for temperatures up to 1750°C



Niobium hot-pot

Power supply and furnace

Nitrogen Inlet



- Pumping valve
- Nitrogen inlet
- Pirani vacuum gauge
- Hot-pot valve

An Nitrogen inlet has been designed with of the shelf components. It will be used to inject a specific amount of N_2 into the furnace.

Conclusion and Outlook

- First samples have been processed to identify impurities induced by the furnace
- Sample processing with nitrogen at different temperatures, pressures and number of injections
- Analysis of samples to find a good process for the forming of δ-phase NbN
- Two 3 GHz single-cell cavities will be processed in 2018
- Quality factor measurements in the vertical bath cryostat at the S-DALINAC before and after the treatment
- soft chemical treatment of samples and cavities possible at the chemical compartment of the S-DALINAC

Bundesministerium für Bildung und Forschung

*Work supported by the Federal Ministry of Education and Research through grant No. 05H15RDRBA.
#rgrewe@ikp.tu-darmstadt.de

Institut für Kernphysik S-DALINAC Technische Universität Darmstadt