LOW ENERGY MUON SPIN ROTATION AND POINT CONTACT TUNNELING APPLIED TO NIOBIUM FILMS FOR SRF CAVITIES

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Abstract

Muon spin rotation (µSR) and point contact tunneling (PCT) are used since several years for bulk niobium studies. Here we present studies on niobium thin film samples of different deposition techniques (diode, magnetron and HIPIMS) and compare the results with RF measurements and bulk niobium results. It is consistently found from muSR and RF measurements that HIPIMS can be used to produce thin films of high RRR. Hints for magnetism are especially found on the HIPIMS samples. These could possibly contribute to the field dependent losses of superconducting cavities, which are strongly pronounced on niobium on copper cavities.

Low energy muon spin rotation(LE-µSR)

LE-µSR enables the measurement of the magnetic field inside a sample as a function of depth (Fig 1). An external magnetic field with a value below H_c can be applied to probe the London penetration depth of a superconductors. If no external magnetic field is applied LE-µSR can be used as a local probe for surface magnetism (Fig. 2) .

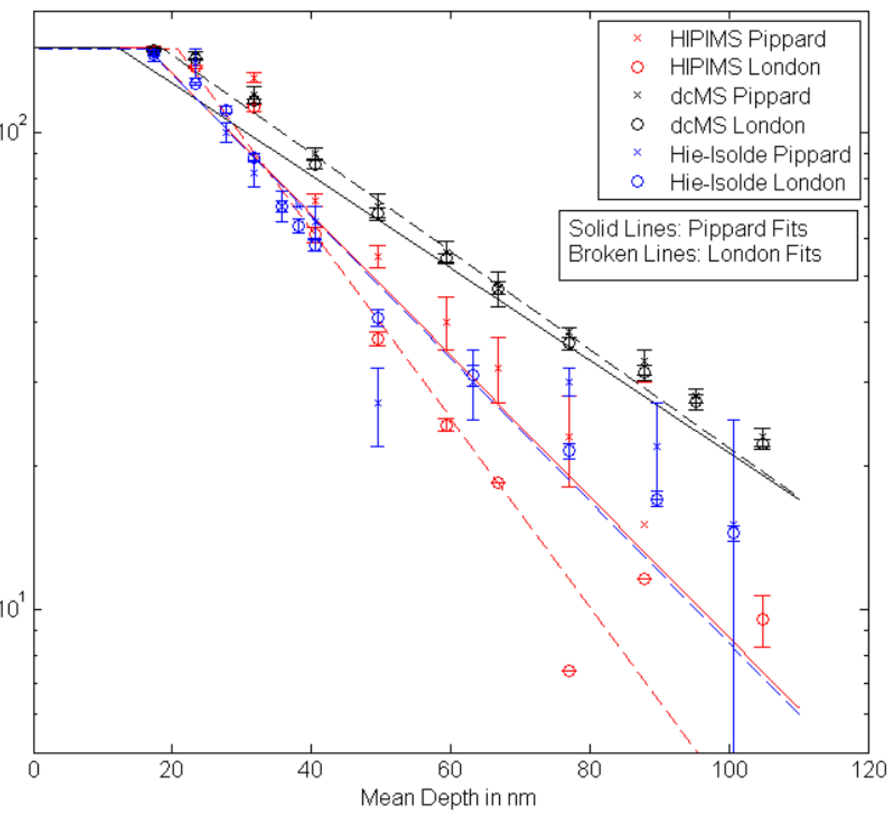

*Figure 1: London Penetration Depth λ of three Nb/Cu samples. This measurement shows that **HIPIMS enables to produce films with low λ and therefore high purity (RRR).** Two fit models were used to obtain each data point. A simple Gaussian model based on London theory, and a numerical time-domain model based on the non-local Pippard/BCS model [A Suter et al. Phys. Rev. B, 72:024506, 2005]. The global Pippard fits have been performed to the whole raw data set. For the HIE-Isolde sample this fit did not converge. The deposition here is done in several runs with breaks in between. This might have resulted in an inhomogeneous penetration profile inconsistent with one set of global fit parameters.*

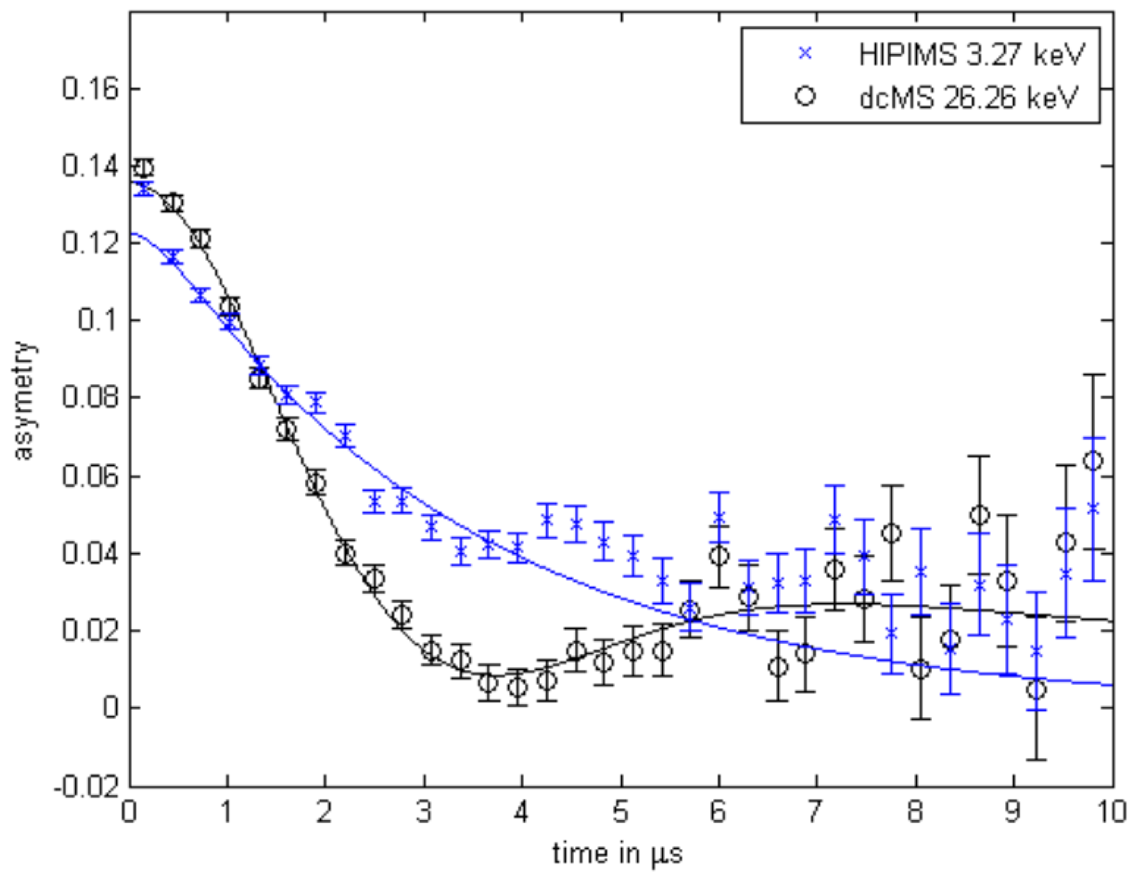

Figure 2: Zero field measurements. The muon spin ensemble depolarization originates from the dephasing of the muon spin in the random dipole field distribution of the nuclear spins . If no magnetization and no muon diffusion is present the asymmetry function shows a dip and its value for long times is one third of its maximum [R. S. Hayano et al. Phys. Rev. B, 20(3):850, 1979]. If there is dynamics involved in the muon time evolution the asymmetry function will deviate from this form; an exponential decay function indicating very strong dynamics . **The HIPIMS sample shows strong signs of magnetization unlike the dcMS.**

Point Contact Tunneling (PCT)

PCT can be used to measure the density of states (DOS) of superconductors. Our Nb/Cu samples show broadened DOS, a finite zero bias conductance, areas with zero bias conductance peaks and areas with low energy gap values (Fig. 3). These findings are consistent with inelastic quasiparticle scattering a magnetic impurities. Areas of low energy gap values will create hot spots and a field dependent surface resistance/Q-slope (Fig. 4)

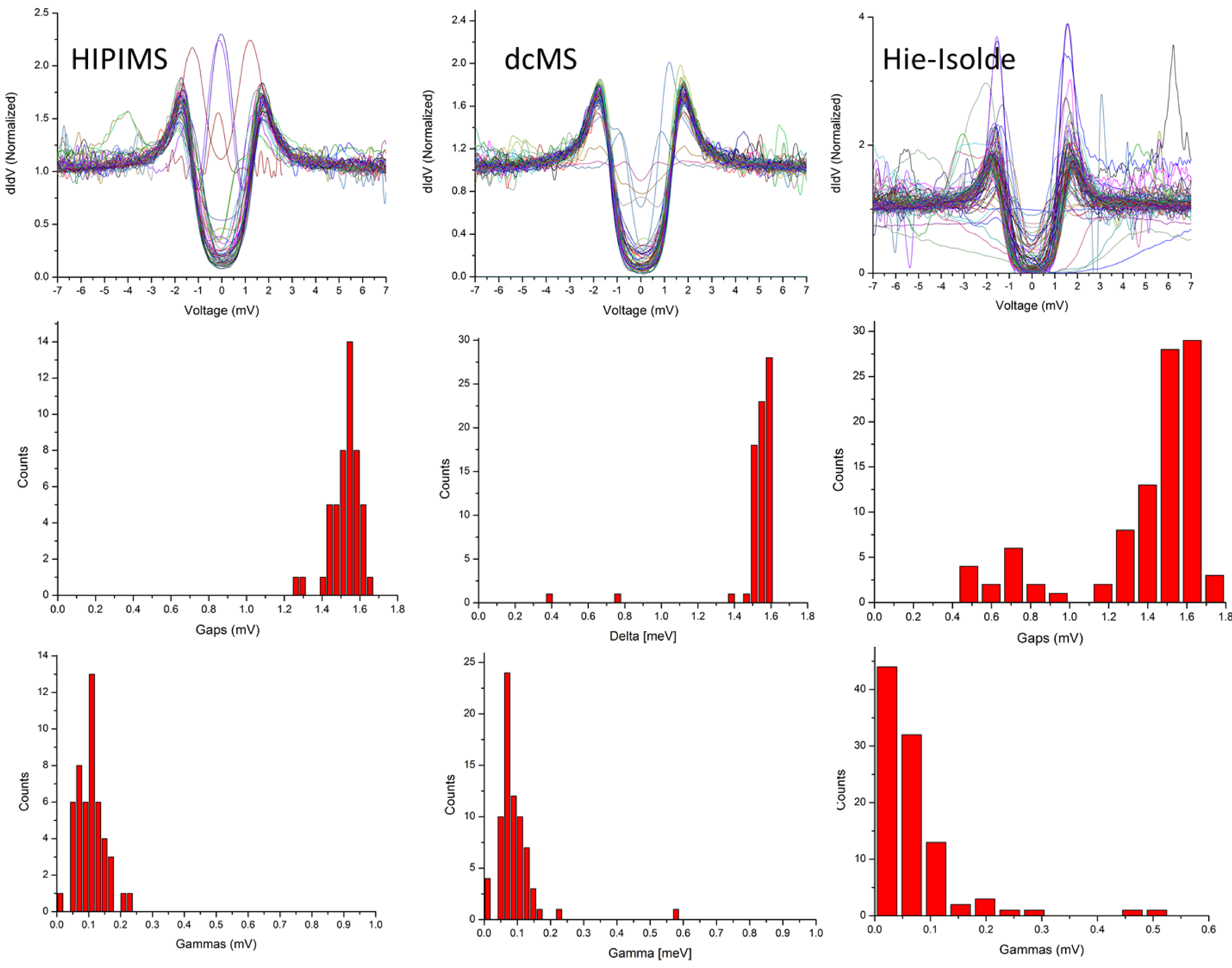

Figure 3: Tunneling spectra of about 80 junctions each for three Nb/Cu samples (top). Corresponding gap values (middle) and phenomenological quasiparticle lifetime broadening parameter (bottom) extracted from fits to the Blonder-Tinkham-Klapwijk (BTK) model [C. Dynes et al. Phys. Rev. Lett., 41:1509, 1978, G. E. Blonder, Phys. Rev. B, 25:4515, 1982]

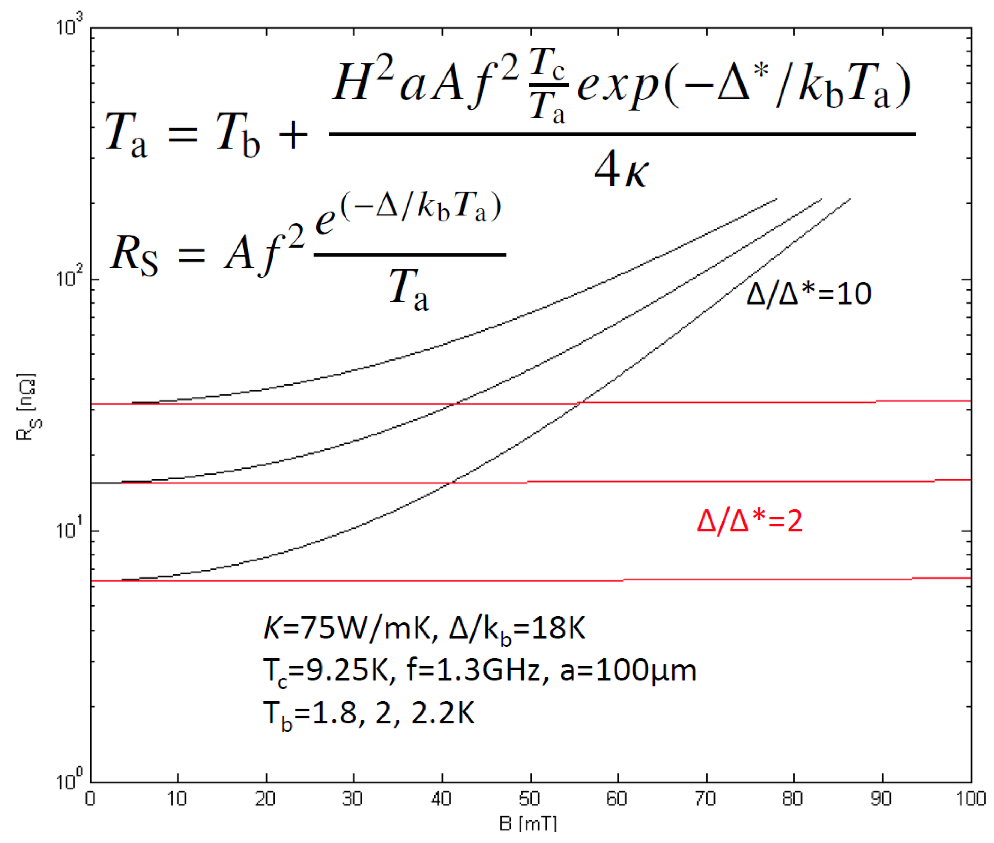

Figure 4: Surface resistance of the area around a defect with suppressed gap value as a function of applied magnetic field. The model is inspired by the model for thermal breakdown from Padamsee et al. [RF superconductivity for accelerators. Wiley, Weinheim, 2. edition, 2008] (see Fig.5). It assumes a defect with lowered gap value of radius a. From the heat flow the surface resistance from the area around the defect is calculated by solving the equations displayed above numerically.

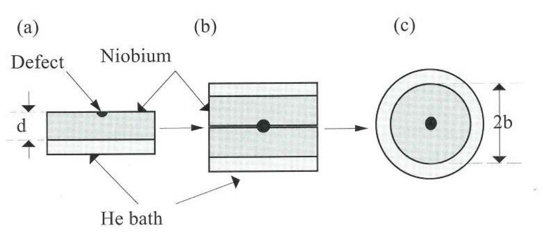

Figure 5: The geometry of our model is inspired by Padamsee et al. We use the idea of modeling a hemispherical defect by heat source inside a sphere.

Conclusion

It has been shown how sub gap values as measured with PCT can have a direct influence on the Q-slope of superconducting cavities by creating hot spots. For bulk niobium it has been shown that sub gaps states can be suppressed by high temperature baking [P. Dhakal et al. *PRSTAB*, 16:042001, 2013]. For Nb/Cu cavities such a treatment is not possible due to the lower melting temperature of copper. The origin of the Q-slope of Nb/Cu might be related to magnetic nanoparticles in the oxide layer and possibly between grain boundaries. It is known from literature that magnetic impurities can severely decrease the energy gap of superconductors [Reif et al. Phys. Rev. Lett., 9(7):315, 1962]. The presence of magnetic impurities is supported here for the HIPIMS sample by LE-µSR zero field measurements.

Acknowledgement

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