TP, 25−Oct−2001

Run 2001, Mu/μ fractions in solid gases

Measure energy dependence of μ^+ fractions in 1000 nm thick layers of s−Ne, s−Ar, s−Kr (s−Xe) s−N_2 deposited on a Ag/Al sample holder plate. The measurement of Mu in s−Xe and s−N_2 is difficult due to the large relaxation rates of 13 μs^{-1} and 7 μs^{-1} , respectively, mainly caused by the nuclear moments of Xe and N. In Run12 these relaxation rates were measured at T = 30 K (s−Xe) and T = 13.5 K (s−N_2). For s−Ar, it was measured to 0.5 μs^{-1} at 10 K.

Measure this time s−Ne and s−Kr for the first time (s−Kr of Run12 was a "quick" shot only). Test B−field dependence at different implantation energies, annealing of layers, different growing conditions. See folder *"Mu/μ^+ in thin solid gas layers"* for more information. Papers on bulk measurements are attached there.

Run 12 results:

- The thermal Mu/ μ^+ fractions **do not agree** with the bulk values for s−Ar and s−N_2 . "Our" fractions appear to correspond with the **prompt** fraction measured in the bulk. This implies that we do not observe a delayed Mu formation in our s−Ar and s−N_2 layers. Delayed Mu formation is attributed to the convergence of spur electrons with the muon. From bulk measurements the distance between the last spur electrons and the stopping site of the muon is estimated to 50−100 nm for s−Ar and s−N_2 and of the order of a few nm for s−Xe and SiO_2 .
- **Energy dependence at 100G for s−Xe, SiO_2 , no energy dependence for s−Ar and s−N_2** . For quartz glass and s−Xe, the thermal μ^+ fraction decreases with increasing energy to reach at implantation energies > 10 keV the bulk values, approximately. For s−Ar and s−N_2 , the μ^+ fraction is nearly constant at 100 G field and implantation energies from 1 to 20 keV. The interpretation could be the following: in s−Xe, SiO_2 , the delayed Mu formation increases with increasing energy, because the number of spur electons is increasing, either. Since the distance between electrons and the muon is short the recombination can take place even in the case of a very porous and grainy layer structure (what is expected for our growth conditions). In s−Ar and s−N_2 , the large distance between electrons and the muon may suppress the delayed Mu formation due to trapping of electrons at the grain boundaries. If this is true, an annealed layer should show an energy dependence, because the grain size should increase.
- **Measured energy dependence at 8G for s−Ar (??)**. This is strange: at 100 G the μ^+ fraction seems to be independent on implantation energy, whereas at 8 G, the μ^+ asymmetry decreases with increasing energy, corresponding to a raising Mu asymmetry.
- **B−Field dependence for s−Ar at low implantation energies (??)**. At 6 keV a B−field scan was performed (8, 20, 50,100G) that clearly shows the reduction of the m^+ asymmetry with increasing field. At higher implantation energies, it is not clear, should be checked. In s−N_2 , no B−field dependence is oberved. Anyway, the B−field dependence

needs an explanation. It could be due to Mu^- formation. A difference between s−Ar and s−N_2 could arise due to a different scattering behaviour of electrons: in Ar, there is the Ramsauer−Townsend effect yielding a minimum in the elastic cross section at about 0.3 eV. This effect is absent in nitrogen, and in Ne either. So, if we don't observe a B−field dependence in s−Ne, this might be an additional hint that elastic scattering of electrons plays an important role. However, it is hard to imagine, how such low B−fields should have an influence on the electrons (for example, the radius of an 0.3 eV electron in an B−field of 100G is about 0.2mm).

<u>Run 2001 measurements:</u>

- **Blank substrate:** 20 K, 100G, (20?, depends on HV...) 18kV, 15kV, 12kV, 10kV settings to "calibrate" asymmetry, 500 k events, 15 keV implantation energy. For Ar and Ne we very probably will need 10 kV settings to achieve the lowest implantation energies. In order to estimate the charged freactions properly we have to know the total asymmetry for the different HV settings.
- **s−N_2:** Start with nitrogen to check, if we get similar results as in Run12: 100G (3,6,12,21 keV). **At (6,15,21) keV B−field scan (8, 20, 50, 100 G).**
- **s−Ne:** energy scan at 100 G (3,(6), 9, (12), 15, (18), 21 keV), 500k events (~1h). Repeat energy scan at 8 G (measure for 1M events, if there is Mu observable). **At (6,15,21) keV B−field scan (8, 20, 50, 100 G).**
- **s−Kr:** same as for s−Ne.
- **s−Ar:** check B−dependence at 15, 21 keV ?
- **Annealing:** try nitrogen first ?, deposition at 13.5 K, heat slowly until nitrogen starts to sublimate (this will be between 20 and 25 K), cool down again. Do an energy scan at 100 G. Try s−Ar, same procedure as for nitrogen.
- Depending on the results try other things (higher deposition temperature...)
- **Growing conditions to start with** (thickness calibration by MP in folder *"Mu/μ^+ in thin solid gas layers"*)

> **s−Ne:** 1000 nm (1000s @ 0.7 x 10^{-5} mbar (**B1 penning gauge, GK closed, 100CF open**)), 5 K
> **s−Ar:** 1000 nm (1000s @ 3 x 10^{-5} mbar (**B1 penning gauge, GK closed, 100CF open**)), 10 K
> **s−N_2 :** 1000 nm (500s @ 3 x 10^{-5} mbar (**B1 penning gauge, GK closed, 100CF open**)), 13.5 K
> **s−Kr:** 1000 nm (1000s**??** @ 3 x 10^{-5} mbar (**B1 penning gauge, GK closed, 100CF open**)) 20 K
> **s−Xe:** 1000 nm (2200s @ 3 x 10^{-5} mbar (**B1 penning gauge, GK closed, 100CF open**)) 30 K

Mu in s−Ne: *Muonium Formation and Diffusion in Solid Neon*, Storchak et al, Hyp. Int. **85** (1994), 109. 75% Mu, 25% μ^+ , l = 0.1 − 0.2 μs^{-1} , natural UHP Ne
Mu in s−Kr: *Muonium localization in solid krypton,* Storchak et al, Phys. Rev. **B 53** (1996), 662.

>70% Mu ??, ??% μ^+ , $\lambda < 1\ \mu s^{-1}$ at 20 K, natural Kr, ~40% loss of Mu asymmetry at 20 K