An ESD-Type High Brightness Negative Hydrogen Source

C. Goeden and G. Dollinger

The new microbeam facility SNAKE at the Munich tandem accelerator is currently under construction [1,2]. The spot size for a proton beam is limited by the transversal emittance of the ion source. Therefore, a new ion source for negative hydrogen is currently under development. The aim of the new source is the minimization of the transversal energy of the accruing ions. Usually, these ions are emitted with energies up to 5 eV from a cesium sputter source. In our present work, electron stimulated desorption of negative hydrogen from a cold, hydrogen covered diamond surface is studied with respect to an application as a bright ion source.

The prototype of such an ion source has been designed and build up (fig. 1).

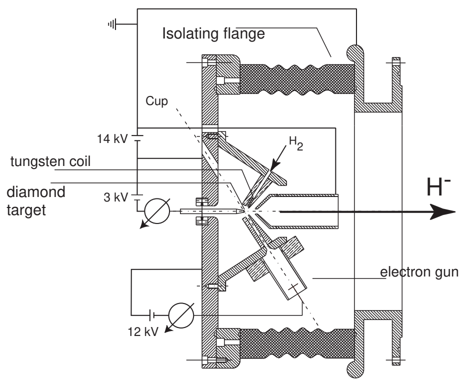

Fig. 1: Sketch of the new ion source with the high voltage circuit.

The diamond is mounted on a sampleholder which is supported on a tube made from stainless steel. The target is surrounded by two extraction electrodes. Negative ions are extracted from the target and analysed by a 90° magnet. An electron gun from a cathode ray tube (CRT) is used as an electron source. The electron beam is steered through the extraction lens to the front side of the target. The spot size was estimated to be 1 mm^2. Usually, the CRT was operated at 12 kV. To serve as an atomic hydrogen source, a tungsten filament is located in a hole of the extraction lens. Molecular hydrogen is dissociated at the tungsten surface and hits the target before recombination occures.

As a first measurement, the negative deuterium current was measured versus time for diamond surfaces deuterated under different conditions. The normalized currents are shown in fig. 2 without deuterium supply during measurement. The total cross section σ for stimulated hydrogen desorption can be obtained from the time constant of the exponential decay of the ion current during constant electron bombardment [3]:

$$I_{D^-} = I_0 \cdot \exp\left(\frac{I_e \sigma}{Ae}\, t\right) \qquad (1)$$

$\frac{I_e}{A}$ denotes the electron current density and e the electric charge. As expected, the ion current shows an exponential decay for the first seconds on a hydrogenated diamond surface (curve indicated C-H in fig. 2). The cross section for the first 20 seconds of the desorption is calculated to be $3.5 \cdot 10^{-18}$cm^2. Looking at longer times, the desorption decelerates. This effect may be caused by changing the electron affinity and therefore the desorption cross section with hydrogen coverage. To proof this explanation, an oxygen terminated crystal was used as a model system for positive electron affinity diamond. The experiment was performed several times, modifying the time for readsorption of deuterium at $1 \cdot 10^{-4}$mbar from 3 to 170 minutes (curves C-O/15 to C-O/170 in fig. 2). As fig. 2 shows, the slope varies with hydrogen coverage.

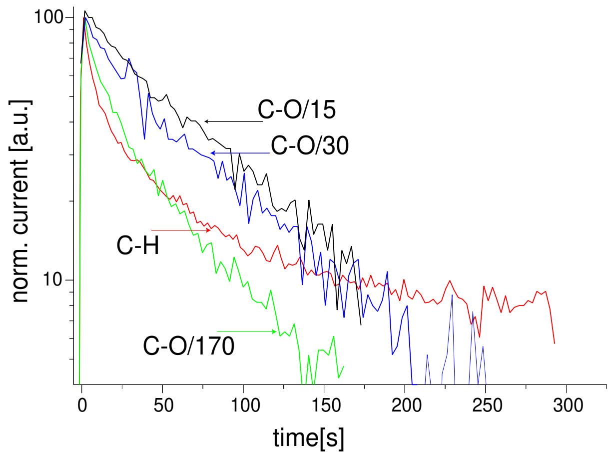

Fig. 2: Measurement of neg. deuterium current vs. time using a (100)-oriented, oxygen or hydrogen covered diamond. The exposure time to the atomic deuterium was varied from 15 to 170 min for the oxygenized surface and the increasing peak current was normalized.

The sample with the lowest deuterium content shows no time depending decay parameter. The total desorption cross section is calculated to $5 \cdot 10^{-19}$cm^2. Looking to longer adsorption times, the cross section increases. After 170 minutes of deuterium exposure, the cross section is identical to that of the hydrogen terminated surface during the first 30 seconds. The desorption decelerates with decreasing deuterium content of the surface and equals for longer desorption times the spectra for 15 min adsorption.

The largest negative hydrogen currents measured up to now were 0.7 nA from a hydrogenated diamond surface for a few seconds. The target was a (100)-oriented, as grown CVD diamond sample, covered by one monolayer of hydrogen. Due to the unknown transmission of the beam line, the desorbed current might be much higher.

As a result of this work, desorption of macroscopic currents of negative ions from a diamond surface by stimulated desorption has been demonstrated for the first time. The desorption cross section increases with hydrogen coverage. This feature might be linked to the changing electron affinity of the diamond surface.

References

[1] G. Datzmann *et al.*, Jahresbericht 1997, p. 106
[2] O. Schmelmer *et al.*, this report pp. 100, 101
[3] T.E. Madey, J.T. Yates, Jour. Vac. Sci. Technol. **8** (1971) 525