Stimulated Desorption of Negative Hydrogen Ions from Diamond [100]

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The new microbeam facility SNAKE at the Munich tandem accelerator has been operated in 1999 for the first time [1] and will come up to its full performance next year. Then, the spot size for a proton beam will be limited by the transversal emittance of the ion source. Therefore, a new ion source for negative hydrogen is currently under development. The aim for a 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.

In a first experiment, the electron stimulated desorption of macroscopic negative ion currents from a diamond surface was observed for the first time. The ionization cross section for negative hydrogen formation by electron impact to a diamond surface has been measured. The cross section has been proven to vary one order of magnitude with hydrogen coverage, according to the changing electron affinity of the diamond [2,3].

For low beam emittance, the initial energy and angular distribution of the ion beam is of great importance. In order to analyze the primary energy, an electrostatic analyser, as it is common for electron spectroscopy, is used. It consists in a spherical capacitor which acts as a 180°-deflector. Transmitted particles are detected by a channeltron. Beam position and divergence is determined by a slit system. This system is capable of an energy resolution up to 1.0×10^{-4} but features no intrinsic mass separation. To distinguish secondary electrons from negative ions, the target was biased at 30 V and the impinging electron beam was pulsed. Ions and electrons can then easily separated by their different time of flight. Desorption was done by a standard LEED/Auger electron gun with an energy range from 0-3000 eV. Usually, a beam energy of 300 eV was used. Hydrogen coverage of the diamond was achieved by a heated tungsten tube acting as an atomic hydrogen source. The system was pumped by a turbomolecular pump to a base pressure of 2.0×10^{-10}mbar.

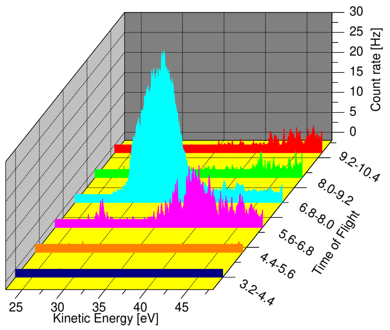

Fig. 1: Energy distribution for different time of flight. Hydrogen is detected in a range from 5.6 to 8.0 μs.

To overcome the effect of changing desorption cross section and subsiding ion currents, the measurement was carried out in an atomic hydrogen atmosphere of 2×10^{-6}mbar. The target used was a nitrogen doped natural diamond. fig.1 shows count rate against kinetic energy for 6 different time of flight ranges.

The negative hydrogen ions are divided to two TOF intervalls. The first one ranges from 5.6 to 6.8 μs, accordant to a kinetic energy of about 40 eV. The second one contains slower ions of about 33 eV kinetic energy, resulting in a longer time of flight in the range of 6.8 to 8.0 μs. For longer time intervalls, some secondary electrons can be seen due to incomplete blocking of the electron gun. To obtain the intrinsic kinetic energy of the desorbed ions, the measured values have to be corrected by the work function of the analyser and the bias voltage applied. The work function and bias have been determined by photoelectron emission of the tantalum holder by Al_{K_α} radiation.

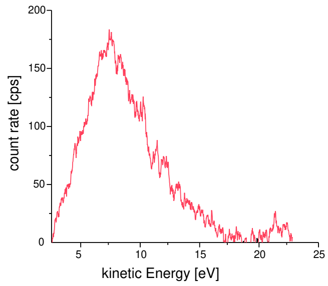

Fig. 2: Energy distribution of negative hydrogen ions. The peak is located at 7.5 eV, the FWHM reaches 6 eV

Fig.2 shows the energy distribution of negative hydrogen ions desorbed in the time of flight intervall between 5 to 8 μs. The maximum of the peak is located at 7.5 eV kinetic energy, the width of the distribution has a value about 6 eV. This is much more than the typical energy distribution of secondary electrons in the diamond conducting band [4]. The explanation for this behavior might be the nitrogen doping of the crystal. As known from photo electron spectroscopy [5], such a surface shows upwards band bending, resulting in an energy barrier for thermalized electrons in the conducting band minimum. Only high energy electrons can escape from the surface, resulting in a high excess energy transferred to the ion. In a forthcoming experiment, a boron doped diamond showing a downward band bending will be investigated. A much smaller energy distribution is expected in this case.

References

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