2 Ultracold Neutrons

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At the Paul Scherrer Institute (PSI), a new high-intensity source for ultracold neutrons (UCN) is currently under construction, to which we presently contribute. It will provide the opportunity to search for the electric dipole moment of the neutron (nEDM, see (1; 2)) with one to two orders of magnitude better sensitivity. At this level, e.g., supersymmetric theories predict a finite nEDM, and its observation would correspond to the discovery of new physics.

2.1 Wall-loss and depolarization of stored UCN

Ultracold neutrons (3; 4) have a kinetic energy which is below the Fermi potential of some materials (e.g. Beryllium 258 neV) and thus are totally reflected by walls covered with such material. This UCN energy corresponds to a temperature of 3 mK, a velocity of 6.8 m/s and a wavelength of about 50 nm. However, Beryllium is highly toxic, and therefore efforts are made to replace it by a non-hazardous material like diamond-like Carbon (DLC), which belongs to the group of amorphous Carbon materials.

In addition to the Fermi potential, the wall-loss probability per wall collision and the depolarization probability are the important parameters for the performance of a material used for UCN storage. In 2004 in an experiment (5) at Grenoble we trapped polarized neutrons in 'bottles', coated with DLC and Beryllium. The resulting measurements of the two parameters were published in 2005 (6; 7) and showed that DLC foils can be used for UCN storage in a wide range of new experiments, as well as for the UCN source at PSI. In addition the first time loss coefficient and depolarisation were measured simultaneously, thus correlations between these two parameters could be studied more reliably

2.2 Production of Diamond-like carbon coatings

In the past year, we developed and optimized a characterization procedure that allows quality control of self-produced DLC samples (8). The procedure consists mainly of two different methods, Raman spectroscopy and X-ray photoelectron spectroscopy (XPS). With this procedure we could characterize samples that were produced in an existing coating facility at PSI, based on the pulsed Laser deposition (PLD) method. There, pyrolytic graphite is ablated by a pulsed UV-Laser and can form a thin layer of DLC on various kind of substrates as stainless steel, Aluminium, Silicon, etc. The advantage of the PLD method is, that it can be performed under (ultra-)high vacuum conditions. This minimizes the incorporation of other elements, especially strong neutron absorbers and up-scatterers, like Boron or Hydrogen. However, the Fermi potential of these first coatings (Laser wavelengths 266 nm and 248 nm) was slightly below that of Beryllium, but was approximately on the same level as the DLC measured in our experiment (7) mentioned above. Figure 2.1 shows the XPS spectrum of a DLC film deposited at 266 nm on Silicon.

An XPS spectrum of a DLC coating can be deconvolved into two peaks corresponding to the sp^2 (graphite bonds) and sp^3 (diamond bonds) fraction. With increasing experience in producing DLC films by PLD, we could increase the sp^3 fraction to about 50% and consequently the Fermi potential to about 260 neV.

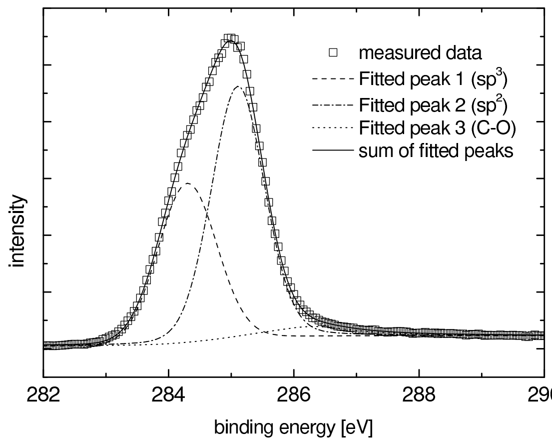

Figure 2.1: XPS spectrum of DLC coating grown on Silicon by PLD with 266 nm wavelength. Measured data (squares) and the corresponding fit (lines) of three peaks are shown.

Finally we began with the construction of a new PLD setup for coating the inside of tubes with an inner diameter of 70-250 mm. Such tubes with a DLC coating can be used as UCN guides. The setup consists of an excimer Laser which is run at 193 nm wavelength and a vacuum chamber, in which the deposition takes place. The laser can reach up to 500 mJ per pulse and can be operated at repetition rates up to 50 Hz. A quartz lens focuses the laser beam onto the graphite target. The power density of the laser beam on the target is in the order of $5 \cdot 10^8$ to $1 \cdot 10^9$ W/cm^2. The substrate tube will be rotated around and translated along the target. The chamber is also equipped with an electrode that allows in-situ glow discharge cleaning of the substrate in order to optimize the adhesion of the DLC film and to minimize impurities in the coating. A more detailed description can be found in (9). In a first stage we will produce small test samples mounted in a few centimeters distance from the target in order to find optimal process parameters. For this purpose we only use the central part of the coating facility, which is a one meter long vacuum tube with 40 cm diameter. In a second step we will extend the vacuum tube to a full length of 2.5 m which gives us enough space for coating tubes with one meter length. First tests have shown that we can reach a pressure of about $2 \cdot 10^{-6}$ Pa without special cleaning and baking out the vacuum tube.
The DLC characterization and the PLD setup for tubes are the thesis subject of Stefan Heule.

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