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1. Development of multilayer coatings on solid state detectors for antireflection and conversion of ultracold neutrons

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In the Jahresbericht 1999 [1,2] was reported about the first success in preparation and investigation of a detector for ultracold neutrons applying 150 thin double layers of ^{6}LiF and ^{62}Ni evaporated on a silicon PIN diode. Details of the setup, the evaporation procedure and the ERD analysis for impurity investigation are described in [3]. The moderate impurity content caused due to the residual gas of the vacuum (10^{-6} Pa range) encouraged us to substitute the expensive ^{62}Ni by natural titanium. The following stack was evaporated on silicon PIN diodes. Their front electrode was about 27 μg/cm^2 Al. On this, a 5 μg/cm^2 Ti film was deposited for good adhesion. On this a layer of 76 μg/cm^2 ^{58}Ni was condensed to function as reflector layer for UCN. On top of this, 100 double layers of 4.7 μg/cm^2 Ti and 1.8 μg/cm^2 ^{6}LiF were planned. The isotopic enrichment of the ^{6}LiF was 95.47%. On this, 33 double layers of 3.4 μg/cm^2 Ti and 0.9 μg/cm^2 ^{6}LiF were deposited. This second thinner stack was designed to be sensitive to very low energetic UCN as well [4]. Finally 6.0 μg/cm^2 ^{nat}V had to be deposited to protect the multilayers from diffusion of water vapor after venting. Vanadium was chosen because its scattering potential of ^{51}V is close to zero. The ERD analysis of this stack, however, showed an intolerable high impurity content, mainly of oxygen, hydrogen and carbon. It was obvious that such an UCN detector would not function well and this was confirmed in a test with UCN, where only negligible detection efficiency could be measured. Details of the setup and the relevant ERD tests are described in [5]. Since we had no suitable vacuum plant with a one to two orders of magnitude better vacuum we returned to the successful ^{62}Ni and produced two charges of UCN detectors, one was for quadratic silicon PIN diodes with their Al front electrode and the second one was for circular (25.4 mm diameter) ones with a silicon nitride front electrode. Since only three positions could be used of the four-position hearth of the electron beam source we were not able to deposit a thin Ti layer on the front electrode for good adhesion because other three different metals had to be deposited. Therefore the front electrode was directly coated with 75 μg/cm^2 ^{58}Ni as reflection layer for the UCN. The Ni should have sufficient good adhesion properties. On this 115 double layers were condensed starting with ^{6}LiF (1.9 μg/cm^2), followed by ^{62}Ni (2.6 μg/cm^2). After this follow 90 double layers ^{6}LiF (1.2 μg/cm^2) and ^{62}Ni with the same thickness as before. Finally 3.0 μg/cm^2 ^{nat}V had to be deposited to protect the multi-layers. This ^{nat}V layer together with its substrate, the last ^{62}Ni film, should have sufficient thickness against diffusion of water vapor after venting. This had to be confirmed by measuring the reflectivity for UCN [6] and investigated by ERD analysis.

The ERD measurements were performed at the Munich tandem accelerator using a 40 MeV Au beam as described in Ref. [3]. Fig. 1 shows quantitative depth profile of the main contributing elements of the surface near part of the UCN detector. It seems that the surface film (^{nat}V) is oxidized and could not completly prevent the diffusion of oxygen and water vapor. The elemental ratio of ^{6}LiF/^{62}Ni in the surface near part of the film can be estimated to be 1.52. Within the measurement error this value is consistent with the desired value of 1.62 (1.2 μg/cm^2 ^{6}LiF/2.6 μg/cm^2 ^{62}Ni)

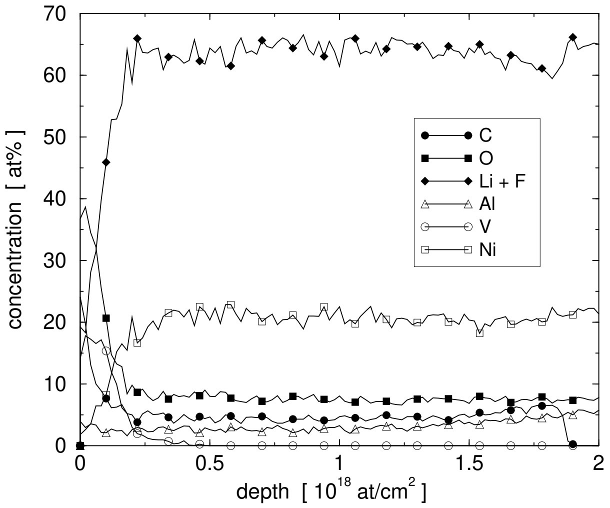

Fig. 1: Depth profiles of C, O, LiF, Al, V and Ni measured by ERD.

2. Proposal for a new UHV plant for the preparation of very thin single and multilayers

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As reported above it is essential to apply ultrahigh vacuum (UHV) when thin multilayers of non noble metals should be prepared e.g. for detectors to identify ultracold neutrons (Physik–Department E18). Another application is the preparation of multilayer structures of magnetic and non-magnetic materials, where impurities reduce or even prevent ordering effects between the layers. Magnetic layers find applications for example for data storage and as optical elements for neutron and synchrotron radiation (Physik–Department E21) [7,8]. Impurity free isotopically marked multilayers are necessary to determine the total response function of high resolution ERD analysis. The best resolution for the investigation of interfaces at ultra thin layers cannot be applied so far, because the surface of all layers is contaminated due to storing in poor vacuum and transportation in open air before installing into the scattering chamber. Producing and storing of such layers in ultrahigh vacuum and transferring of the samples via an UHV interlock system into the scattering chamber would solve such problems. Due to the multiple interests of the three research groups a proposal for the development of a suited UHV plant was written and sent to the DFG (Deutsche Forschungsgemeinschaft) for critical examination in order to get funding in the frame of HBFG (Hochschulbauförderung). Main reasons for the proposal were the absolute necessity to apply UHV, because there the monolayer time is several hours, thus the switching time from one evaporation source to another one is negligible since less than 1% of a monolayer of the residual gas is deposited within five minutes. For most evaporation–condensation processes a small deposition rate is favorable which is only possible when UHV is applied otherwise larger amounts of the impinging molecules are buried in the layer. We plan to build a vacuum chamber of about 60 cm diameter and a height of about 120 cm. Preliminary estimates of the costs of such a special UHV evaporator with a starting vacuum in the 10^{-9} Pa range are about 400 kEUR. The reason for such a high price is the necessity to bake the system up to 470 K. Normal UHV gate valves and the cryopumps withstand at most 420 K. Therefore we need special development as well for the gate valves as for the UHV vacuum pumps. Also many installations require special constructions to meet the high baking temperature of 470 K.

References

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