Application of a Nuclear Reaction Analysis for Aging Investigations

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In order to provide precise measurements of the concentration and depth distribution of the light elements (fluorine, oxygen, carbon, nitrogen, etc.) which come from the gas avalanches and penetrate inside the wire, a 'Nuclear Reaction Analysis' (NRA) was applied. For aging investigations nuclear reactions such as 16O(dp)17O, 12C(d,p)13C, 14N(d,p)15N, 14N(d,X)12C, 19F(p,X)16O can be used. Some of them have already been performed in our aging investigations with deuterons and protons in the energy range of 1 MeV. The sensitivity of the NRA to carbon, oxygen and nitrogen is better than $5{\cdot}10^{-2}$ %. The precision of the quantitative evaluation of the element content depends on the accuracy of the knowledge of the differential cross section for the considered nuclear reaction and is 5%. Using NRA in combination with a SEM/XEM analysis, aging studies of straw drift-tubes operating with a $Xe/CO_2/CF_4$ gas mixture were performed. The concentration of oxygen along the wire was measured. It was shown that after irradiation the amount of oxygen and carbon noticeably increased. It is determined that deposits containing tungsten, oxygen and carbon are distributed along the wire corresponding to the gas flow direction. The concentration of oxygen and carbon as a function of depth within the wire has also been investigated using NRA.

Summary of Talk: It is clear that the new generation of wire chambers will need a higher level of radiation hardness. Thus, the study of aging effects for these new detectors is especially important. Usually, aging effects result in a surface degradation of both the anode and cathode electrodes, which occur in the form of "deposits". An SEM/XEM analysis yields qualitative information on the morphology of the wire surfaces, by imaging with scattered and secondary electrons, and on the atomic composition of the surface material by X-ray fluorescence spectroscopy. This analysis is good for the wire surface deposit investigations. However, in order to complete the evidence for the aging mechanism and to establish the fact that the elements penetrate into the gold of the wires, a nuclear reaction method is proposed. For the detection and quantitative evaluation of the oxygen, carbon, fluorine and nitrogen content as a function of depth in the gold, we propose to use the following nuclear reactions with deuterons and protons in the energy range of 1 MeV:

- 12C + d → 13C + p + 2.722 MeV
- 16O + d → 17O + p + 1.049 MeV
- 14N + d → 15N + p + 1.305 MeV
- 14N + d → 12C + α + (9.146 or 13.579) MeV
- 19F + p → 16O + α + γ + 8.144 MeV

As one can see from these nuclear reactions, the energy and type of emitted particle is characteristic of a specific element. The (dp) reactions are exothermic and thus the exiting protons and α-particles have higher energies relative to the incoming deuterons scattered on the target. This allows us to completely absorb the deuterons with a few microns of aluminum foil placed in front of the semiconductor detector, which is used in detecting the final state particles. The energy of the bombarding deuterons (E_d = 0.9 MeV) is not sufficient for nuclear interaction with higher atomic number elements due to the Coulomb barrier. Hence, the protons and α-particles produced in the interaction with light elements are detected practically without background. One of the advantages of the nuclear reaction analysis method is that it gives us an opportunity to investigate the depth profile of atomic composition for thin film without etching. Thanks to ion braking the energy of the exiting particle gives information on the depth where that reaction occurs. The thickness of the investigated layer depends on the absorption range of the particles, and amounts to about a few microns. Thus, this technique allows us to evaluate the light element content not only in the gold coating of the wire ($\approx$ 1 mm) but also in the tungsten with a depth resolution of 0.1 mg/cm^2. This proposed method looks very promising and unique due to the above mentioned advantages of high sensitivity, the lack of etching, quantitative evaluation of the light element content, and the large depth of analysis. This method has been developed by us considering first the needs of the aging investigation. It is very probable that this nuclear reaction method will become a customary technique for aging investigations of the new generation of gas-filled chambers. Using NRA in our aging investigations it was reliably confirmed that the role of oxygen in the wire swelling mechanism is important and that the oxygen transportation into the depth of the gold coating really exists. Some of these results are presented in this report.