Comparison of Polarized Target Materials in Different Magnetic Fields

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Tests were performed at the Paul Scherrer Institute (PSI) and CERN to determine the maximum polarization for two deuterated materials being considered for use in the SMC polarized target. The two materials studied were butanol and propanediol, both doped with Cr(V) complex. The maximum attainable polarization was found for magnetic field values of 2.5, 3.5 and 5.0 Tesla.

The Spin Muon Collaboration (SMC) is an experiment to measure the spin structure function of the neutron by use of a large polarized deuteron (and hydrogen) target. The volume of this target is approximately 2 liters and the desired deuteron polarization is in excess of 40%. Although this target is designed to operate at 2.5 Tesla, and has successfully produced *hydrogen* polarizations greater than 90% at this field, the operating parameters for deuterium were not as well-known, and it was decided to test the proposed deuterated materials at different magnetic field values, since significant improvements may be possible.

Studies of polarized target materials are often complicated by the wide variation in the facilities used by various groups. The ultimate polarization of "identical materials" is known to depend upon such (non-independent) factors as sample size, temperature, microwave irradiation power and magnetic field inhomogeneity. Unfortunately, data on the complicated variation with these parameters is often anecdotal in nature and a comparison of two materials which have been studied by different groups is somewhat risky. In this study, two materials were chosen for testing under conditions as identical as possible. The first material was fully-deuterated 1,2-propanediol (P-D8) doped with about Cr(V) complex to a concentration of about $6 \cdot 10^{19}$ spins/cc. EPR analysis of this complex at 298 K gave a width of 3 10^{-4} Tesla for the distance between points of maximum slope. This material has been used extensively in previous experiments with polarizations of about 40% reported[1]. The second material was a fully-deuterated butanol-D_2O (Bu-D10) mixture doped with fully deuterated EHBA-Cr(V) complex (EDBA) also to a concentration of $6 \cdot 10^{19}$ spins/cc. The dopant concentration and ratio of water to alcohol was roughly optimized in a separate series of experiments at CERN to produce a mixture with phase transitions well above the boiling point of liquid nitrogen in order to facilitate handling. The sample described below had the ratio 95%-butanol to 5%-water. Butanol was prefered as a target material over propanediol because of it's higher deuteron content, although this factor is largely offset by it's lower density.

The samples were placed in a ^3He-^4He dilution cryostat [2] with a base temperature of about 75 mK and a magnetic field whose homogeneity has been measured to be about $1 \cdot 10^{-4}$ over the $1 cm^3$ volume of the sample. The same sample holder geometry and NMR coil were used for the two samples to minimize differences due to magnetic field. The NMR coil consisted of conducting lines etched out of both sides of an annular piece of silver-clad G-10 with a square cross-section. The inductance was varied by shorting a different number of turns for each magnetic field value. Although the microwave sources for the dynamic nuclear polarization had to be changed with magnetic field, the input power was monitored by the same germanium diode and thus their relative values for both samples are roughly known. The input microwave power was limited by the cooling power of the dilution refrigerator.

The inherent noise in the system did not allow us to perform an absolute calibration of the deuteron polarization by measurement of the thermal equilibrium signal. However, the polarization as determined from the peak asymmetry is accurate and reproducible to about +/- 5%, and is therefore sufficient to identify significant variations between samples or magnetic field values [3]. The available microwave sources allowed us to try three different values of the magnetic field: 2.5, 3.5, and 5.0 Tesla. EIO sources were available for the two lower field tests while the test at 5.0 Tesla employed a carcinotron source.

Figure 1 summarizes the results for the maximum attainable polarization for each sample as a function of magnetic field. Although the precise regimen of applied microwave power and frequency was varied for each sample, the final values were found to be independent of this schedule to within the accuracy of the peak asymmetry measurements. The polarization of -53 +/- 5% obtained for the P-D8 sample at a field of 2.5 T is the highest deuteron polarization ever reached for this well-examined material. This might indicate the importance of a highly homogeneous magnetic field for high deuteron polarizations.

Further tests are planned, but we draw the following tentative conclusions from these data: Firstly, higher fields give lower polarizations. Since the polarization must decrease for very low field values, it would obviously have been of interest to determine the optimum field value. We were, however, prevented from testing at 1.5 Tesla by the small size of the cryostat waveguide. Secondly,the maximum attainable polarization is roughly 15% greater in the P-D8 sample than the Bu-D10 sample.

Maximum Polarization

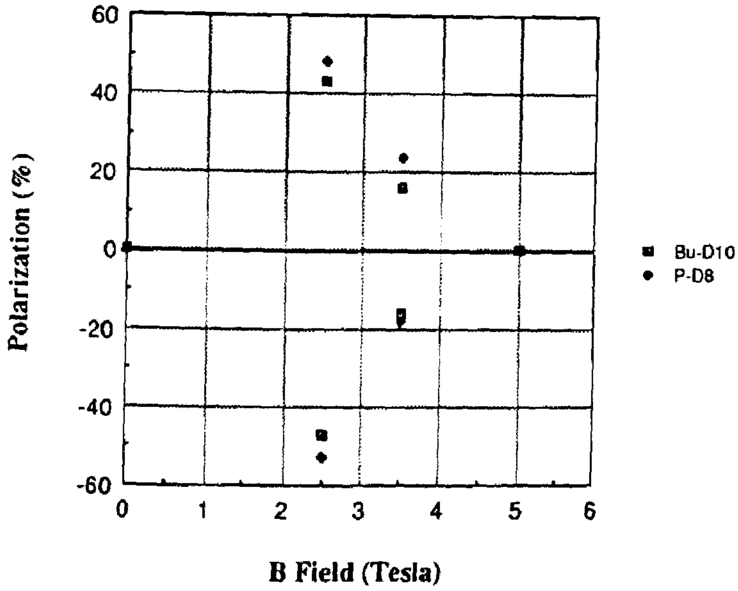

Figure 1 Maximum Polarization as a function of Magnetic Field.

We can define a first-order figure of merit for using the two deuterated materials for spin-physics scattering experiments as the product of the deuteron content squared, the maximum polarization squared and the density. Using the measured polarizations and densities measured at liquid nitrogen temperatures, the figure of merit for P-D10 would amount to 0.92 of the figure of merit for Bu-D10. The higher deuteron content of the Bu-D10 is largely offset by it's lower maximum polarization and density.

References:

1.) E.I. Bunyatova and N.N. Bubnov, Nucl. Instr. and Methods **A254** (1987) 252.

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3.) O. Hamada et al., Nucl. Instr. and Methods **189** (1981) 561.