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Extraneous Scattering Background in SANS Instruments

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Three often overlooked sources of extraneous background scattering from surfaces in small angle neutron scattering (SANS) instruments have been examined in detail. Figure 1 shows schematically these sources: (i) the red ray shows a path from scattering of the direct beam off the beam stop which then scatters off the vessel lining and onto the detector; (ii) the blue ray shows a path from scattering from the sample onto the vessel lining and onto the detector; and (iii) the green ray shows a path from scattering from the sample onto the surrounding sample environment and onto the detector. The paper Barker et al. [1] describes scattering measurements, calculations and design ideas to mitigate all three sources of background.

Extraneous scattering affects the accuracy of SANS measurements in a number of ways. The scattering from the beam stop, and rescatter from the vessel lining, enhance the empty beam background. The enhancement is typically only observable when the detector is far from the sample and air and window scattering have been minimized. The enhanced background from the beam stop only adversely impacts the statistical error of weakly scattering samples. The extraneous scattering from the sample environment and the detector lining have a more insidious effect because the absolute scattering intensity from incoherent scattering by the sample is actually enhanced. The incoherent scattering is found to be enhanced from the detector vessel elastomer lining by 4% and by poor shielding in a nine position sample block by a further 16% for water samples. In addition, measurements indicate the enhanced incoherent cross-section also depends upon the sample-to-detector distance. For instruments using multiple carriages, such as the vSANS instrument at the NCNR, D33 at the ILL, and Bilby at ANSTO, the front-carriage detector panels variably screen background affecting the downstream carriage panels, producing differences in the inferred absolute scattering signal between panels.

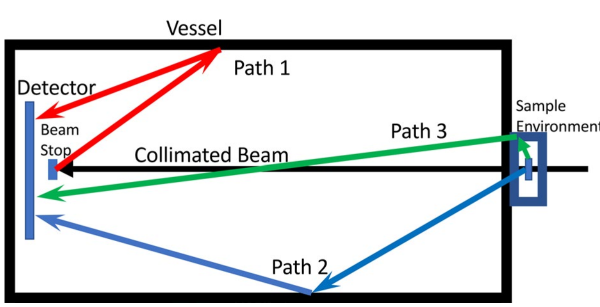

Figure 1. Sketch of three possible paths to extraneous background.

In order to assess the best-performing materials with respect to their albedo, reflective scattering from 16 commonly used materials for both shielding and construction have been measured on an absolute scale at five cold neutron wavelengths. Many of the polycrystalline materials had scattering dominated by Bragg diffraction at shorter wavelengths. Figure 2 plots the fraction of the incident beam that scatters back from the surface, called the albedo, for each of the 16 materials at a neutron wavelength of 4.5 Å. The albedo varies by nearly four orders of magnitudes, with the lowest being from Gd having a high absorption cross-section and the highest being from polyethylene which is an excellent reflector due to scattering from hydrogen. Three elastomers containing similar high levels of natural boron for neutron shielding with similar attenuation of neutrons in beam transmission measurements were found surprisingly to have an albedo that varies by over an order of magnitude due to differences in the quality of dispersion of the boron component. Considerable enhancement in albedo was found between the different wavelengths of 4.5 Å, 6 Å, and 8 Å for some crystalline materials such as Al, Fe, BN, and PTFE as the prominent d-spacing in the different materials was positioned at large scattering

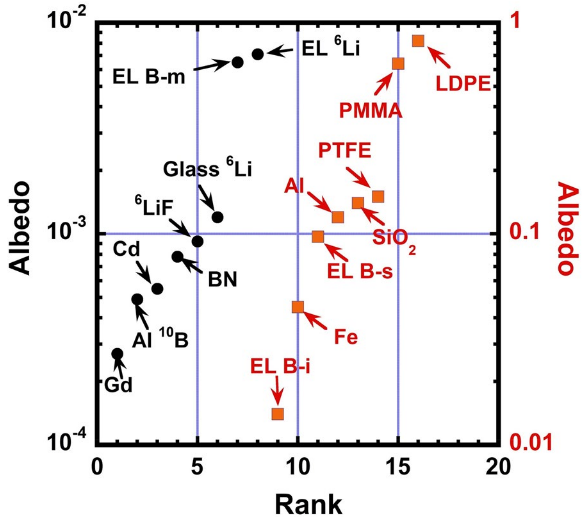

Figure 2. Plot of the measured albedo from 16 different materials ranked from lowest to highest. Black points use left scale and red points use right scale. Material abbreviations: hydrocarbon elastomer (EL), low density polyethylene (LDPE), poly methyl methacrylate (PMMA), poly tetrafluoroethylene (PTFE), and -s,-I and -m stand for different material vendor sources.

angles. The lowest albedo was measured at the 12 Å and 15 Å wavelengths. The measured albedos agreed with the observed changes in background obtained from the various choices of beam stop and detector lining materials.

To mitigate the background from the detector vessel lining, lower-albedo materials such as Cd should be used in preference to flexible boron containing elastomers that exhibit excessive albedo due to hydrogen scattering. In addition to high absorption with low-energy gamma or low gamma production, it is also critical that the beam stop has the lowest albedo possible. The best beam stop materials in this respect are ^{6}LiF or $^{10}B_4C$. Albedo background from the sample environment is mitigated by placing shielding downstream of the sample, but with openings that allow unimpeded passage of the sample's SANS to the detector. The reduction of all three of these background sources has measurable benefits for the accuracy of SANS measurements.

References

1. J. G. Barker et al., *J. Appl. Crystallogr.* **54** (2), 461 (2021).