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New generation of slow neutron reflectors using purified nanodiamonds

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Advances in neutronics are of great importance in fundamental science in many fields, from biology to physics. However, with the current global trend to increase the range of useful slow neutrons (SNs), progress in this area is limited by the sharp decrease in the flux of available SNs. ^[1,2] This is mainly due to the nature of neutron reflectors, as they are composed of atoms generally spaced of ~ 1 Å, as soon as the neutron wavelength reaches this value the neutrons are almost no longer diffracted, drastically limiting neutron research and nuclear applications. The key to increasing the efficiency of the SNs flux therefore lies in the development of efficient reflectors for such neutrons.

To create these reflectors, the strategy of the present work is to mimic standard reflectors and replace the atoms/nuclei with nanoparticles of highly scattering materials with low absorption - thus changing the characteristic length scale. A new class of reflectors based on nanodiamonds (NDs) and fluorine graphite intercalation compounds (F-GIC) will provide a virtually continuous reflectivity curve, with a high albedo minimising the so-called neutron reflectivity gap. ^[1-3] NDs with a mean diameter of 4-5 nm, synthesized by detonation (DND), are available in an industrial scale and extremely stable under neutron fluxes. However, the purification treatments used after their synthesis lead to some impurities that are unfavourable for neutron applications because of their high neutron absorption (e.g. hydrogen, sp^2 C, other surface functional groups or metallic impurities). Thus, ultrapure DNDs are highly required for this application.

With the aim of selectively purify DNDs, our approach is based on a combination of gas phase purification treatments: chlorination, oxidation, inert atmosphere annealing and fluorination. Chlorination will be used to remove the metallic impurities at the surface and within the DNDs. Oxidation will emphasize the remaining impurities left after total combustion of DNDs. The annealing of DNDs under a nitrogen atmosphere will determine their thermal stability and distinguish the influence of temperature on the chlorination treatment. Fluorination has two features, first is to eliminate the surface functional groups and sp^2 C shell ^[2], then to increase the interplanar distance between graphite layers. A multitude of structural, morphological and chemical characterization techniques are involved to deeply characterize the treated DNDs and their impurities. In addition, the design of a unique neutron experimental set-up at the PF1B line at the ILL aims to record simultaneously reflectivity and diffraction of neutrons with a wide range of wavelengths, including slow and very slow neutrons. Data on various powdered DNDs and F-GICs (powders and papers with different F/C ratio and C-F bonding) were recorded as well on the precursors before fluorination.

References

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