Inert-Gas Solids with Nanoscale Porosity

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Nanostructured materials are currently of immense interest in both fundamental and applied science. Recently, we have reported[1] the structural and thermal properties of novel mesoporous inert-gas solids. The materials were prepared by injecting a jet of helium containing dilute amounts of inert atoms and molecules (Ne, Kr, N_2) into superfluid helium. A special x-ray cryostat equipped with a gas preparation system allowed us to study these materials with x-ray diffraction. In the initial experiments, we found that complex mesoporous substances with densities of the order of 10^{20} impurity atoms per cm^3 with the characteristic size of the constituent building block of 6 nm form in the superfluid helium. The Kr and Ne solids were stable outside of liquid He up to temperatures above 10 K.

In this work, we continue to investigate nanoporous inert-gas solid samples with x-ray diffraction techniques. We report successful preparation of samples made of deuterium (D_2), and also deuterium-nitrogen mixed samples. By varying preparation conditions, we were able to achieve synthesis of nitrogen samples with the characteristic size of the building block less than 3 nm. Our experiments indicate that by varying the experimental conditions, it is possible to control the size (and, possibly, morphology) of the nanostructured inert solids. We also demonstrate that these solids can be made of a large variety of chemical elements. In addition to the standard powder diffraction measurements, we have also performed small-angle scattering studies of the porous inert-gas samples. Our measurements indicate that the samples to not possess a well-defined fractal structure, and that the nanoscale morphology of the samples substantially varies from sample to sample. These materials may find various applications as a new type of porous medium for fundamental physics, as well as in cluster physics, matrix isolation spectroscopy, and catalysis of low-temperature chemical reactions. Better control of the sample properties achieved in our measurements is an essential first step towards these possible applications.

References: [1]V. Kiryukhin, B. Keimer, R. E. Boltnev, V. V. Khmelenko, E. B. Gordon, Phys. Rev. Lett. **79**, 1774 (1997)