Large magnetic anisotropy induced by high-pressure torsion straining

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High-pressure torsion (HPT) is a useful technique to introduce a large amount of lattice defects (dislocations and grain boundaries) in metals and alloys. These changes in crystal structures often bring exotic mechanical and magnetic properties. We have recently found that submicrocrystallined Fe fabricated by the HPT process (HPT-Fe) shows irregular small-angle neutron scattering (SANS) patterns at a high magnetic field. This result exhibits that a spin misalignment in nanometer scale remains even at a magnetic field enough to saturate the magnetization of pure Fe. Therefore, strong magnetic anisotropy is probably induced in Fe by the HPT straining.

To clarify the origin of this strong magnetic anisotropy, the effects of lattice defects and crystal structure were investigated. The amount of lattice defects (dislocation and grain boundary) was controlled by annealing treatment after HPT of Fe. In order to elucidate the relation between the magnetic anisotropy and the crystal structure, the SANS measurement of HPT-Ni was also performed in this study.

The SANS measurements were carried out at the SANS instrument Quokka installed at OPAL, Australian Nuclear Science and Technology Organisation (ANSTO). Four disc samples with the thickness of 0.5 mm were stacked for the SANS measurements. We confirmed that multiple small-angle scattering did not occur from the comparison of the scattering profiles between a disc and four discs. A magnetic field up to 10 T was applied to the samples perpendicular to the incident neutron beam using a superconducting electromagnet.

With decreasing the amount of grain boundaries by annealing treatment of HPT-Fe, the size and volume fraction of the spin misalignment decrease while dislocation density has small effect, suggesting that grain boundaries play important role on the strong magnetic anisotropy in HPT-Fe.

In the scattering profiles of the HPT-Ni, a clear shoulder is observed at the magnetic field of 1 T and becomes small with increasing the magnetic field (Figure). These behaviors are similar to those observed in HPT-Fe. This confirms that the spin misalignment is also generated in HPT-Ni. Therefore, a localized large magnetic anisotropy field is probably induced in a wide variety of magnetic materials by the HPT straining. The scattering intensity observed in HPT-Ni is lower than that in HPT-Fe. This suggests that the lower volume fraction of the spin misalignment and/or lower scattering contrast.

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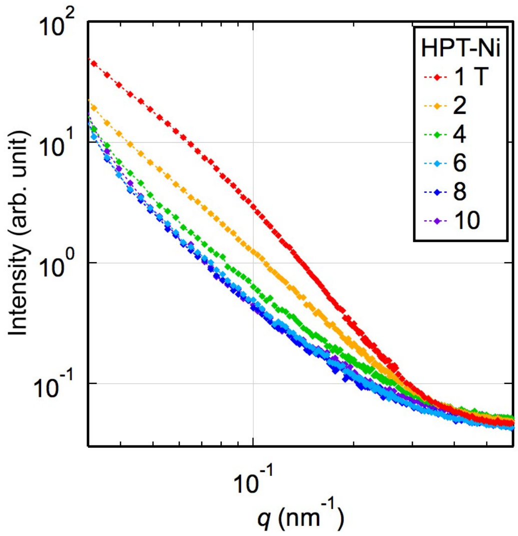

Fig. 1. Scattering profiles of HPT-Ni measured in the magnetic field between 1 and 10 T.