Anomalous magnetic small-angle neutron scattering in severely deformed Fe

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High-pressure torsion (HPT) is one of the most important techniques to develop advanced materials because grain refinement and increase of crystal defects produced by HPT often give rise to significant improvement of mechanical and magnetic properties. To fully elucidate the attractive features of the HPT process, precise characterization of microstructures is needed. We have recently conducted small-angle neutron scattering (SANS) experiment of submicrocrystallined Fe fabricated by HPT (HPT-Fe) and found that the HPT-Fe shows anomalous scattering patterns. The scattering patterns indicated that the magnetization of HPT-Fe was not saturated even in a magnetic field of 1 T. Therefore, strong magnetic anisotropy was probably induced in Fe by the HPT process. This result has great potential to lead a new theory governing the magnetic anisotropy. This is also useful for industrial applications as a new technique to enhance or control the magnetic anisotropy.

However, the origin of the tilted scattering pattern was not clear because in the unsaturated magnetization state, the magnetic scattering contribution cannot be separated from nuclear scattering contribution. In this study, the SANS measurement of the HPT-Fe at a high magnetic field was performed using a superconducting magnet.

The SANS measurements were carried out at the SANS instrument Quokka installed at OPAL, Australian Nuclear Science and Technology Organisation (ANSTO). The shape of the HPT-Fe was a disc with the thickness of 0.5 mm. Four discs were stacked for the SANS measurements. To investigate a magnetization process and saturate the magnetization, a magnetic field between 0-10 T was applied to the samples perpendicular to the incident neutron using a superconducting electromagnet.

Figure shows the scattering profiles of the HPT-Fe. A shoulder observed in the profile in 2 T indicates the formation of nanostructures in the HPT-Fe. With increasing the magnetic field, the shoulder becomes weak. Since the magnetic field probably causes no change in the chemical nanostructures, the result means that the shoulder is mainly composed of a magnetic scattering contribution. Hence, spin-misaligned regions remain even in the magnetic field higher than 1 T. Above 6 T, the SANS intensity is close to steady. This indicates that the magnetic anisotropy field induced in the HPT-Fe is around 6-8 T. The result also shows that the scattering patterns contain almost no nuclear scattering contribution. This suggests that the chemical nanostructures which generate scattering contrast in SANS region are scarcely formed by the HPT process.

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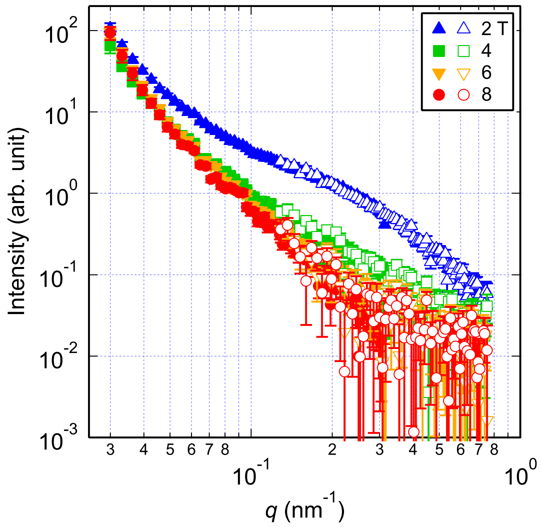

Fig. 1. Scattering profiles of HPT-Fe measured in the magnetic field between 2 and 8 T. Filled and Open symbols are the profiles measured at low-q and high-q settings, respectively.