Application of Small Angle Neutron Scattering and Neutron Reflectometer in metals and alloys

B. S. Seong, E. J. Sin, Y. S. Han, J. S. Lee, H. R. Kim, Y. J. Kim
HANARO Utilization Technology Division, Neutron Physics Department, Korea Atomic Energy Research Institute, P. O. B 105, Yuseong, Daejeon, 305-353
bsseong@kaeri.re.kr

1. Introduction

The neutron scattering technique is widely used in materials science research. The various complementary neutron beam facilities at HANARO, such as High Resolution Powder Diffractometer(HRPD), Small Angle Neutron Scattering Spectrometer(SANS), Four Circle Diffractometer(FCD), Residual Stress Instrument(RSI) and Reflectometer(REF) were developed and applied in materials research. In this paper, SANS and REF were introduced with their applications.

2. SANS

Small angle neutron spectrometer(SANS) covers the low scattering angle(<10^{o}) and probes nano sized inhomogeneities in the length scale of a few to several hundred nanometers in materials. SANS is the crucial facility in NT and BT research such as polymers, nano-magnetic materials, ceramics, metals and alloys [1,2]. In Table 1, the characteristics of HANARO SANS were presented.

Table 1. Characteristics of HANARO SANS

Monochromator : Neutron velocity selector
Detector : 2-dimensional position sensitive detector
Sample to detector distance : 1.5~4.6 m
Q range : 0.06~6 nm^{-1}
Flux : 3.0 x 10^{4} n/cm^{2}s
Sample environments - Circulation bath (-20~80 ^{o}C) - Heating block (25~200 ^{o}C) - Electromagnet (<1.5T)

Especially, in this part some applications of SANS in metal and alloy researches were introduced. Fig. 1 presented the 1-dimensional small angle neutron scattering intensities of API steels having different chemical composition and thermal history. In API steels, the inhomogeneity cause for scattering intensity are precipitates mostly. If the chemical compositions of the precipitates and matrix are known, the size distribution and volume fraction of the precipitates can be calculated through the model fitting [3]. In Fig. 2 and 3, the volume fractions of precipitates calculated from the model fitting were presented as a function of their size.

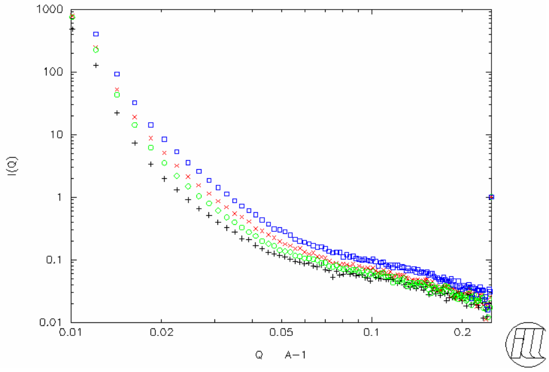


Fig. 1. Small angle neutron scattering intensitis of API steels , A:+ , B:×, C:○ , D:

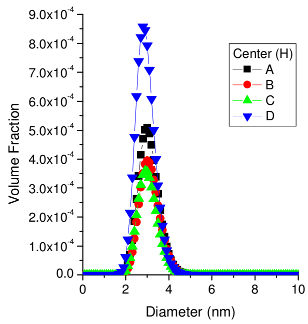


Fig. 2. Volume fraction of precipitates less than 10 nm in API steels.

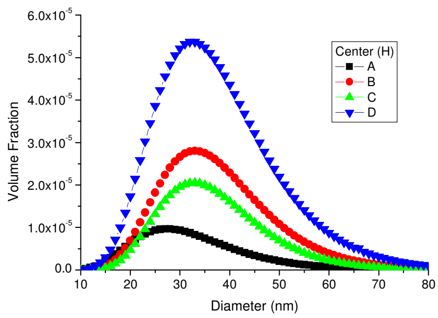
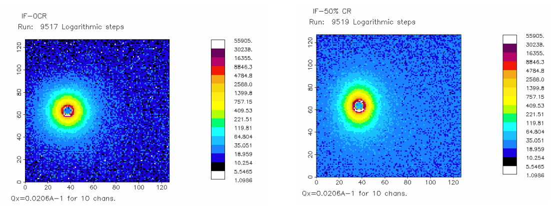


Fig. 3. Volume fraction of precipitates more than 10 nm in API steels.

In Fig. 4, the 2-dimensional small angle neutron scattering patterns of IF steels were displayed. The sample for Fig.4 (b) is the cold rolled sample with a

50 % reduction rate. After cold rolling, the scattering pattern was changed from spherical to ellipsoidal shape. In IF steels, the inhomogeneity cause for scattering is also precipitates for initial sample mostly. However after cold rolling, other inhomogenities affect the scattering. And it is shown that the inhomogeneities were oriented to some direction.

Fig. 5 shows the scattering intensities for unirradiated and irradiated RPV steels. For Q>0.05 region, the scattering cross section of irradiated sample is higher than that of unirradiated sample. The difference between unirradiated and irradiated data is a contribution of irradiation induced defects.



(a) (b)

Fig. 4. Small angle neutron scattering patterns of cold rolled IF steels, (a) initial sample, (b) 50 % cold rolled sample.

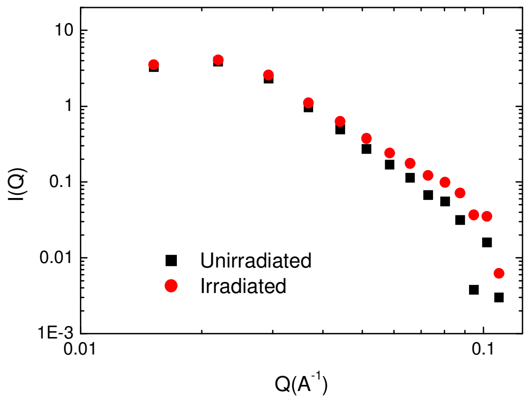


Fig. 5. Small angle neutron scattering intensities of Al nano powder and its compact.

3. REF

Neutron reflectometry is a non-destructive technique to examine the characteristics such as thickness, surface roughness, interfacial roughness, composition and defects in a surface structure down to a 10 Å resolution. This technique uses neutrons scattered at grazing angles from a flat specimen to probe the layer profile of various materials. Examples of materials studied include biological membranes, thin polymer films and layered metallic materials, Application of polarized beams permits the determination of the magnetic, as well as nuclear, profiles of thin films. Neutron reflectivity detects the variation in the scattering length density(SLD) as a function of the depth. Also it is strictly a function of the neutron momentum perpendicular to the surface of the specimen under investigation [1,2]. In Table 2, the characteristics of HANARO REF-V were presented.

As an example of the application, the reflectivity of a Ni/Ti monochromator was presented in Fig. 4. From the reflectivity data, the thickness and roughness of Ni and Ti layers are calculated.

Table 2. Characteristics of HANARO REF-V

Reflection plane : vertical
Monochromator & Filter : PG(002)
Wavelength, $\Delta\lambda/\lambda$: 0.245 nm, ~1.5 %
Minimum reflectivity : ~10^{-6}
Q range : ~ 0.04 nm^{-1}
Flux : 6.64x 10^6 n/cm^2 s at open
Sample to detector distance : 1.3 m
Slit1-Slit2 distance : 2.5 m
Sample size : 40 mm(H), 40~100 mm(L)

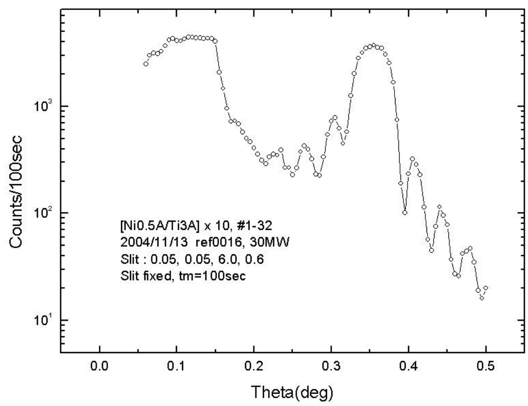


Fig. 6. Reflectivity of Ni/Ti monochromator

5. Conclusion

SANS and REF have been a very powerful tool in various scientific and engineering research area. Now HANARO are planning to construct a 40 m SANS and horizontal-REF using cold neutron. It will be also a very important tools to investigate nano-scale polymer, bio-materials, etc.

ACKNOWlEDGEMENTS

Part of this work was supported by the HANARO Nuclear R&D Program of the Ministry of Science and Technology.

REFERENCES

[1] HANARO Utilization Technology Development Brochure
[2] http: // hanaro.karei.re.kr
[3] U. Keideling, et al, J. Appl.Cryst.33, (2000) 483-487