§9. Radial Profile of Impurity-line K_α in LHD

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The radial profiles of K_α lines emitted from metallic impurities such as titanium, chromium and iron have been observed with an assembly of soft X-ray pulse-height analyzers (PHA) in Large Helical Device (LHD). The energy shifts of the K_α lines are successfully evaluated as the function of plasma radius. The shifts reflect diffusion coefficients of the impurities. The absolute density of the metallic impurity has been also estimated in comparison between the experimental result and an impurity code analysis.

The assembly is equipped with a radial scanning system which makes it possible to measure detailed radial profile of X-ray spectra, especially in long pulse discharges.[1] The energy resolution of the PHA is 160 eV at 3.2 keV for an argon-K_α line. The maximum counting rate is 10 kcps. As a result, the radial profile of the X-ray spectra are measured with a spatial resolution of approximately 20 mm. Accordingly, the local emissivity profile of the X-ray spectrum is quantitatively obtained using an Abel inversion technique.

Figure 1 shows the examples of the X-ray spectra obtained with the assembly. Taking into account the transmission rate of a beryllium filter with a thickness of 1 mm, the spectrum has to be modified. The spectra consist of continuum emission from free electrons as bremssstrahlung and the K_α lines emitted from the metallic impurities.

Figure 2 shows the energy shift of the iron-K_α lines. In the code analysis the diffusion coefficients of the impurities are assumed to be constant radially. The code suggests that the energy shift is sensitive to the diffusion coefficient in the region of $\rho \geq 0.5$. The experimental result can be approximately explained by a diffusion coefficient of 0.1 m^2/s. The coefficient estimated here is very close to previous experimental results in LHD.

Figure 3 shows the final result indicating the density profile of iron. In LHD the amounts of fully stripped iron and hydrogen like iron are much lower than that of helium like iron. The iron density is dominantly contributed from helium like iron in the plasma core of $\rho \leq 0.4$. Using the present method, the concentration of iron is determined to be 4.5 10^{-3} % to the electron density of 2.6 10^{13} cm^{-3} at the plasma core. As a result, it is confirmed that the densities of metallic impurities are much less than that of electrons in LHD.

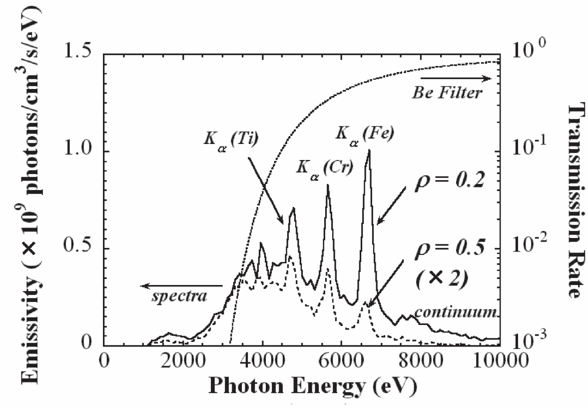

Fig.1. Typical X-ray spectra emitted from NBI plasma. The spectra are quantitatively obtained from the Abel inversion. Solid and broken lines represent spectra locally emitted from ρ = 0.2 and ρ = 0.5, respectively. The K_α emissions from titanium, chromium and iron appear at 4.7 keV, 5.6 keV and 6.6 keV, respectively. Dotted line represents the transmission rate of the beryllium filter.

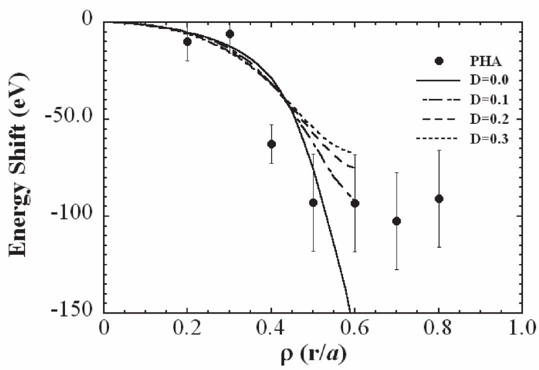

Fig.2. Energy shift of the iron-K_α lines. Filled circles with error bars represent the energy shifts estimated from the experimental result and lines represent results from the code calculations in several diffusion coefficients.

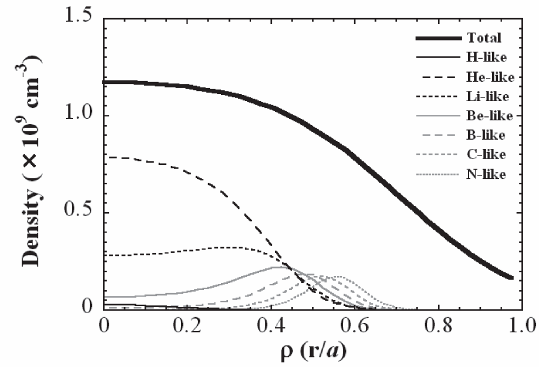

Fig.3. Typical density profile of iron in LHD.

[1] S.Muto *et al.*, Rev.Sci.Instrum. **72**, 1206 (2001).