Micro-XAFS Analysis of Micro Histological Specimen and Its Application for Pathological Diagnosis

The bronchoalveolar lavage fluid (BALF) from a patient with pneumoconiosis induced by cemented tungsten carbide (WC) was analyzed by micro X-ray absorption fine structure (XAFS) analysis. The BALF was centrifuged, and the precipitated solid component in BALF was analyzed by fluorescence XAFS using polycapillary focused X-rays. From the W L_1-edge XANES spectrum, tungsten contained in the BALF solid component could be identified as WC. Thus, a low concentration of WC could be detected from BALF using XAFS without excess biopsy.

Cemented tungsten carbide (WC) is widely used for cutting tools and rock drills because of its quite high hardness. However, fine particle dust of WC generated during the work using cemented WC causes severe pneumoconiosis called tungsten carbide pneumoconiosis (WC-P). To distinguish WC-P from general pneumoconiosis, detection of tungsten in lung biopsy specimens is important. X-ray microanalysis (XMA) has been applied for the detection of tungsten in biopsy specimens [1]. However, the detection probability depends on the position of the biopsy because the distribution of inhaled WC in the lung is inhomogeneous. Thus, specimens from different points are required for a reliable analysis. However, lung biopsy is invasive and involves pain and risk to the patient, therefore, excessive biopsy for elemental analysis should be avoided. In addition, the chemical state of tungsten should be identified as carbide for a conclusive diagnosis of WC-P, however, the chemical state cannot be identified by XMA or similar methods (e.g. X-ray fluorescence spectroscopy (XRF)).

XAFS analysis provides chemical state information of the target element and would be more appropriate for the diagnosis of WC-P. In this study, we tried to detect WC from the bronchoalveolar lavage fluid (BALF) from the patient. BALF is popularly used for cytodiagnosis in lung diseases and it is collected by instilling saline into the lung via an intrabronchial endoscope, after which the wash-out fluid is retracted through the endoscope as shown in Fig. 1. The solid component of BALF contains cells and inhaled particles in the lung. If it were possible to detect WC from the solid component in BALF, less invasive diagnosis of WC-P could be carried out. However, the volume of the solid component of BALF is quite small and the concentration of WC in it is low. Thus, we applied fluorescence XAFS using micro focused synchrotron radiation to analyze tungsten in the solid component of BALF.

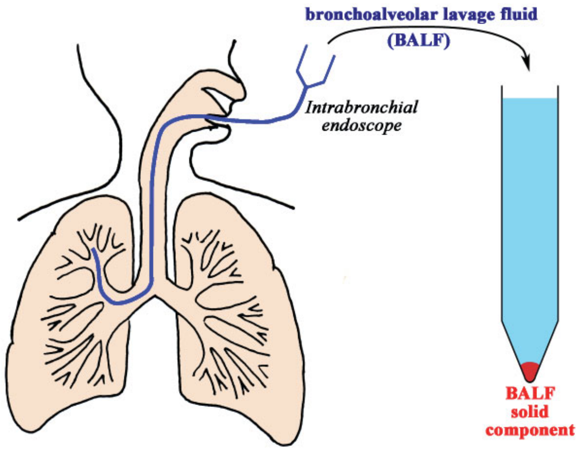

Figure 1
Specimen preparation from BALF.

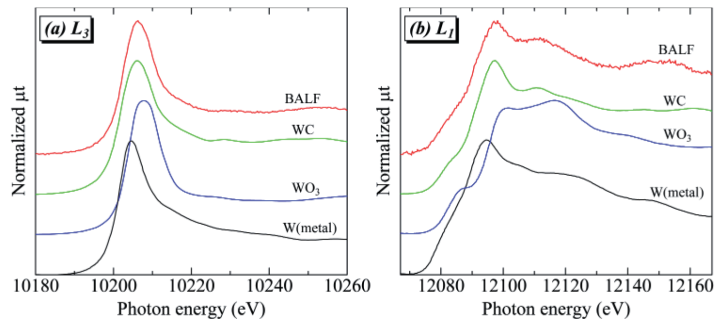

Figure 2
The W L_3-edge (a) and L_1-edge (b) XANES spectra of BALF solid component, metallic W, WC and WO_3.

15 ml of BALF, which was obtained from a patient who was suspected of having WC-P, was centrifuged and the precipitated solid component (smaller than 0.5 mm) was dried. The solid component was applied for XAFS analysis at BL-9A. The incident X-ray was focused using polycapillary optics (X-ray Optical Systems, NY, USA) into 50 μmϕ. The W L_1- and L_3-edge XANES spectra of the BALF solid component were measured with the fluorescence XAFS method using a multi-element solid-state detector. The XANES spectra of reference materials (metallic tungsten, WC and WO_3) were measured by the transmission method.

Figure 2 shows the W L_3- and L_1-edge XANES spectra of the BALF precipitate and references. The XANES spectrum of a small BALF solid component was successfully measured using polycapillary focusing optics. In the W L_3-edge [Fig. 2(a)], the BALF solid component showed a clear XANES spectrum, but its shape and edge position were similar to those of both WC and WO_3, and so precise distinction was not possible. In contrast, in the W L_1-edge XANES spectra [Fig. 2(b)], the peak edge position and edge height of the BALF solid component were similar to those of WC and clearly different from WO_3 and metallic tungsten. Thus, the W L_1-edge XANES spectrum clearly identifies the chemical state of tungsten contained in the BALF.

Tungsten concentrations in BALF of WC-P patients were reported to be 1.5 ng/g [2]. Thus, the total amount of tungsten in 15 ml of BALF was supposed to be approximately 20 ng. This is quite a small amount, but it was effectively concentrated in the solid component by centrifuging. Therefore, W L-edge XANES spectra could be measured by the fluorescence XAFS method using focusing optics. Compared with conventional biopsy, bronchoalveolar lavage is useful for effectively collecting inhaled materials attached to alveoli without invasion and pain for the patient. XAFS analysis of the BALF precipitate provides non-destructive detection and chemical state information on inhaled materials. This method should be useful for the diagnosis of low concentrations of foreign bodies in pneumoconiosis patients without excess biopsy [3].

REFERENCES

[1] H. Kitamura, H. Kitamura, T. Tozawa and Y. Kimula, *Acta. Path. Jpn.* **28** (1978) 921.
[2] G. Rizzato, P. Fraioli, E. Sabbioni, R. Pietra and M. Barberis, *Sarcoidosis* **9** (1992) 104.
[3] M. Uo, K. Watanabe and K. Asakura, *Chem. Lett.* **39** (2010) 852.

BEAMLINE

9A

M. Uo and K. Asakura (Hokkaido Univ.)