# Analysis of Ingredients that Penetrate into the Inside of Hair by Infrared Microspectroscopy

Japanese women have come to enjoy various hair color tones and hairstyles that accompany changes in fashion with the diversification of lifestyles in recent years. Although the black hair coloring boom of several years ago may be on the wane, hair dying still remains popular among young people as a way of changing their image. Many senior citizens are also concerned about gray hair. Therefore, their interest in hair dyes remains strong and the market for such products is gradually increasing. Hair-dying products contain hydrogen peroxide to adjust the color of the dye substances and induce a chemical reaction between the hair and the dye. For this reason, repeated use may result in damaged hair, such as changes to the hydrophilicity of the hair surface and to the internal structure of the hair.

The use of hair treatments for preventing such damage, and for hair protection and easy styling has been increasing in recent years. These formulations contain ingredients such as proteins, amino acids, oils, polymers, minerals, surfactants and moisturizers, and the control of the penetrability of these ingredients is an important factor for the effective realization of their functions. Therefore, an analysis of the penetrability of these functional substances is important for the development of highly effective formulations.

One conventional method for confirming the penetrability of a substance into hair is to dye the hair with a pigment and afterwards make an indirect estimate of penetrability by measuring the degree of color difference. Regarding direct measurement, one method of analysis is to employ a substance labeled with a radioisotope or fluorescent material. However, such labeling may cause changes in the chemical and physical properties of the tested substances, and thus may not be a completely accurate method for evaluating the penetrability of a substance.

Similarly, small-angle X-ray scattering experiments have been carried out using the X-ray microbeam of the high flux beamline **BL40XU** to analyze the structure of the cell membrane complex (CMC) at the hair's cuticle, which is considered to be a penetration route for applied substances, and the contribution of the CMC to substance penetration has previously been examined. Nevertheless, regarding penetrability, analysis has been limited to the indirect method in color-difference measurements, and the penetrabilities of the ingredients in hair treatment product have not been confirmed directly [1].

We have focused our attention on a particular high-molecular weight (HMW) phospholipid-derived polymer that exhibits excellent styling performance. Generally, the HMW polymer does not react inside hair. However, it has been surmised from our initial observations that a close relationship exists between the polymer's penetrability into the inside of hair and the styling performance. Thus, we decided to confirm the penetrability of this polymer by determining the infrared absorption properties of the phospholipid-derived polymer, which differs from other components in hair.

The experimental methods and their results are described below. Two types of hair bundles (healthy and damaged by bleaching) were immersed in a phospholipid-derived polymer water solution for 72 hours, and then the bundles were extracted and dried. The dried bundles were then embedded in resin, and cross sections (with thickness about 3 μm) of each bundle were prepared for the measurement. The samples were placed in the microspectroscopy beamline **BL43IR**, and one quarter of the cross-

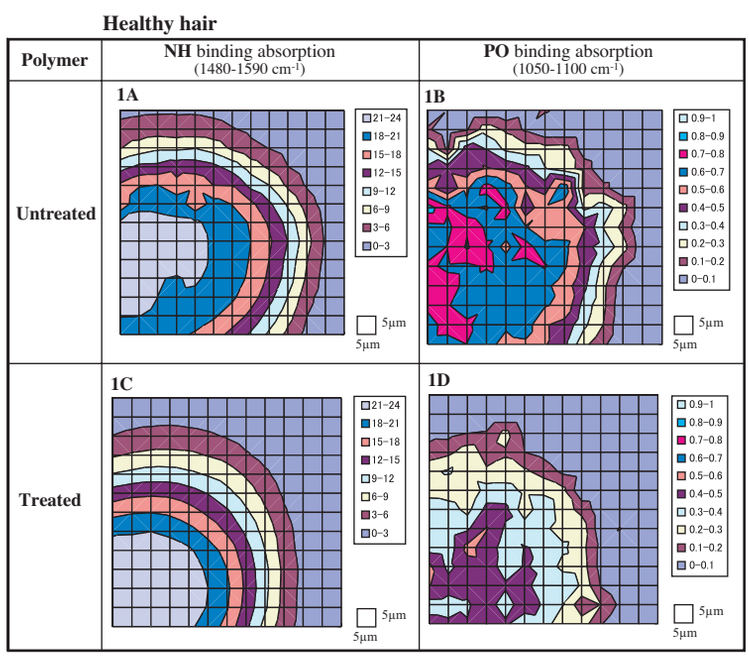


Fig. 1. Comparison of absorption intensity image mapping data (healthy hair). Higher absorption intensity represents higher values in each graph. Spatial resolution: 5 μm. Wave number range: 8000-450 $cm^{-1}$.

sectional area (roughly 70 μm × 70μm) was measured by the transmission method while moving the mapping stage every 5 μm in the wave number range from 8000 to 450 $cm^{-1}$.

On the basis of the measurement results, we created an image map of the NH binding absorption peak (Figs. 1A, 1C, 2A and 2C) derived from keratin protein amide, and the PO binding absorption peak (Figs. 1B, 1D, 2B and 2D) derived from the phosphate components of the hair and the phospholipid-derived polymer.

As a result, we could capture the hair contours by image mapping the NH binding absorption peak (healthy hair: Figs. 1A and 1C, damaged hair: Figs. 2A and 2C). Moreover, from the results of the hair untreated with the polymer, it became evident that damage to the hair led to an apparent decrease in the PO binding absorption peak (Figs. 1B and 2B) of the hair itself. When each hair bundle was treated with polymer, the following results were obtained. In the case of healthy hair, there was no major change in the PO binding absorption intensity (i.e., no penetration of the polymer was observed). In the case of damaged hair, a high rate of PO binding absorption was observed over a wide range of the internal part of the hair, particularly at the intermediate part (i.e., a high rate of penetration into the hair). It was also confirmed that the target polymer selectively penetrated deeper into the damaged hair.

From the experimental results, we concluded that an analytical method for assessing the penetrability of the target substance into hair had been established. In the future, we plan to realize the widespread application of this method by analyzing other target substances.

From the results of experiments using fluorescence-labeled compounds, the phospholipid-derived polymer's excellent hair styling performance is considered to be closely related to the polymer's ability to penetrate into hair. In the current experiment, we clarified this penetration phenomenon directly and confirmed the relationship between penetration and styling performance. In other words, this polymer may achieve its excellent styling performance by penetrating into the inside of hair and affecting its internal structure.

We have already carried out a structural analysis of the CMC in the cuticle layers of hair using BL40XU, and examined its contribution to substance penetration. In combination with the new method for analyzing penetration by IR microspectroscopy established in this experiment, it is expected that the relationship between structural changes in the cuticle CMC and a substance's penetration ability will become clearer, enabling the development of more effective hair treatment products.

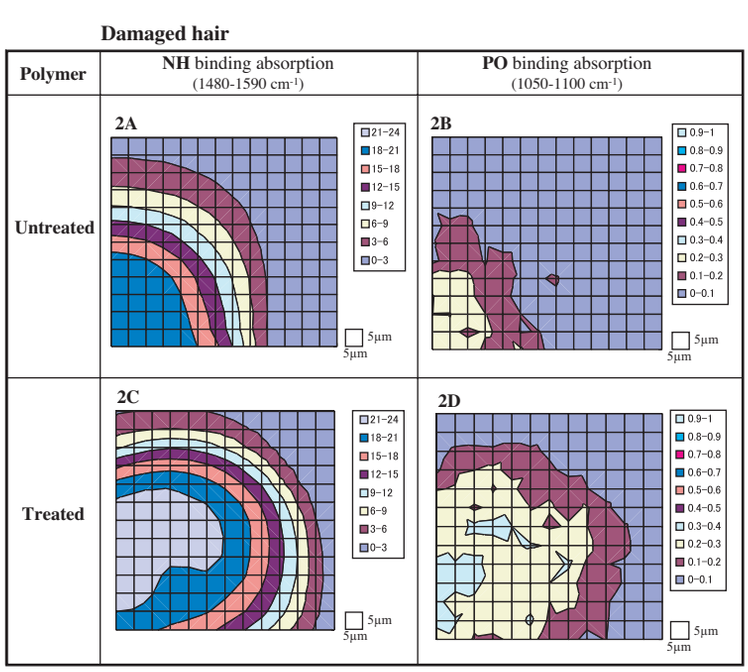


Fig. 2. Comparison of absorption intensity image mapping data (damaged hair). Higher absorption intensity represents higher values in each graph. Spatial resolution: 5 μm. Wave number range: 8000-450 $cm^{-1}$.

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## References

[1] T. Inoue *et al.*: J. Cosmet. Sci. **58** (2007) 11.