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Extended Abstract of PSA-19 (review)
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Practical applications of SIMS in material and biological research

Masayuki Okamoto
[1]*Kao corporation, 1334 Minato Wakayama-shi, Wakayama, Japan*
*corresponding author's e-mail: okamoto.masayuki@kao.com

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In our laboratory, secondary ion mass spectrometry (SIMS) technique has been used for the analysis of surface contaminants, surface adsorbates, and the penetration of agents, and for the investigation of surface degradation and damage of both materials and biological samples. In this paper, the applications of SIMS for hair and skin researches are explained. The outermost surface of human hair is covered with a thin layer of fatty acids, which plays an important role in creating the feeling of smoothness, and surface hydrophobicity. In this study, changes in fatty acids were characterized using time-of-flight secondary ion mass spectroscopy (TOF-SIMS) in order to investigate hair damage. In the skin research, the penetration of cosmetic ingredient was examined. The surface of skin is the stratum corneum, which works as a barrier against both external stimuli and transepidermal water loss. It was found that treatment with synthetic pseudo-ceramide (sphingolipid E; SLE) is effective for improving the barrier function. TOF-SIMS and Nano-SIMS studies revealed that the SLE penetrated into the stratum corneum via an inter-cellular pathway, and that the barrier function was improved by replenishing intercellular lipids at damaged sites on the stratum corneum.

1. Introduction

Secondary ion mass spectrometry (SIMS) is one of the most powerful analytical tools for the detection of surface components and molecular imaging. SIMS has been employed in a wide range of research fields. In particular, time-of-flight (TOF)-SIMS is utilized in the chemical industry because many of the objects of analysis are organic materials. In our laboratory, SIMS techniques have been used for the analysis of surface contaminants, imaging of surface adsorbates, and the penetration of agents, and for the investigation of surface degradation and damage of both materials and biological samples. In this paper, the practical applications of SIMS in hair- and skin-care research are explained.

2. Application in hair-care research

In this study, damage to the outermost hair surface and the mechanism by which it occurs were investigated using TOF-SIMS. Human hair is composed of highly organized strata, and the outermost surface is covered with a thin layer of fatty acids. The major component of these fatty acids is 18-methyleicosanoic acid (18-MEA), which plays an important role in creating the feeling of smoothness, and surface hydrophobicity. First, the damage done to 18-MEA as a result of daily hair care routines and the change in surface hydrophobicity are surveyed. It was revealed that the damage level of surface 18-MEA varied widely, and a relationship between the damage level and surface hydrophilicity was confirmed (Fig. 1).

Next, the factors causing the damage to 18-MEA was examined. Fig. 2 shows the change in the 18-MEA amount after each treatment. The results are represented by the residual ratio, which corresponds to the percentage of the surface amount of 18-MEA that remained after the treatments. The TOF-SIMS analysis revealed that hair coloring causes a reduction of 18-MEA, with more than 80% of 18-MEA removed even in a single treatment. On the other hand, shampooing and UV exposure also cause 18-MEA damage; however, a long period of time was needed for 18-MEA to be removed. It is considered that chemical

treatments, especially hair coloring, are a dominant factor in the removal of 18-MEA, while shampooing and UV exposure cause long-term degradation.

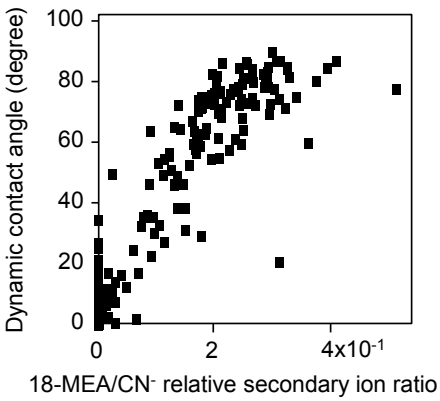

Fig. 1. The relationship between the dynamic contact angle and the negative secondary ion ratio of 18-MEA(*m/z* 341) and CN-(*m/z* 26).

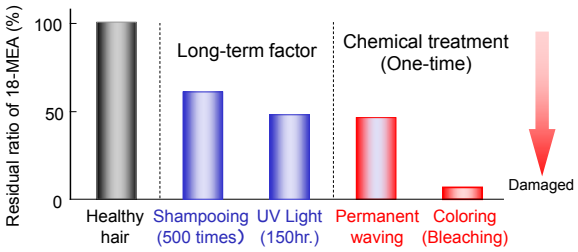

Fig. 2. The change in 18-MEA amount before and after the treatment.

3. Application in skin-care research

Human skin consists of tissue layers, and the outermost layer is the stratum corneum. This layer is 10- to 20-μm thick, and the tissue works as a barrier against both external stimuli and transepidermal water loss. The stratum corneum consists of corneocytes and intercellular lipids; a "brick and mortar" model can be used to illustrate its structure. The intercellular lipids, and in particular the ordinality of the multilamellar structure of the lipids, are responsible for maintaining the barrier function. It was found that treatment with synthetic pseudo-ceramides, whose structure is similar to that of intercellular lipids, is effective for improving the barrier function. Intercellular lipids were thought to be replenished by pseudo-ceramides (sphingolipid E; SLE) which reinforced the multilamellar structure. Verification of the existence of SLE in the stratum corneum, however, has been lacking. In this study, TOF-SIMS and Nano-SIMS studies were carried out to clarify the penetration of SLE into the stratum corneum.

For SIMS measurement, the specimens were embedded in a resin, and the thin sections of the specimens were carefully cut using an ultramicrotome. TOF-SIMS imaging of the cross-section of the skin was performed to visualize the distribution of SLE in the stratum corneum (Fig. 3). The results revealed that the SLE penetrated into the stratum corneum. Furthermore, the penetration pathway of the SLE in the stratum corneum was studied using Nano-SIMS. It is believed that the cosmetic ingredient penetrated the stratum corneum through the intercellular or intracellular pathway of the corneocytes. In the Nano-SIMS analysis, SLE was detected in the intercellular spaces between corneocytes. These results suggest that SLE penetrates into the stratum corneum via an intercellular pathway, and that the barrier function is improved by replenishing intercellular lipids, especially at the damaged sites in the stratum corneum.

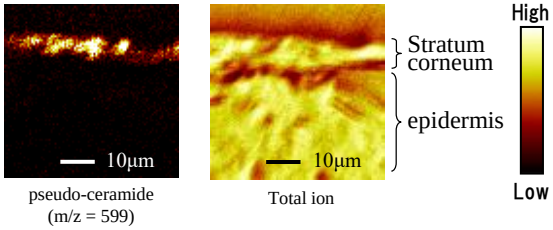

Fig. 3. TOF-SIMS images of cross-section of the skin. Secondary ion of pseudo-ceramide ; $[C_{37}H_{76}NO_4]^+$

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