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A Novel Analytical Approach Using TOF-SIMS for Imaging the Distributed States of Constituent Components in Friction Materials

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Automotive brake friction materials are required aimed performance and physical properties such as an appropriate friction coefficient, wear resistance, strength (tensile, flexural, compressive), and NVH characteristics (Noise, Vibration, Harshness). Friction materials are produced by mixing raw materials consisting of about 20 kinds of organic, inorganic and metallic materials to meet these requirements. In order to manufacture friction materials with stable quality, it is desired that these raw materials are uniformly dispersed, and at the same time it is important to understand the state of distribution during material developments. In general, an analysis method for observing the dispersion state of raw materials in a composite material such as a friction material may include surface analysis techniques such as SEM-EDS and EPMA. However, it is difficult to identify and visualize all raw materials. Especially, in the case of organic raw materials such as phenol resins, cashew particle, and aramid fiber, which are substances composed of a combination of limited elements such as C, H, O, etc., it is difficult to identify raw materials from information about elements. As methods for identifying a solid organic substance, analysis techniques such as spectroscopy (FT-IR, RAMAN) are known. However, it is difficult to apply them to the structural analysis of a friction material for the following reasons: (1) a friction material is a composite material; (2) a thermal history exceeding 200°C changes the chemical state of the organic substances; and (3) particle sizes of raw materials widely range from 1μm or less to approximately 500μm. This study investigated the applicability of TOF-SIMS mass spectrometry as a new structural analysis method to visualize the dispersion state of organic substances in friction materials. The results, which show good capability to image the dispersion state of organic materials, will now be reported.

TOF-SIMS, which stands for Time-Of-Flight Secondary Ion Mass Spectroscopy, irradiates primary ions onto the sample surface, and performs mass separation of the secondary ions emitted from the surface based on the flight time difference. In the analysis process, long molecular chains of polymer materials are cleaved into fragments reflecting their molecular structure by the irradiation energy of primary ions, and released. Therefore, information about the molecular structure can be obtained from the mass of a fragmented molecule even in the case of polymers.

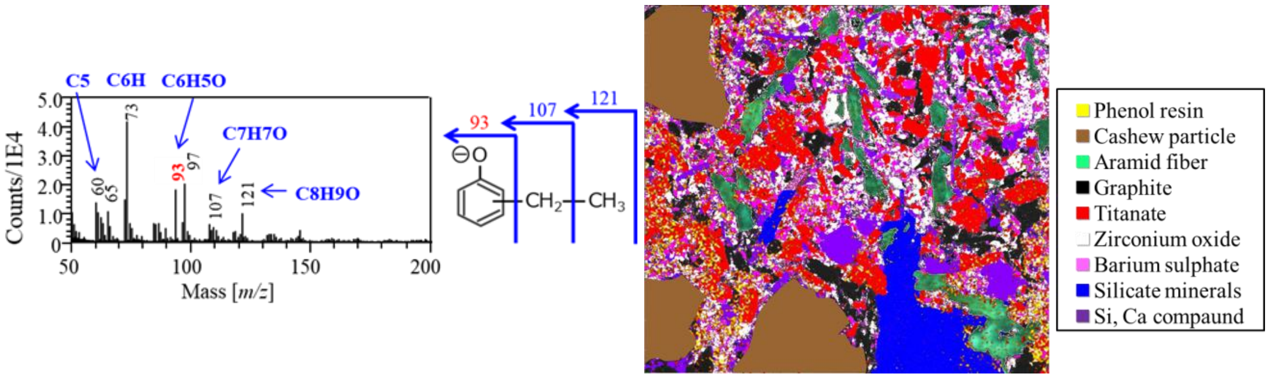

Fig.1 TOF-SIMS spectrum of Phenol resin and image of the distributed states of constituent components.

On the basis of mass spectrometry data acquired from the TOF-SIMS spectrum analysis, imaging the distributed states of constituent components in friction materials were performed. (Fig.1) This imaging measurement enabled us to identify the typical organic compounds contained in a friction material, and to create an image showing the dispersion state. The most important point is that TOF-SIMS analysis made it possible to visualize the dispersion state of organic raw materials composed of the element C, which had been difficult with conventional methods. In addition, clear images of raw materials such as inorganic and metallic materials were successfully generated. Information about the dispersion state or structure obtained from TOF-SIMS analysis is considered useful not only to find whether there is mixing or molding failure such as segregation, but also to estimate material strength or the mechanism of friction abrasion, therefore it is a very effective technique.