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Three-Dimensional Elemental Analysis of Human Enamel and Dentin by Laser-Assisted Atom Probe Tomography

IMR Tohoku Univ.[1], Tokyo Medical and Dental Univ.[2]

°Y. Shimizu[1], B. Han[1], H. Takamizawa[1], T. A. Bakhsh[2], A. Sadr[2], J. Tagami[2], K. Inoue[1], and Y. Nagai[1]

E-mail: yshimizu@imr.tohoku.ac.jp

The mineral tissue of tooth is composed of hydroxyapatite (HAp) crystals with incorporated trace elements, which are influenced by such factors as environment and dietary habits [1]. The trace elements are expected to play a role in the properties of dental hard tissue such as acid resistance, and assessing their precise distribution in tooth is essential for understanding tooth development and health maintenance. Quantitative imaging and chemical composition analysis of such a mineralized tissue are challenges.

Laser-assisted atom probe tomography (APT) has attracted attention to obtain three-dimensional elemental distributions on the order of atomic-scale resolution, which has contributed to the research field of materials science [2]. The main limitations for applying APT to the tooth are 1) difficulty of needle-specimen fabrication of brittle and hard materials and 2) high threshold potential of atom evaporation for such a non-conductive material. Recently, one could overcome the latter issue, thanks to introduction of shorter wavelength laser assisting [3]. In this work, we applied the APT with an ultraviolet laser (wavelength: 355 nm) to human teeth.

Enamel and dentin zones of sound tooth were prepared [Fig. 1(a)]. For needle-specimen fabrication, SEM/FIB dual beam system was employed. Local-electrode atom probe (LEAP4000XHR, Ametek) was used for APT analysis.

Figures 1(b) and (c) show the atom maps in enamel zone and its mass spectrum, respectively. The peaks of the main component Ca, PO_2, and their related ions were clearly obtained. Mg segregation was found, whereas clear segregation of the other elements was not observed. In this presentation, the detail data of dentin and HAp block (as a reference) will be shown.

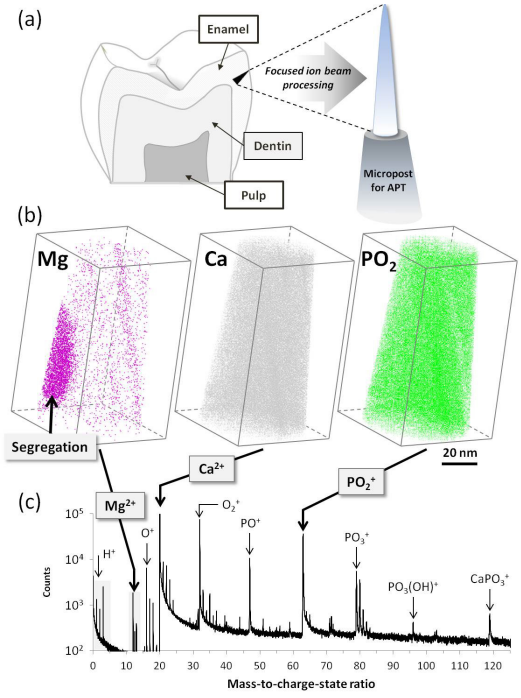

Fig. 1: (a) Sample preparation by focused ion beam processing for APT. (b) 3D map of Mg, Ca, and PO_2 in the enamel zone. (c) APT mass spectrum of the enamel zone.

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