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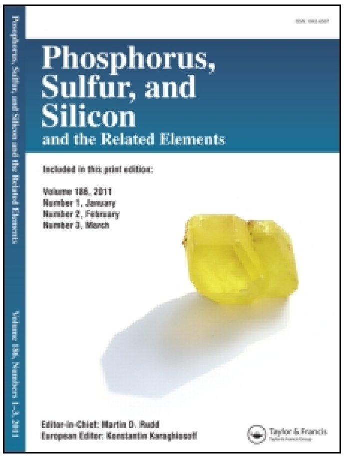

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Electrovectorial Effects of Electrically Polarized Hydroxyapatite on Biological Phenomena

Kimihiro Yamashita[a]
[a] Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental University, Chiyoda, Tokyo, Japan

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ELECTROVECTORIAL EFFECTS OF ELECTRICALLY POLARIZED HYDROXYAPATITE ON BIOLOGICAL PHENOMENA

Kimihiro Yamashita
Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental University, Chiyoda, Tokyo 101-0062, Japan

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Electrically polarized hydroxyapatite ceramics have chemical, physical, and biological effects upon their surrounding constituents in vivo *as well as* in vitro *as electrets, independent solids irradiating electrostatic force. Using the polarized hydroxyapatite, we have observed that crystal growth from a simulated body fluid can be accelerated or decelerated, and microorganisms can be manipulated on the surfaces of hydroxyapatite, depending upon the electric signs.*

Keywords: Crystal growth; electric polarization; electrovectorial effects; hydroxyapatite; simulated body fluid

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INTRODUCTION

In addition to its excellent biocompatibility with living tissues, hydroxyapatite ($Ca_5(PO4)_3OH$; HAp) has invaluable electric properties in relation to biomedical applications:[1,2] Due to the proton diffusivity through HAp structure,[3] HAp can be polarized under a dc field.[4] We have developed the chemical, physical, and biological effects of the electrically polarized HAp (polHAp). Considering the effectiveness of polHAp, we referred to such effects as electrovectorial effects. In this report, the preparation of polHAp is demonstrated, and then the remarkable effect on crystal growth in a simulated body fluid (SBF) will be introduced.

Address correspondence to Kimihiro Yamashita, Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental University, Chiyoda, Tokyo 101-0062, Japan. E-mail: yama-k.bcr@tmd.ac.jp

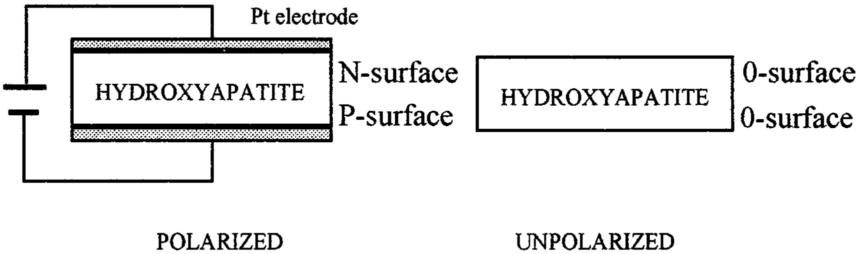

FIGURE 1 Polarization and designation of polarized surfaces. N, P, 0: negatively charged, positively charged, and nonpolarized surfaces.

ELECTRIC POLARIZATION OF HAp

Polarization of HAp was carried out with dc 1 kV/cm at 300°C using Pt plates as electrodes. As electrovectorial effects are dependent upon the electric signs of surface charges, the polarized surfaces were named as N- and P-surfaces (Figure 1). The non-polarized surface was designated as 0-surface for reference. To confirm polarization and evaluate the stored charges in HAp, a thermally stimulated current technique was employed in which the thermally dissipated current was measured at temperatures of room temperature to 800°C (Figure 2). A polHAp thus polarized was experimentally evaluated to store ca. 1 $\mu C/cm^2$.

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ELECTROVECTORIAL EFFECT IN SBF

Although slow crystallization took place dispersedly on non-polarized HAp, large crystals 1–4 mm in diameter covered the N-surface of

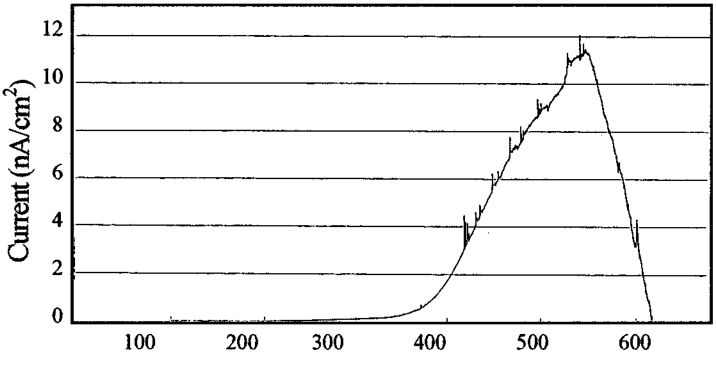

FIGURE 2 Thermally stimulated current of polarized HAp ceramic specimen.

polarized HAp after an immersion in 1.5 SBF for only 12 h. Higher field strength gave rise to faster crystal growth; sizable agglomerated crystals of 10 mm in diameter were observed in some spots on polarized HAp under 1 kV/cm, and the acceleration effect was confirmed even by the polarization as weak as 12 V/cm. The accelerated crystal growth was observed on the N-surface, whereas no crystal growth ever took place on the P-surface, even after 3-day immersion in 1.5 SBF. Although the polarization at 300°C was effective for the acceleration of crystal growth, we also identified the acceleration effect by the polarization at 200°C. The crystal growth was dependent upon the dc field strength, temperature, and time for polarization. Some experiments confirmed 1 h-polarization, enough for the optimum acceleration of crystal growth; under this condition, the surfaces of HAp were already coated with thick bone-like layers within 6–12 h. Under an optimum polarization condition (120 V, 1 h), the growth rate was estimated as 6 μm/day, more than 3 times the result obtained by the biomimetic method (1.7 μm/day). The growth rate was increased to 10 mm/day, several times as big as that of non-poled HAp (Figure 3). In the present study, the enhancement of the growth rate was observed even in the poling of 10–50 V/cm. At the early stage of the crystal growth, the grown crystals were spherical and their sizes were dependent on the field strength and time for poling. The poling is therefore considered to effect the nucleation as well as the crystal growth.

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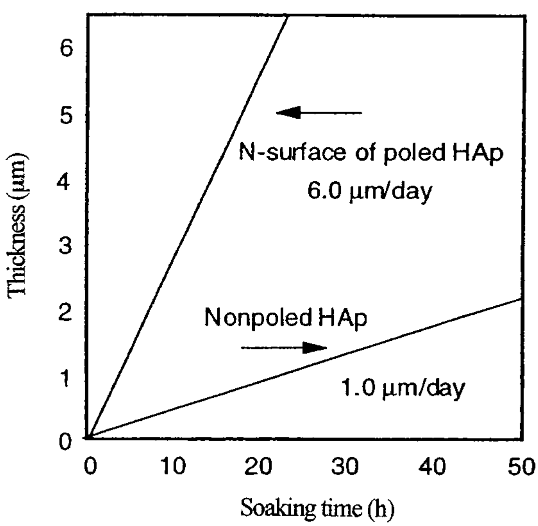

FIGURE 3 Evaluation of the electrovectorial effect on crystal growth in SBF (actually 1.5 SBF) in terms of growth rates on N-, P-, and 0-surfaces.

Biological effects were also observed on polHAp: the proliferation of cells was accelerated on N-surface much faster than 0-surface, whereas P-surface delayed the proliferation of cells. The electrovectorial effects of polHAp is under development for biomedical uses.

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