The bioactivity evaluation of bioactive glass coated titanium surface with simulated body fluid

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For the purpose of reinforce both the bioactivity and mechanical strength of implant material, which recovers bone defects, bioactive glass is coated on the surface of titanium substrate. To evaluate the function of bioactivity, immersion test in simulated body fluid is carried out and confirmed the performance of this material, that the apatite precipitates on the surface of coated glass in two days. This coating method of bioactive materials is effective for the reinforcement of bioactivity for metal implants.

Keywords : Bioactive glass, Apatite precipitation, Surface coating, Titanium substrate, Simulated body fluid

I. INTRODUCTION

Apatite, tri-calcium phosphate, and bi-phase ceramics are well known as well bioactive materials and have developed as artificial bone replacement.¹

However, these ceramics have disadvantage of mechanical strength such as shear and flexural strength than that of bone². Thus, metals such as stainless steel and titanium alloys are used for the load bearing bone replacement such as artificial joint though the bioactivity such as bone affinity is inferior to that of apatite ceramics.

In order to reinforce the bioactivity for these replacement, the coating of bioactive materials on the surface and forming the porous layer is applied. It is accepted that the apatite formation in the body fluid is one of the evaluation factor as a criteria for the bioactivity³. For evaluating the bioactivity of bioactive material coating, simulated body fluid immersion test was carried out.

II. METHODS AND MATERIALS

II-A. Sample preparation

From 0.01 to 0.03mm thickness of bioactive glass powder, that chemical composition is shown in Table 1, is coated on the 20mmX20mmX1mm of Titanium plates and heated 2 hours at 950 °C.

Table 1. Chemical composition of bioactive glass

Components (weight%)				
CaO	SiO ₂	P ₂ O ₅	MgO	CaF ₂
44.4	33.6	15.9	4.8	0.6

Also the porous titanium substrate is prepared by the plasma spray coating method with titanium powder onto the bottom surface of 20mmΦX10mm Ti-6Al-4V, in order to form 0.7mm thickness of porous layer. And the bioactive glass powder is coated to 0.03mm thickness into the bottom of porous layer, then heat treated at 950°C in 2 hours.

Specimen is controlled that the porosity is about 60% and also the pore diameter is 0.4mm at the depth from the porous layer surface of 0.25mm.

Same size of bioactive glass plate as titanium plate is also prepared.

Simulated body fluid is prepared as follows; individual portion of every reagents as shown in Table 2 are dissolved and made up 1 L solution, and then regulated the pH of solution to 7.2 with 1N-HCl.

Table 2. Composition of simulated body fluid

Reagent	Weight(g/L)
NaCl	7,996
NaHCO ₃	0,350
KCl	0,224
K ₂ PO ₄ · 3H ₂ O	0,228
MgCl ₂ · 6H ₂ O	0,305
CaCl ₂	0,278
Na ₂ SO ₄	0,071
Tris.NH ₂ C(CH ₂ OH) ₃	6,057

II-B. Experimental method

50mL of prepared simulated body fluid is filled in a 100mL plastic bottle equipped with inner cap, and then carefully put the specimen into the bottom of bottle, to direct the coated plane to top. Then, after capped the bottle, incubated in the water bath at 37°C in the period of required.

After three weeks sample is rinsed with ion exchange water and slightly adsorbed the excess water with paper filter. After this treatment, surface of the specimen is observed with SEM(Hitachi Scanning Electron Microscope, S-800).

III. RESULTS AND DISCUSSION

III-A. Observation of Glass coated titanium plate surface

As SEM photographs are shown in Photo.1, surface of specimen before immersion is porous and many of the pores of lower than 0.001mm is observed. After a day passed, the particle of coated glass tend to be round and the distance between particles become narrower than that of before

immersion. After three days of immersion, the fine needle like crystals precipitated on the surface of

As thin film X-ray diffraction pattern is shown in Fig.1, Apatite and Wollastonite peaks are observed in the specimen before immersion.

While Wollastonite peaks decreases, the background of X-ray diffraction increases. This suggests that the low crystalline material precipitation becomes higher.

Photo. 1. SEM micrographs showing the surface structure of bioactive glass coated surface coated glass particles, and this precipitates fill the space between the glass particle after four days of immersion.

From the result, the reason Wollastonite peaks diminished is assumed that the precipitates on the coated glass surface could be apatite, and this precipitation covered the coated glass surface.

Fig. 1. Thin film X-ray diffraction pattern of bioactive glass coated surface

This result shows same trends as bioactive glass plate test result, therefore, it is considered that the bioactivity is reinforced also when the bioactive glass coating on Titanium surface, because the main evidence of the bioactivity could be apatite layer formation or precipitation on the surface of implant.

III-B. Observation of glass coated porous titanium surface

As shown in Photo.2, the surface observation result of titanium porous specimen indicates that slight crystal precipitation was observed, however, the glass coated porous titanium specimen showed analysis though the only Ti spectrum was detected on

Photo.2. SEM micrographs of the porous titanium Surface layer and the EDS spectra

that Ca and P spectra were detected by the EDX the surface of porous titanium without bioglass coating.

This phenomena resembles that of glass coated titanium substrate, therefore, it is assumed that this crystal is apatite.

IV. CONCLUSION

For the purpose of reinforce both the bioactivity and mechanical strength of implant material, which recovers bone defects, bioactive glass is coated on the surface of titanium and evaluated the function of bioactivity with the immersion test in simulated body fluid. And it is confirmed that the apatite precipitates and covered not only the surface of coated glass but in the vicinity of porous surface. It suggests that this coating method of bioactive materials is effective for the reinforcement of bioactivity for metal implants.

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