Corrosion Behavior of New Beta Type Titanium Alloys in Modified Artificial Saliva

In order to know exactly the corrosion behavior of a new developed β type titanium alloy Ti-29Nb-13Ta-4.6Zr (TNTZ) in oral cavity environment, corrosion rate of this alloy in a modified artificial saliva was then investigated by using potensiostat in IMR. The corrosion rate of the most popular titanium, Ti-6Al-4V was also determined for comparison. Corrosion rate of TNTZ in the modified artificial saliva solution is much lower than that of Ti-6Al-4V due to formation of passive layers of Ti, Nb, Zr and Ta oxides in the surface of TNTZ.

It is reported that TNTZ alloy can have wide range of mechanical properties by performing heat treatment or thermo-mechanical treatments [1,2]. This alloy has an excellent corrosion resistance in air and body fluids [3-5]. In order to know the behavior of this alloy in oral cavity environment, corrosion rate of this alloy is then investigated in modified artificial saliva medium. Our previous investigation in Indonesia on the corrosion test of TNTZ in artificial saliva using weight loss method indicates that the weight loss of TNTZ is zero up to exposuring time of 480h [6]. At the same time, weight loss of two conventional alloys for dental application; stainless steel (SS) and cp-Ti can be easily measured, that is 0.01g and 0.03 g, respectively. In order to know exactly the corrosion rate of TNTZ in a modified artificial saliva, the corrosion rate is then measured by using potensiostat in IMR. The corrosion rate of the most popular titanium, Ti-6Al-4V was also determined for comparison.

The samples of TNTZ contains (in mass%) 31.5Nb, 11.6Ta, 4.7Zr, 0.03Fe, <0.02Al and bal. While, the content of Ti-6Al-4V (Ti64) is 6.2 Nb, 3.9V,87Ti and remains other elements. Three pieces of circular plate specimens of TNTZ and 3 pcs of those Ti64 with a diameter of 10 mm and 3 mm thickness were machined from as-received bars. All sample surfaces were grinded, polished and cleaned prior to corrosion test to obtain smooth surface specimens. The surface of specimens was then fully covered with epoxy resin except for top surface for exposing to the artificial saliva solution.

Corrosion measurements were conducted in 600ml solution of artificial saliva Fuyasama Meyer containing 0,4g NaCl, 0.4g KCl, 0.795g $CaCl_2.2H2O$, 0.69g NaH_2PO_4, and 1 g urea, maintained at pH 5.2 and 37°C using a potentiostat model (VERSA studio-200) controlled by a personal computer. Potentiodynamic polarization studies were carried out at a scan rate of 1 mV/s to obtain Tafel slot of all 6 specimens. After corrosion test, specimen surfaces were observed by SEM, EDX and XPS.

Tafel curve of all specimens that is obtained from potensiostat test is shown in Fig.1. While calculation result of the Tafel curve is tabulated in Table 1. It can be seen that I_{corr} of TNTZ is much smaller than that of Ti64. As for the average E_{corr} of TNTZ is also smaller that of Ti64. However, the E_{corr} of Ti64 is more stable than that of TNTZ. Since corrosion rate (CR) is proportional to I_{corr} value, the corrosion rate of TNTZ is much lower than that of Ti64. Averaged corrosion rate of TNTZ is 4,48x10^{-9} mmy^{-1}, while Ti6Al4V is 6,37x10^{-8} mmy^{-1}. This rate indicates that the corrosion rate of TNTZ is much smaller than the conventional dental wires of NiTi and stainless steel at pH 5 [7].

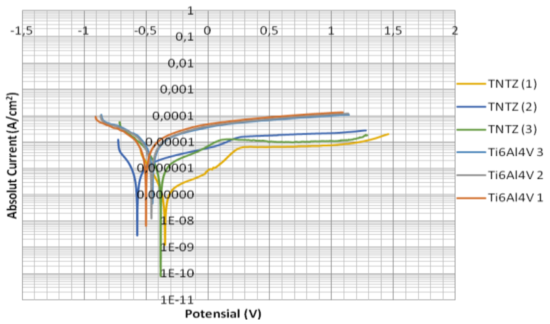


Fig. 1. Tafel plot TNTZ and Ti64 specimens

Table 1 Result of potensiostat test on TNTZ and Ti6Al4V

Specimen		I_{corr} (A)	E_{corr} (mV)	CR (mmy^{-1})
TNTZ	1	1,57 x10^{-7}	-350	1,36 x10^{-9}
	2	6,99 x10^{-7}	-570	6,00 x10^{-9}
	3	6,91 x10^{-7}	-380	6,07 x10^{-9}
	Avrg	5,16 x10^{-7}	-433	4,48 x10^{-9}
Ti-64	1	7,29 x10^{-6}	-406	6,33 x10^{-8}
	2	7,51 x10^{-6}	-440	6,52 x10^{-8}
	3	7,20 x10^{-6}	-490	6,25 x10^{-8}
	Avrg	7,33 x10^{-6}	-463	6,37 x10^{-8}

SEM observation shows that there is micro-pitting in TNTZ and Ti64 (Fig.2). Micro-pitting in TNTZ is deeper than that in Ti64. EDX examination near pitting area show that the content of oxygen in this area is much higher than other area on the surface of TNTZ (Fig.3). This confirms formation of pitting corrosion in this area. However, the pitting area of Ti64 is swallower than that of TNTZ.

Typical binding energy of TNTZ is shown in Fig. 4. This XPS result show that binding energy and intensity of Oxygen and Titanium is higher than that of Nb, Zr and Ta. The binding energy of those of Ti64. This indicates that formation of predominantly TiO_2 layer in the surface of TNTZ in addition to Nb, Zr and Ta oxides. While, binding energy and intensity of oxygen and Titanium in Ti64 is lower than those of TNTZ.

We need some discussion with Prof. Niinomi and his laboratory members to interprete this result. However, the limitation of time ask us to back to our country. It is great pleasure for me to join in Biomaterial Science for 2 months (July and August 2014). Thank you very much to Prof.Niinomi, Dr. Nakai and all IMR staff for kindness and cooperation during this visiting professorship.

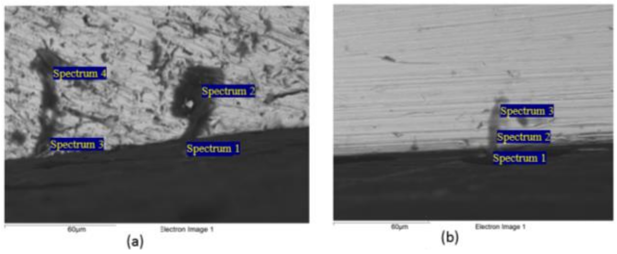
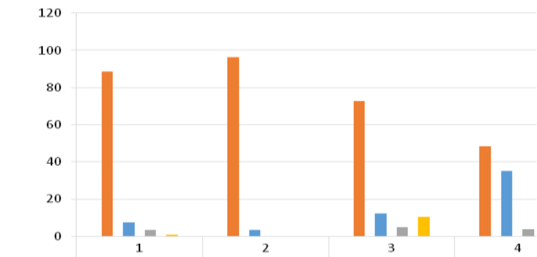


Fig.2 SEM micrograph of (a) TNTZ dan (b) Ti64



	1	2	3	4
Oksigen	88,69	96,55	72,59	48,36
Titanium	7,35	3,45	12,13	35,2
Zirkonium	3,2		4,82	3,71
Niobium	0,76		10,45	12,74

Fig.3 Element distribution near micropitting of TNZ

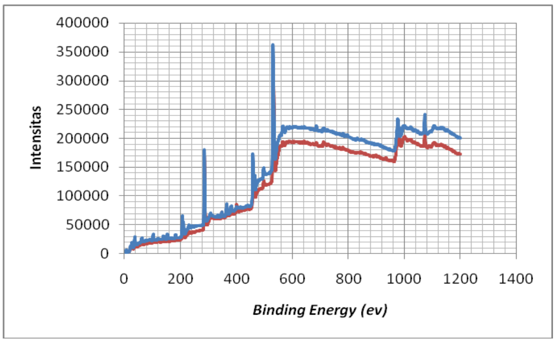


Fig.4. Binding energy spectrum of TNTZ

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