Repassivation on Type 316L Stainless Steel with Cyclic Deformation in Simulated Body Fluid including Cells

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Type 316L stainless steel is widely used as surgical implants because of high corrosion resistance owing to the passive films. However, in body environment, the passive films are liable to be broken mainly by cyclic deformation and harmful ions, such as chloride. The breakdown of passive films may cause localized corrosion to release metallic ions which results in toxic reactions to body. Usually, the passive films are repaired after breakdown. This is called repassivation. However, the role of the proteins and cells on the breakdown of passive films and repassivation has not been well understood. In this work, therefore, we examined the metal dissolution and repassivation behavior of type 316L stainless steel with cyclic deformation in simulated body fluid including proteins and cells.

Material examined was type 316L stainless steel. The tensile test samples with a gauge size of 15×4×1 mm^3 were sealed with PTFE adhesive tapes leaving the gauge section exposed to an electrolyte and immersed in α-MEM+10 % FBS which is commonly used for cell culturing. The immersion period was 1day or 1 week. In order to examine the role of cells adhered on the samples, osteoblast-like cells (MC3T3-E1) were cultured on some samples for 1 week. Then the sample accommodated in an electrochemical cell was attached to a hydraulically-operated servo-pulsar. The electrochemical cell was filled with α-MEM + 10 % FBS kept at 37 °C under atmosphere controlled as 5 % CO_2, 20 % O_2 and 75 % N_2. Then a cyclic stress which was modulated as sinusoidal wave was applied to the samples. The stress ratio (R: minimum stress/maximum stress) was 0.1 and the maximum stress was 300 MPa. The stress frequency was 10 Hz. During the test, the transient of strain, stress and corrosion potential were recorded.

Figure 1 shows typical transient of corrosion potential during cyclic deformation until 100,000 cycles for the samples exposed under three conditions prior to the cyclic test. Initially, corrosion potential of all samples decreased immediately after the beginning of cyclic deformation. Then, the corrosion potential increased. The decrease and increase of the corrosion potential indicate the breakdown of passive films and repassivation.

The corrosion potential decreased to about -140 mV for the sample immersed in α-MEM+10 % FBS for 1 day. On the other hand, the corrosion potential decreased to about -120 mV for the sample immersed for 1 week and about -80 mV for the sample with cells. This suggests that proteins and cells adhered on the sample surface suppress the metal dissolution. Successively, the corrosion potential of the sample immersed for 1 day began to increase from about 1,800 cycles, although the corrosion potential of the sample immersed for 1 week and the sample with cells began to increase from about 2,200 cycles and about 4,000 cycles, respectively. This suggests that proteins and cells adhered on the sample surface hinder the repassivation. When proteins or cells adhered on the sample surface, they prevent the newly created surface from contacting with the solution. However, between proteins or cells and the sample surface, an occluded space is made. In this space, the diffusion of solute is blocked. Therefore, metallic ions concentrate to exceed their solubility to form hydroxide and H^+ ions as hydrolysis reaction. As a result, the pH in the occluded space becomes lower and repassivation is hindered.

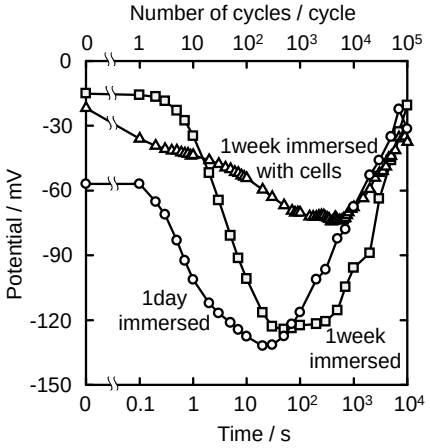

Fig. 1 Typical transient of corrosion potential of three condition samples during cyclic deformation until 100,000 cycles.