Effect of Applied Stress on Dissolution Morphology and Pit Initiation Behavior of MnS Inclusion in Stainless Steel

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Sulfide inclusions such as MnS are known to be preferential sites for pit initiation of stainless steels. Under applied stress, austenitic stainless steels suffer from stress corrosion cracking in chloride environments. Therefore, the influence of applied stress on the corrosion behavior of the inclusions is an important and interesting subject from a scientific and practical point of view. [1] Microelectrochemical measurements were carried out to ascertain the effect of stress on the dissolution morphology and pit initiation behavior of MnS inclusions.

Type 304 stainless steel bar, containing around 0.02 mass % S, was used. Flat tensile specimens (thickness: 2 mm) were cut transverse to the rolling direction. The length and width of the gage section was 11 mm and 3 mm, respectively. The tensile specimens were heat-treated at 1353 K for 1.8 ks and water-quenched. Their surfaces were polished down to 1 μm diamond paste. The inclusions were elongated to the rolling direction, and it was confirmed that the inclusions consisted of manganese, sulfur, and a small amount of chromium (around 11 at.%). This type of inclusion was simply referred to as MnS.

A constant stress was applied in the air. After that, potentiodynamic microscopic polarization curves (electrode area: 140 μm in diameter) were taken in a naturally aerated a 1.5 mol kg^{-1} $MgCl_2$ solution at 298 K. The applied stress was set at 60% of the 0.2% proof stress of the specimen. Figure 1 shows the effect of stress on the polarization and dissolution behavior of the small areas with MnS inclusion. The increase in current density around 0.35 V was due to MnS dissolution. [1,2] In the measurement without stress, even though the MnS dissolution occurred, no pitting was initiated. After the polarization, the selective dissolution (trench formation) at the boundaries of the MnS and the steel matrix was observed. In contrast, a stable pit was initiated in the MnS dissolution region of the specimen with stress. In this case, the MnS inclusion was seem to be perforated by the inclusion dissolution. In addition to this, grooves were visible on the MnS surface. It is suggested that applied stress affects the dissolution behavior of the MnS inclusions and promotes the pit initiation at the inclusions.

Figure 2 shows the effect of potential on the inclusion morphology with applied stress. The polarization of specimen A was stopped before the MnS dissolution. As seen in Fig. 2b, no groove was observed, whereas the grooves appeared on the inclusion in specimen B, which was polarized until the MnS dissolution took place. The applied stress is likely to cause the grooves, by which the MnS inclusions are perforated. The steel matrix under the inclusions is exposed to the solutions, and then a stable pit is readily initiated at the inclusions under applied stress.

1. T. Suter, E. G. Webb, H. Böhni, and R. C. Alkire, *J. Electrochem. Soc.*, **148**, B174 (2001).
2. A. Chiba, I. Muto, Y. Sugawara, and N. Hara, *J. Electrochem. Soc.*, **159**, C341 (2012).

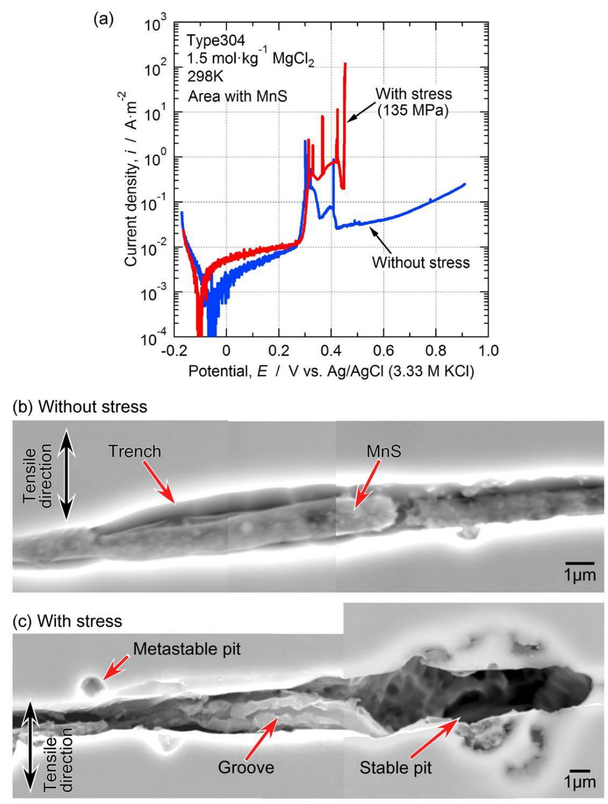

Fig.1 (a) Effect of stress on microscopic polarization curves for the small areas with MnS inclusion in 1.5 mol kg^{-1} $MgCl_2$ at 298 K. (b, c) SEM images of the inclusions after the polarization measurements: (b) with stress and (c) without stress.

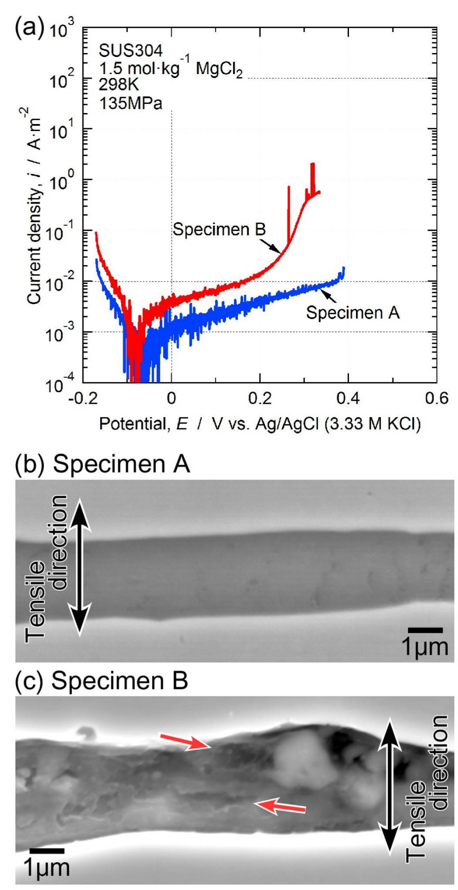

Fig.2 Effect of electrode potential on MnS morphology with applied stress. (a) Microscopic polarization curves for the small areas with the inclusion in 1.5 mol kg^{-1} $MgCl_2$ at 298 K. (b, c) SEM images of the inclusions after the polarization measurements. The arrows indicate the grooves.