Introducing a new solution for detecting the StSt IGC susceptibility based on DL-EPR method

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Sensitization is a well-known phenomenon in stainless steels which make them susceptible to intergranular corrosion (IGC) or intergranular stress corrosion cracking (IGSCC). Accurate measuring of the degree of sensitization (DOS) is crucial and several methods[1-5], have been developed for this purpose including electrochemical reactivation (EPR) technique as a standard procedure[1]. EPR is a quantitative, non-destructive method which indicates increasing sensitization by increasing C-ratio in 0.5M H_2SO_4 + 0.01M KSCN solution[1]. However, improving the EPR resolution, to detect the lowest possible DOS, by either modification in technique[3-6], and/or solution constituents[6-8], is of great demand. In this study, a new solution owing better resolution on austenitic stainless steels DOS assessment is proposed. Moreover, replacing KSCN with the new dipassivator, make the new solution more immune with less hazardous effects.

The new suggested solution is based on hydrochloric acid and sodium thiosulfate (0.05M HCl+0.0005M $Na_2S_2O_3$). Comparing to the standard solution, both the acid and dipassivator agent have been modified[1]. To evaluate the new solution efficiency, three sensitization heat treatments procedure at 650°C for 0, 10 and 60 min were applied on candidate alloy, 304L stainless steel. A double loop EPR (DL-EPR) was employed in which the specimen was polarized from 50 mV below OCP to the passive region. Once the pits initiation was occurred[8-9], the potential was immediately reversed toward the OCP and DOS was calculated as a ratio of maximum reactivation to the maximum activation current density[4,6,8].

Comparing the results of new solution with the standard one, shown in Fig. 1, reveals that in the new solution, the C-ratio has been significantly increased. For instance, after sensitization time of 60 min, C-ratio's of 17 and 30 are extracted form standard and the new solution, respectively. This indicates an improving of about 50% in DOS detection in compare with standard solution[1,3-5]. The new solution is even more responsive to the lower sensitization time; See Fig. 1. Generally, DOS responsive depends on the acid type as well as the dipassivator agent. In the new solution, the principle of DOS detection is almost similar to the standards one. However, in the presence of HCl, the passivity is slightly deteriorated; only regions with sufficient chromium content can form an integrated passive layer and a defective passive layer at the vicinity of grain boundaries is produced. As a result, in reactivation stage, in the new solution, the passivity breakdown can occur more feasible in compare with the standard solution[10]. Moreover, the presence of $Na_2S_2O_3$ (in fact $S_2O_3^{2-}$ ions) as dipassivator agent accelerates the passivity breakdown in chromium depleted regions close to the grain boundaries. This in turn, is led to improving in DOS detection resolution. As an example, Figure 2 shows DL-EPR result for specimen which has been sensitized (inserted micrograph in Fig.2) for 60 minutes in 650°C in new solution. The activation and reactivation current density can be calculated and the C-ratio is estimated to be 30, which is 50% more than the standard one[1], as shown in Fig. 1.

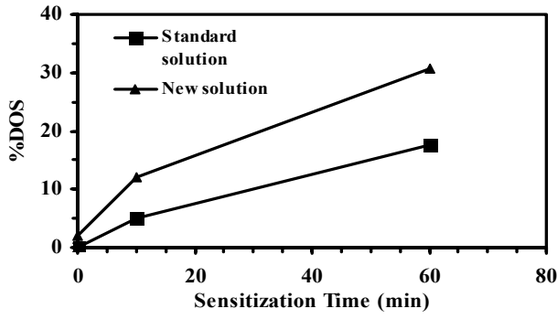

Figure 1. %DOS in standard solution and new solution

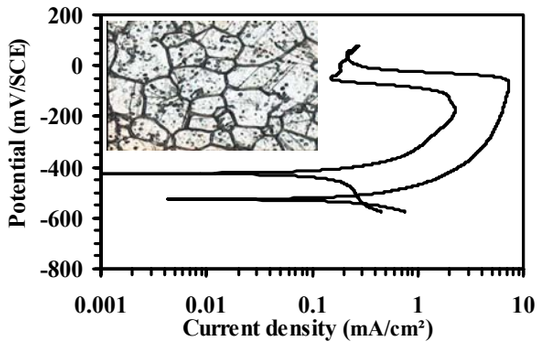

Figure 2. DL-EPR of 304 StSt after 60 min sensitization time in new solution

In summary, the new introduced solution based on 0.05M HCl+0.0005M $Na_2S_2O_3$ is faster and gives higher resolution in compare with the standard solution with less hazardous effects.

References:

1. ASTM G 108-94, standard test method for electrochemical reactivation (EPR) for detecting sensitization of AISI type 304 and 304L stainless steels
2. ASTM A 262 – 02a, standard practices for detecting susceptibility to intergranular attack in austenitic stainless steels
3. H.-E. Buhler et al., Corrosion Science 45 (2003) 2325-2336.
4. Pedro de Lima-Neto et al, Corrosion Science 50 (2008) 1149-1155
5. A.Arutunow, K.Darowicki, Electrochemical Acta 53 (2008) 4387-4395
6. Vivekanand Kain, Yutaka Watanabe, Journal of Nuclear Materials 302 (2002) 49-59
7. Tsung-Feng Wu, Wen-Ta Tsai, Corrosion Science 45 (2003) 267-280
8. Tsung-Feng Wu, Tzu-ping Cheng, Wen-Ta Tsai, Journal of Nuclear Materials 295 (2001) 233-243
9. Vladimir Cihal, Rudolf Stefec, Electrochemical Acta 46 (2001) 3867-3877.
10. V.Cihal et al., EPR, Chem. Biochem. Eng. Q. 21 (1) 47-54- (2007)