

Passivation Mechanism of NiCoCrMo alloy with Cu Addition in HF Acid Solution

A small addition of Cu yielded a tremendous improvement in corrosion resistance of Ni–30Co–16Cr–15Mo–6Fe alloy, even after cold forging. In addition, the passivation of the alloy by a Mo-oxide-dominated passive film was completely changed to passivation by a Cu-dominated one during immersion in hydrofluoric acid solution.

Recent research has indicated that substituting Co for Ni by up to 30 wt.% can greatly increase the strength of the alloy without sacrificing its corrosion resistance to HF solutions [1]. This is made possible by greatly reducing the stacking fault energy (SFE) of the alloy by alternating its plastic deformation mechanism because the cross slip is significantly inhibited in low-SFE materials, leading to higher work hardening of materials and therefore higher hardness or strength. The strength of NiCoCrMo alloy can be further enhanced by cold working, although the corrosion resistance of the deformed NiCoCrMo is greatly reduced in comparison to that of NiCrMo [2]. More recent research indicated that even a small addition of Cu (approximately 2 wt.%) yielded a tremendous improvement in the corrosion resistance of NiCoCrMo, even after severe plastic deformation. However, the passivation mechanism of the Cu-modified alloy has yet been clarified. In the present research, the passivation mechanism of NiCoCrMo alloy modified by 2 wt.% Cu during immersion in HF solution was investigated and discussed in detail.

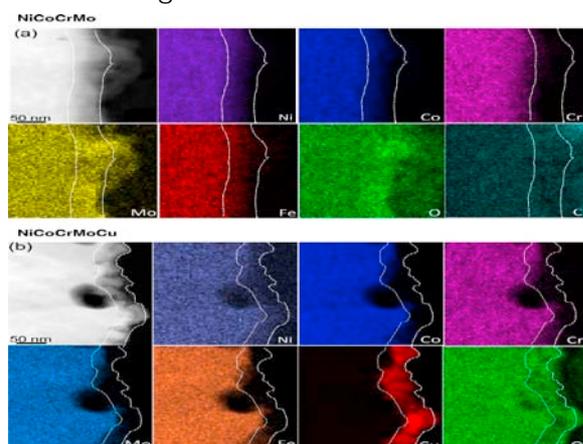


Fig. 1 SEM images and corresponding EDS elemental mappings in the cross section of the passive film of (a) NiCoCrMo alloy for Ni, Co, Cr, Mo, Fe, O, and C, and (b) NiCoCrMoCu alloy for Ni, Co, Cr, Mo, Fe, Cu, and O after immersion in HF solution (5.2 M) at 100 °C for 100 h.

Fig.1 shows that the passive film of NiCoCrMo alloy is approximately 20 nm in depth and is slightly rich in both Mo and O, and the concentrations of other elements are lower. In NiCoCrMoCu sample, the passive film is rich in Cu, and the O intensity is slightly higher than that of the matrix. It is worth noting that Mo, which is the dominant component in NiCoCrMo alloy, was almost completely replaced by Cu in the film, although its concentration in matrix is low.

From the obtained results, it is evident that the addition of 2 wt.% Cu greatly enhanced the corrosion resistance of NiCoCrMo alloy to HF solution, which is more obvious on the samples subjected to cold forging. Cu demonstrates a positive effect in terms of enhancing the corrosion resistance of the alloy, which is characterized by the extremely low mass loss during immersion testing and a Cu-rich passive film on the sample surface. In addition, such a small addition of Cu completely altered the passivation mechanism of NiCoCrMo alloys from Mo-dominated passivation into Cu-dominated passivation in HF solution.

Although the high resistance of pure Cu and its alloys in HF acid solution has been well known, its tremendous effect even under a minor addition has not been reported extensively. In the presence of Cu, due to the highest standard electrode potentials of Cu (Cu^{2+}/Cu , 0.342 V) Cu does not react with HF acid solution, and with the progress of selective leaching of other elements from the alloy in HF solution into stable ions, Cu segregated as a compact film on the out most surface of sample. This would be the predominant reason for the inhibiting effect of Mo fluorides by Cu.

References

- [1] Y.P. Li, X.R. Fan, N. Tang, H.K. Bian, Y.H. Hou, Y. Koizumi, A. Chiba, *Corros. Sci.*, 78 (2014), 101–110.
- [2] Y.H. Hou, Y.P. Li, C. Zhang, N. Tang, Y. Koizumi, A. Chiba, *Corros. Sci.*, 90 (2015), 133–139.

Keywords: Alloy, corrosion, microstructure

Yunping Li, School of Materials Science and Engineering, Central South University

E-mail: lyping@csu.edu.cn

<http://www.csu.edu.cn>