Journal of Alloys and Compounds 639 (2015) 365–372

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: www.elsevier.com/locate/jalcom

Inhibition of localized corrosion of Ni–Ti superelastic alloy in NaCl solution by hydrogen charging

Ken'ichi Yokoyama [a,*], Yuki Hirata [a], Toshiaki Inaba [b], Kenichiro Mutoh [b], Jun'ichi Sakai [c,d]

[a] *Department of Materials Science and Engineering, Kyushu Institute of Technology, 1-1, Sensui-cho, Tobata-ku, Kitakyushu 804-8550, Japan*
[b] *Furukawa Techno Material Co., Ltd., 5-1-8, Higashi-yawata, Hiratsuka 254-0016, Japan*
[c] *Faculty of Science and Engineering, Waseda University, 3-4-1, Okubo, Shinjuku-ku, Tokyo 169-8555, Japan*
[d] *Kagami Memorial Laboratory for Materials Science and Technology, Waseda University, 2-8-26, Nishiwaseda, Shinjuku-ku, Tokyo 169-0051, Japan*

ARTICLE INFO

Article history:
Received 5 December 2014
Received in revised form 23 February 2015
Accepted 8 March 2015
Available online 14 March 2015

Keywords:
Nitinol
Shape memory alloy
Corrosion
Surface modification
Hydrogen embrittlement

ABSTRACT

Inhibition of the localized corrosion of Ni–Ti superelastic alloy in 0.9% NaCl solution has been attempted by charging with a small amount of hydrogen, which causes negligible hydrogen embrittlement. Upon a small amount of hydrogen charging, no pitting potential is observed in anodic polarization curves. From scanning electron microscope observations, localized corrosion is inhibited on the entire side surface of charged specimens. With increasing amount of charged hydrogen, the corrosion potential shifts in the less noble direction and the current density increases under anodic applied potential. When the hydrogen charged specimens are aged in the atmosphere at room temperature, the corrosion potential becomes almost the same as that of the non-charged specimen, but the inhibition of localized corrosion remains. The present study indicates that a small amount of hydrogen charging is effective for inhibiting the localized corrosion of the alloy in NaCl solution.

1. Introduction

Ni–Ti superelastic alloy generally exhibits good corrosion resistance and high reliability along with excellent mechanical properties [1–4]. Hence, the alloy is widely used in medical devices such as stents and orthodontic wires [5–8]. However, the alloy is often subjected to localized corrosion in the presence of chloride ions [9–13]. This may lead to medical accidents such as nickel allergy resulting from nickel ion dissolution or device fracture due to environmental degradation of the material [14,15]. Therefore, localized corrosion should be inhibited to further improve the reliability of the alloy.

To inhibit the localized corrosion of Ni–Ti superelastic alloy, improving the corrosion resistance by surface modification seems to be feasible and various methods have been attempted [4,16–20]. However, applicable surface modifications to prevent localized corrosion have not yet been reported. One of the reasons for this is that the modified surface layers are broken during superelastic deformation of the substrate because they do not exhibit superelasticity. Once the modified surface layers are broken, they are not regenerated. In fact, a TiN coating or oxidation of the surface of the alloy is not very effective [21,22]. A new method of inhibiting localized corrosion is thus required.

Corrosion behavior often depends on the existence of hydrogen in metals and alloys [23–27]. For example, for stainless steels [28–33], a substantial amount of hydrogen is considered to result in a decrease in corrosion resistance. In the present study, conversely, we instinctively attempt to inhibit the localized corrosion of Ni–Ti superelastic alloy in NaCl solution by charging with a small amount of hydrogen, which results in only slight hydrogen embrittlement. If hydrogen charging inhibits the localized corrosion of Ni–Ti superelastic alloy, it may be an effective method. In addition, an advantage of this method is that it changes the corrosion resistance of the matrix of the alloy rather than the surface layer; hence, it is expected to inhibit localized corrosion even under applied stress or after wear.

From another perspective, Ni–Ti superelastic alloy in an oral cavity often absorbs hydrogen [34–37]. When the amount of absorbed hydrogen exceeds 50–200 mass ppm, degradation of the mechanical properties, i.e., hydrogen embrittlement, occurs [35,38–41]. However, the effects of a small amount of hydrogen absorption on the corrosion behavior of the alloy are unknown. If the corrosion resistance is markedly reduced by a small amount of hydrogen absorption, the method of assessing the alloy for corrosion resistance should be modified. Therefore, the obtained findings will have not only academic value but also practical value.

---

* Corresponding author. Tel.: +81 93 884 3356; fax: +81 93 884 3351.
E-mail address: yokken@post.matsc.kyutech.ac.jp (K. Yokoyama).

http://dx.doi.org/10.1016/j.jallcom.2015.03.069
0925-8388/© 2015 Elsevier B.V. All rights reserved.

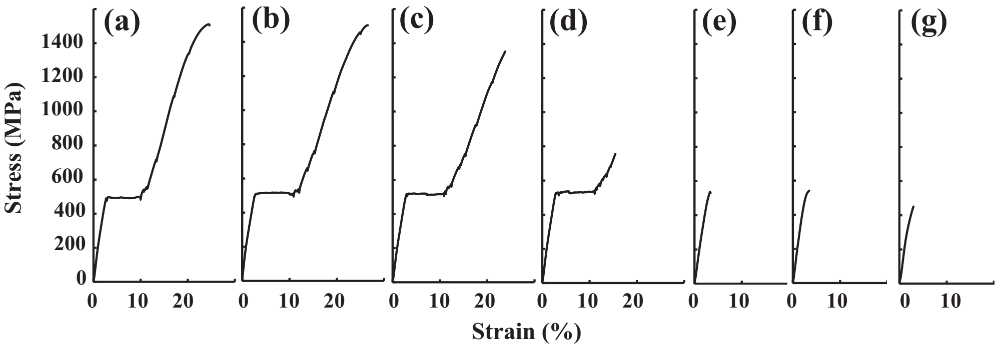

Fig. 1. Representative stress–strain curves of specimens (a) non-charged specimen and specimens charged with current density of 10 A/m^2 for (b) 10 min, (c) 1 h, (d) 2 h, (e) 4 h, (f) 8 h and (g) 24 h. The strain is calculated from the elongation (displacement of the cross head) and the initial gauge length.

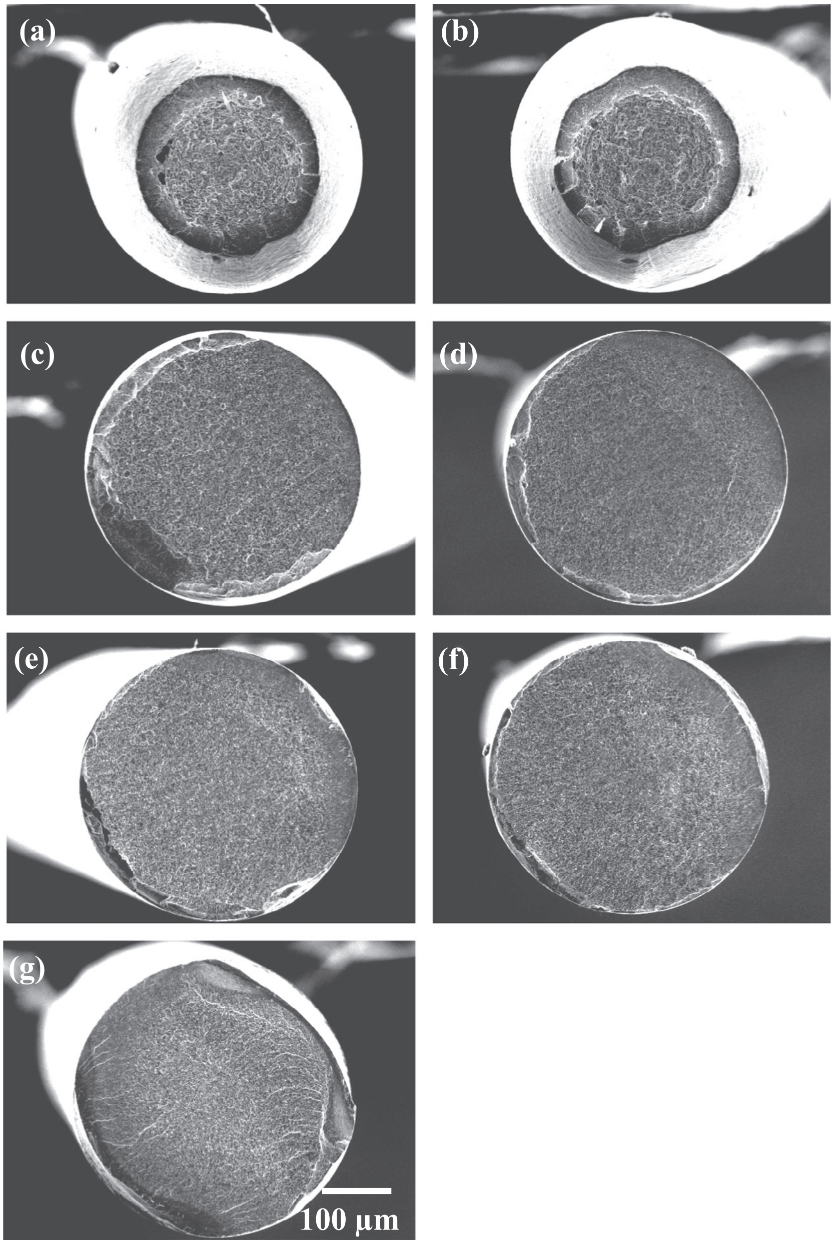

Fig. 2. SEM images of typical fracture surfaces of specimens (a) non-charged specimen and specimens charged with current density of 10 A/m^2 for (b) 10 min, (c) 1 h, (d) 2 h, (e) 4 h, (f) 8 h and (g) 24 h.