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# Effects of High Temperature Oxidation on the Structure and Properties of NiTi Alloy†

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In order to explore the ideal thermal oxidation process of NiTi alloy, mechanical polishing NiTi alloy were treated at different temperatures (400, 500 and 600 ºC) and the water affinity, super-elasticity and corrosion resistant were investigated. The results indicated that the hydrophilicity and hydrophobicity, super-elasticity and corrosion resistant of the sample, which treated at 500 ºC for 0.5 h and natural cooled in the air was more ideal compared with other samples.

**Key Words: NiTi Alloy, Hydrophilicity, Super-elasticity, Corrosion resistant.**

## INTRODUCTION

Nickel-titanium (NiTi) alloy possesses a distinctive shape memory effect, super corrosion resistance and biocompatibility, which make it most suitable for medical applications[1,2]. Various methods of surface treatment have been applied. The thermal oxidative method possesses an advantage that is simple and easy to apply[3]. The process conditions were optimized to produce the first-rank comprehensive properties of NiTi alloy. Recently there are many researches on thermal oxidative processing of NiTi alloy. Shabalovskaya and co-workers[4] reported after all samples processed by heat treatment that temperature rose of about 500 ºC for 15 min, external carbon content of all samples declined observably while nickel content raised with titanium and oxygen contents nearly unchanging. In addition, a number of experts researched on effects of various heat treatment temperature on property of some kind in a certain environment[5-8]. After thermal oxidation, corrosion resistance and histocompatibility in physiological environment can be improved[9]. However the shape memory effect can be affected if the temperature is too high[10]. In this paper, the effect of different temperatures (400, 500 and 600 ºC) on NiTi alloy was investigated.

## EXPERIMENTAL

The sample is hot rolling NiTi board and its chemical composition Ti-55.8 wt. %.

The contact angle was tested through type Data Physics OCAH200 optics contact angle meter for bearings with highly rate video to assess its hydrophilic or hydrophobic. The mechanical performance was tested by WSW3010 Electric Universal Testing Machine; the corrosive nature was tested by CP6 potentiostat manufactured by Dalian University of Technology. The corrosion conduct was carried in the Hanks' imitation liquid at 37 ºC.

TABLE-1
DIFFERENT SURFACE TREATMENT OF NITI ALLOY SAMPLES

| Surface treatment | Process condition |
|---|---|
| MP | Mechanical polishing |
| MP400 | After mechanical polishing, keeping warm at 400 ºC for 0.5 h and then cool in the air |
| MP500 | After mechanical polishing, keeping warm at 500 ºC for 0.5 h and then cool in the air |
| MP600 | After mechanical polishing, keeping warm at 600 ºC for 0.5 h and then cool in the air |

## RESULTS AND DISCUSSION

**Hydrophilicity and hydrophobicity:** Fig. 1 shows that with the increase of the temperature, the contact area between the sample and deionized water become largely and the contact angle decrease gradually. Fig. 1A is similar to Fig. 1B indicate that oxidation treatment at 400 ºC have little effects on the hydrophilicity and hydrophobicity of the samples. However, while the temperature continue increase to 500 and 600 ºC, the heating treatment process can improve the hydrophilicity of the NiTi alloy obviously.

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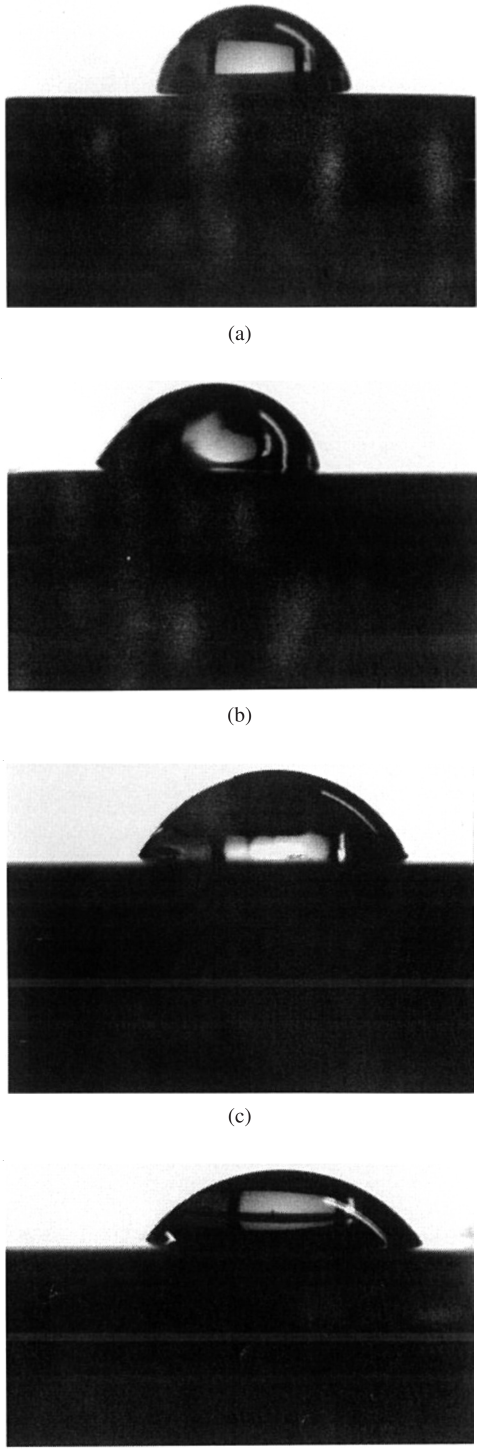

(a)

(b)

(c)

(d)

Fig. 1. Images of the contacting state of the water and different treated NiTi alloy (A:MP, B:MP 400, C:MP 500, D:MP 600)

**Mechanical property:** Fig. 2 shows the cyclic stress-strain curve of the NiTi alloy which treated by heating oxidation. When the temperature was at 400 or 500 ºC, the residual strain is between 0.1 and 0.2 %, it can almost fully recover; but when the temperature reach to 600 ºC, the bottom stress platform of the cyclic stress-strain curve disappeared and the residual stress increased to 4.4 %, then, the superelasticity of the sample disappear.

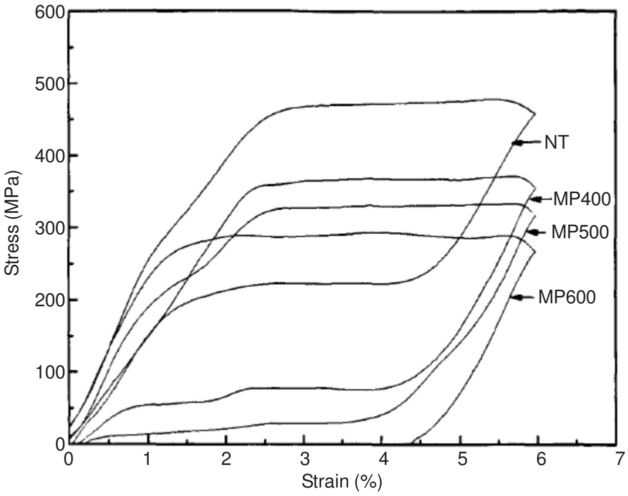

Fig.2 Stress-strain cycle curves after oxidation treatment

**Corrosion resistance:** It is concluded that the $E_{corr}$ of mechanical polishing NiTi alloy decreased obviously after oxidation treatment at 400 ºC for 0.5 h, the corrosion resistance is improved (Table-2, Fig. 3). The $E_b$ of mechanical polishing NiTi alloy is 0.55 V, which is treated by heating oxidation at 500 ºC for 0.5 h and the $I_p$ decreased an order of magnitude, so, the corrosion resistance is better. To continue increase the temperature of the oxidation, the change of corrosion resistance is not obvious.

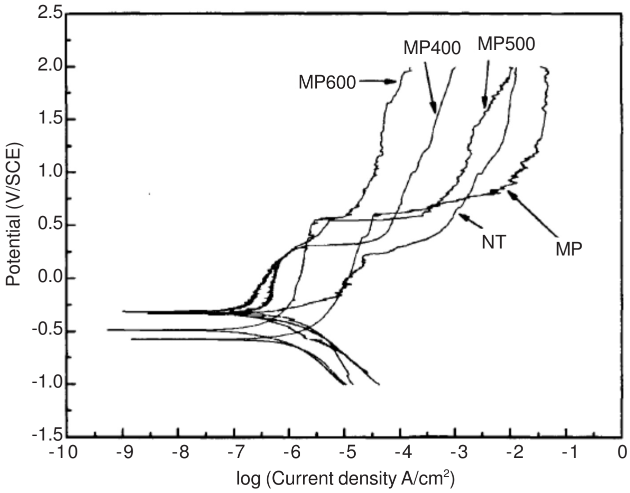

Fig. 3. Effects on the potentiodynamic curves of NiTi alloy in Hanks' solution

TABLE-2
POTENTIODYNAMIC TEST RESULTS
IN HANKS' SOLUTION FOR NiTi ALLOY

| Surface treatment | $E_{corr}$ (V) | $E_b$ (V) | $I_p$ (A/cm$^2$) |
|---|---|---|---|
| NP | -0.32 | 0.23 | $7.94 \times 10^{-6}$ |
| MP | -0.57 | 0.61 | $7.82 \times 10^{-6}$ |
| MP400 | -0.31 | 0.32 | $2.34 \times 10^{-7}$ |
| MP500 | -0.33 | 0.55 | $4.57 \times 10^{-7}$ |
| MP600 | -0.49 | 0.57 | $9.12 \times 10^{-7}$ |

## Conclusion

Heating treatment process can improve the hydrophilicity and the corrosion resistance of the NiTi alloy. When the temperature increased from 500-600 ºC, the change of corrosion resistance is not obvious,but the superelasticity of the sample disappear. In conclusion, the hydrophilicity and superelasticity and corrosion resistant of the mechanical polishing NiTi alloy treated at 500 ºC for 0.5 h is more ideal and the comprehensive effect is the best.

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