

Surface modified NiTi alloy for biomedical application

N. Shevchenko, M.-T. Pham, and M.F. Maitz

Forschungszentrum Rossendorf, Institute of Ion Beam Physics and Materials Research
P.O.B. 510119, 01314 Dresden, Germany

Introduction

Shape memory and
superelastic NiTi alloy



Medical application:
craniocerebral surgery, stents, ...

NiTi has extremely good
biocompatibility ← nature
TiO₂ layer



Ni can be released from
NiTi in biological
environments

← mechanical damage of
oxide layer

T. Duerig et al. *Mat. Sc and Eng.*
A273-275 (1999) 149-160

PROBLEM
for medical
applications:



- ✓ Toxicity
- ✓ Allergic hazards
- ✓ Carcinogenicity

Objective

Surface modification
of NiTi by plasma
immersion ion
implantation (PIII)

- ✓ Formation of Ni depleted
surface layer
- ✓ Increase of the surface layer
stability
- ✓ A barrier creation against the
Ni release from NiTi alloy

Experimental: Plasma Ion Implantation

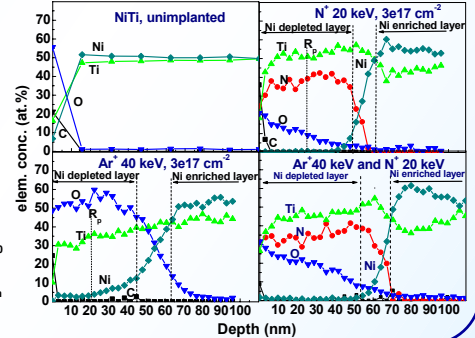
- Ions: N⁺ or Ar⁺
- Ion energy: 20 - 40 keV
- Temperature: ~200 °C
- Ion fluences: (3-5) × 10¹⁷ cm⁻²
- Substrate: NiTi alloy (55.90 wt.%Ni and 44.08 wt.%Ti)

AES: elemental depth profiles in NiTi

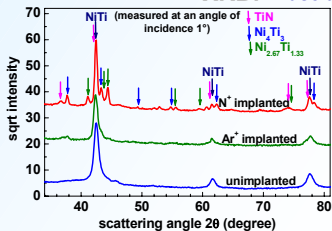
➤ Surface
composition
changes:

- ✓ Ni free layer
- ✓ Ti-N (or O)
- ✓ Ni enriched layer

| | |
|---------------------------------------|------|
| Ti-N (O) | 0 |
| Ni _y Ti _x , y>x | -50 |
| Bulk NiTi | -500 |



XRD: Phase analysis



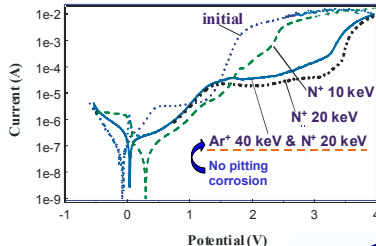
Ar⁺ and N⁺ implanted NiTi:
20 keV, 3 × 10¹⁷ cm⁻²

Phase composition:

- ← NiTi (B2); TiN; Ni₄Ti₃; Ni_{2.67}Ti_{1.33}
- ← NiTi (B2); Ni₄Ti₃ - ?
- ← cubic NiTi (B2) - austenite

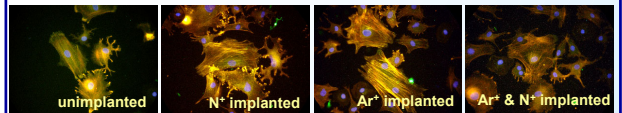
Corrosion: Potentiodynamic polarization testing in Ringer's solution

➤ The implantation leads
to an increase of the
corrosion resistance:
the corrosion current
decreases and the
corrosion potential
increases.



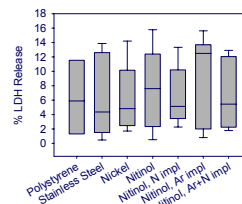
Biocompatibility

Adherence of rat bone marrow cells

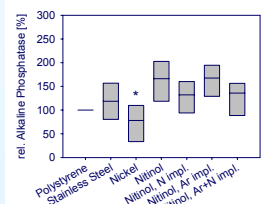


➤ No major differences in the cell morphology

Cytolysis of the cells after 4 hours (toxicity property)



Alkaline Phosphatase after 7 days (bone specific activity)



➤ No statistically significant differences can be seen between
the different surfaces

Conclusions

- The formation of the nickel - free TiN(O) surface layer by the plasma implantation of NiTi alloy is shown.
- The corrosion stability of the surface layers is increased.
- The modified surface layers show the same biocompatibility as the initial surfaces.

Acknowledgments : Dr. H. Reuther (FZR) for AES measurements.