Institute of Ion Beam Physics and Materials Research

Forschungszentrum Rossendorf

# Surface modified NiTi alloy for biomedical application

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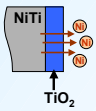
## Introduction

**Shape memory and superelastic NiTi alloy** — **Medical application:** craniosugery, stents, ...

NiTi has extremely good biocompatibility ← nature $TiO_2$ layer

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




Ni can be released from NiTi in biological environments

← mechanical damage of oxide layer

**PROBLEM for medical applications:** Ni →
- ☑ Toxicity
- ☑ Allergic hazards
- ☑ Carcinogenicity

## Objective

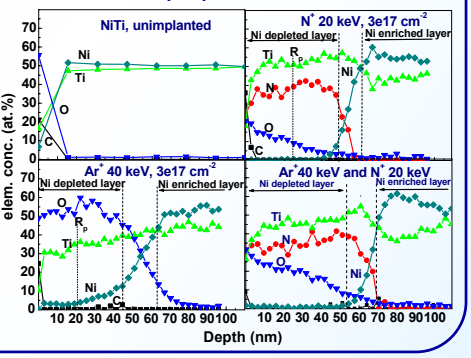
**Surface modification of NiTi by plasma immersion ion implantation (PIII)** →
- ✓ Formation of Ni depleted surface layer
- ✓ Increase of the surface layer stability
- ✓ A barrier creation against the Ni release from NiTi alloy

## Experimental: Plasma Ion Implantation

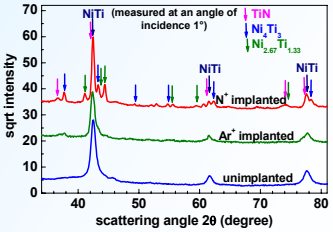
- Ions: $N^+$ or $Ar^+$
- Ion energy: 20 - 40 keV
- Temperature: ~200 °C
- Ion fluences: (3-5)x$10^{17}$ $cm^{-2}$
- Substrate: NiTi alloy (55.90 wt.%Ni and 44.08 wt.%Ti)

## AES: elemental depth profiles in NiTi

**Surface composition changes:**
- ✓ Ni free layer
- ✓ Ti-N (or O)
- ✓ Ni enriched layer


## XRD: Phase analysis

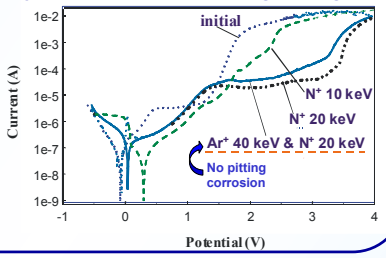



$Ar^+$ and $N^+$ implanted NiTi: 20 keV, 3x$10^{17}$ $cm^{-2}$

**Phase composition:**
- ⇦ NiTi (B2); TiN; $Ni_4Ti_3$; $Ni_{2.67}Ti_{1.33}$
- ⇦ NiTi (B2); $Ni_4Ti_3$ - ?
- ⇦ cubic NiTi (B2) - austenite phase

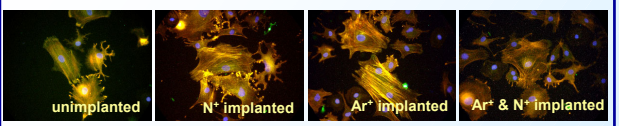
## Corrosion: Potentiodynamic polarization testing in Ringer's solution

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



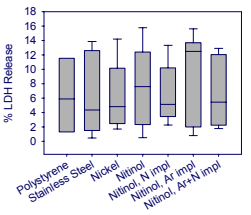

## Biocompatibility

### Adherence of rat bone marrow cells

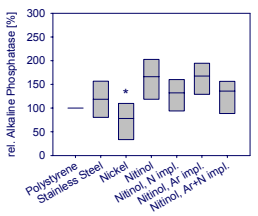



- No major differences in the cell morphology

### 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.

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