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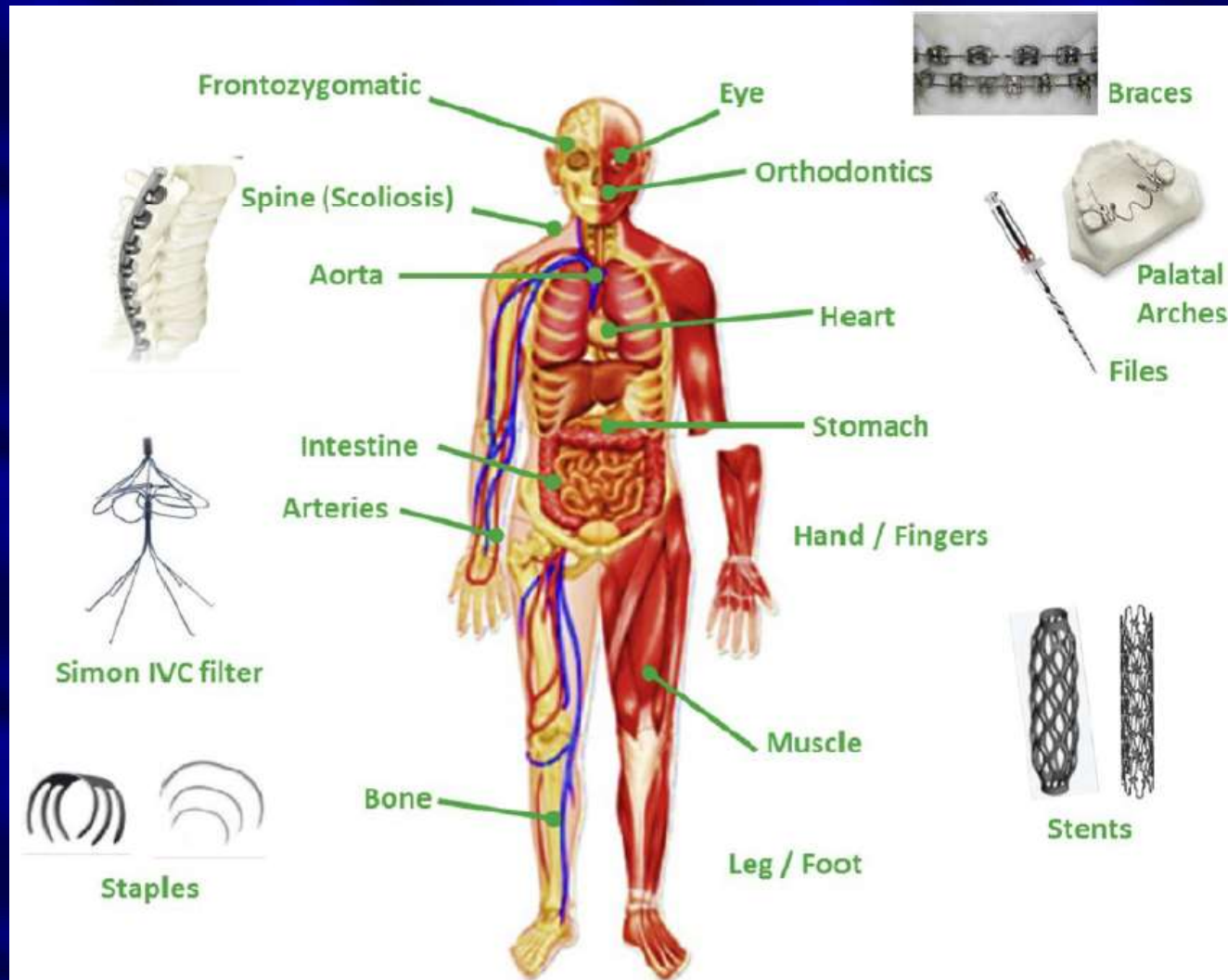
# Surface modification of the NiTi shape memory alloys for medical applications

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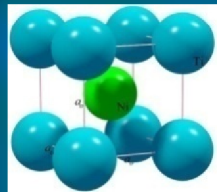
# NiTi in medicine



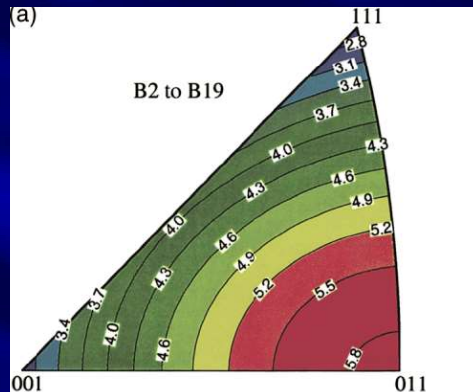
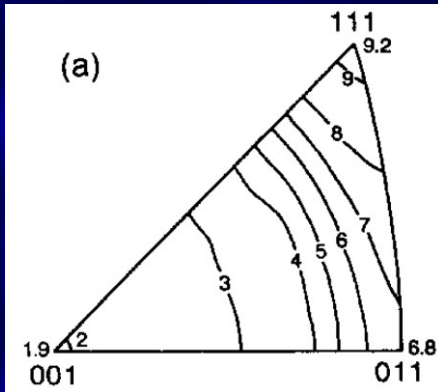
# Ways of NiTi modification

## Chemical composition

~~NiTi~~



Fe, Cu, Cr, Co, Ag, Au, Al, Mo  
Zr, Nb, Ta, Pt, Pd,



## Surface

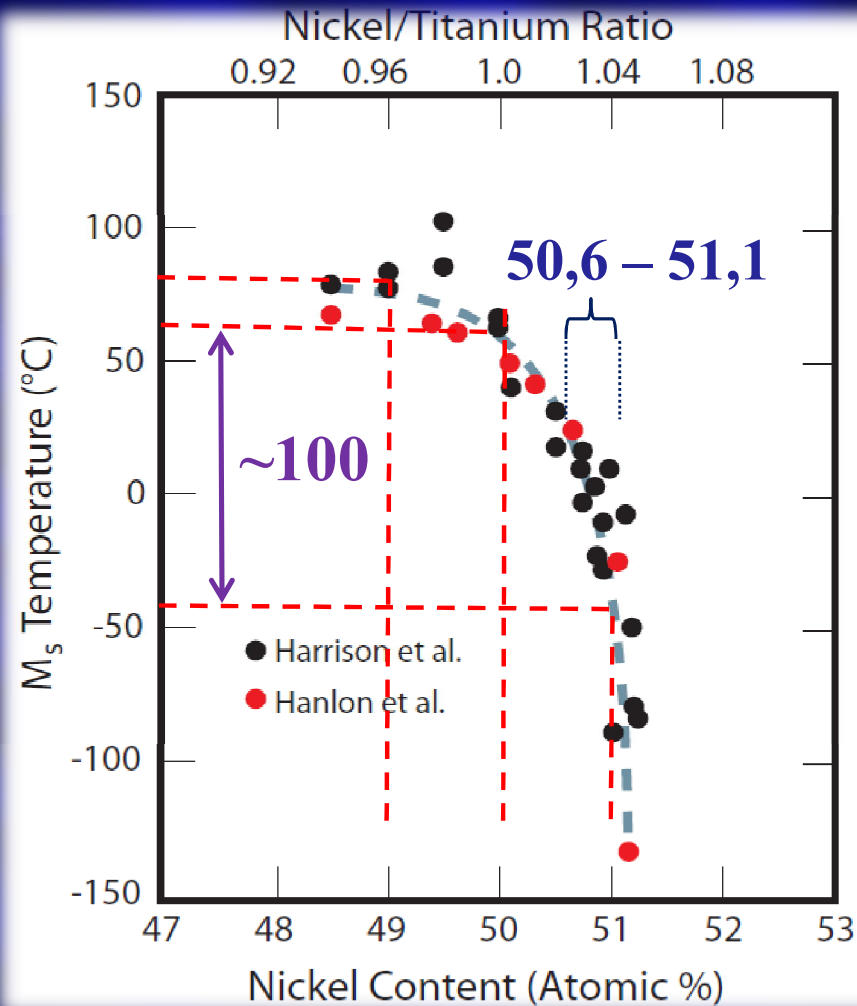
### Treatment/Layers/Coatings

Passivation  
Thermal meth.  
Implantation  
Lasser tech.  
Electrochemical..  
.....

Oxides  
Nitrides  
Nitride-Oxide  
DLC  
 $\text{ZrO}_2/\text{Al}_2\text{O}_3$   
Apatyte  
PLA, Ch....



# Effect of chemical composition on PM temperatures



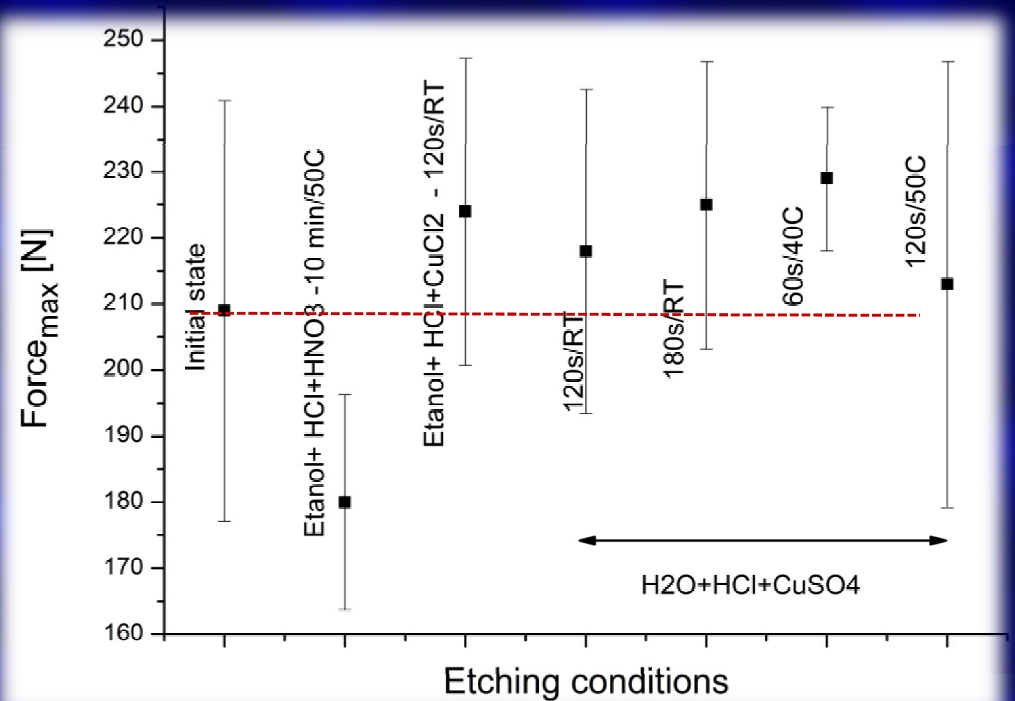
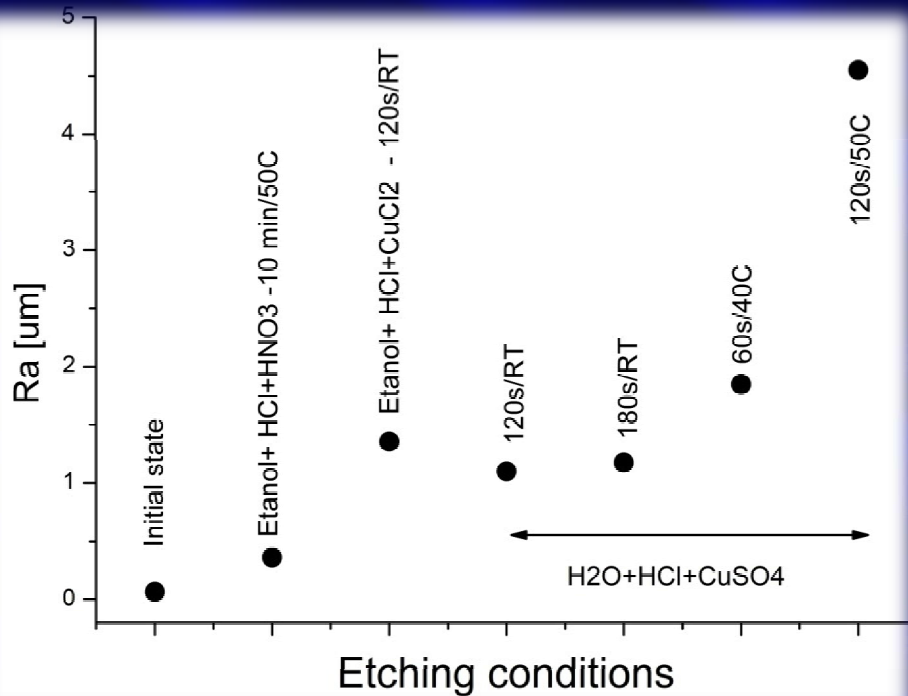


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# Surface modification

- surface treatment
  - layers/coatings depositions
-

# Etching - effects



This increases the breaking force by about 10% in comparison to the initial state. The conditions of chemical etching do not affect the course of the martensitic transformation.

# Surface modification by layers/coatings

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- carbon, diamond-like DLC;
  - aluminum oxide, zirconium oxide, phosphate, silicates;
  - titanium oxide or nitride or titanium oxy-nitride;
  - polyurethanes, polylactide or chitosan with silver additives;
  - combinations
-

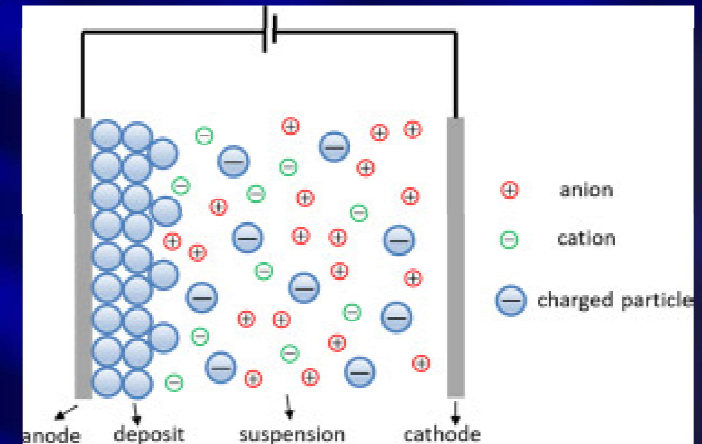


# Surface modification by technology

## ● Electrophoretic deposition (EPD) hydroxyapatite/

Voltage from 20 to 500 V

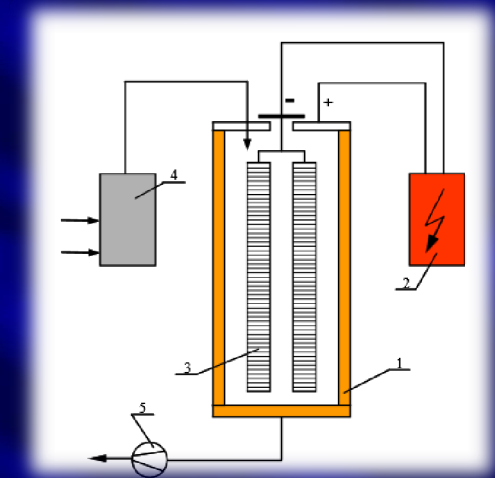
Time from 30 to 240 s



## ● Low-temperature glow discharge (LTGD) nitriding/oxidation

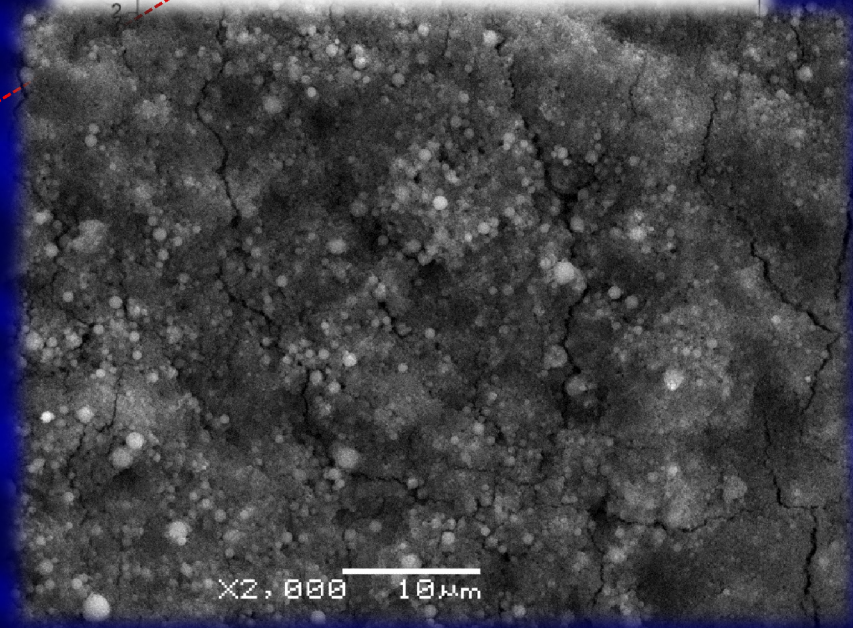
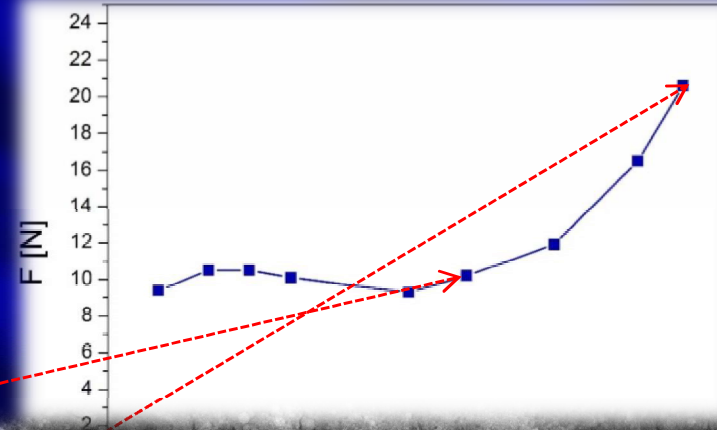
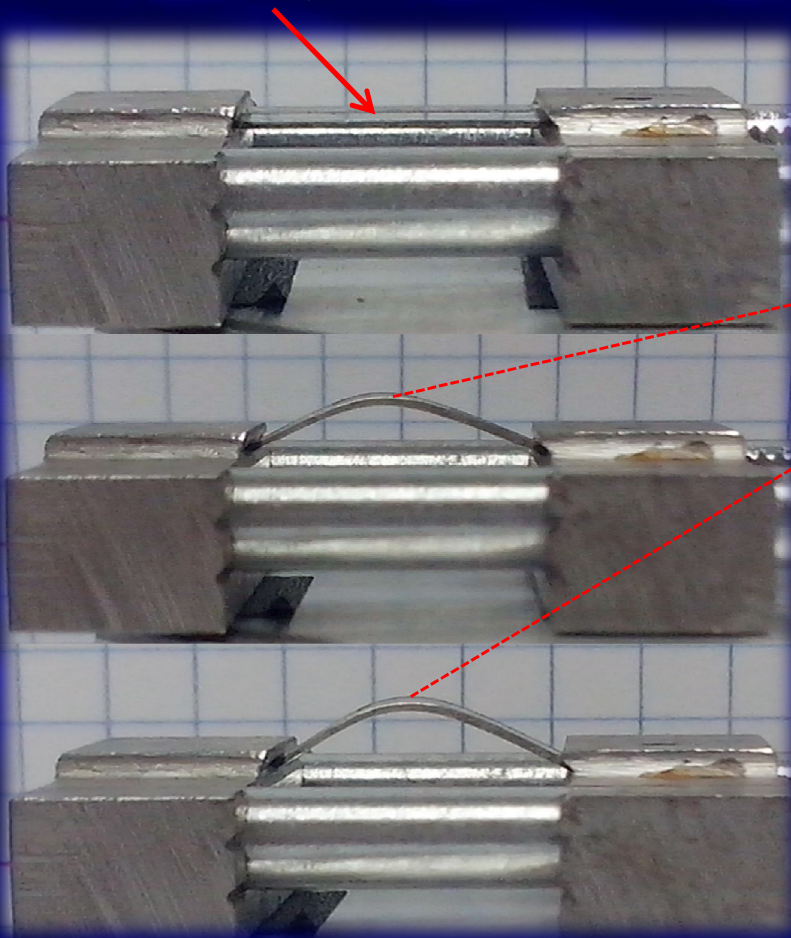
Temperature 200 °C 800 °C

Time from 10 min. to 2 hours



# Shape memory in HAP/NiTi

Sample





# Facts and discussion

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- Presence of  $\text{Ti}_2\text{Ni}$  phase about 880 nm thick

Loss of transforming phase  
Protection against Ni

- The HAP cracks at deformation of 3.5%

Layer adheres to matrix  
Does not split from matrix

Need of better protective interlayer

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# Increases of multi-properties

FIB cross-section

Glow discharge technique

Titanium oxide/nitride

NiTi alloy

Ion polishing

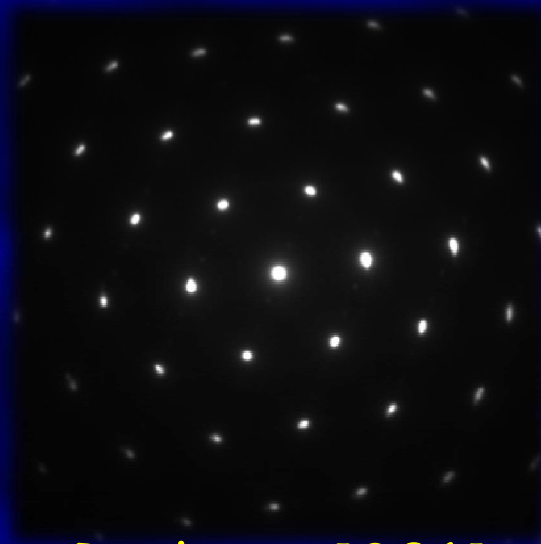
Temperature:  
250°C - 800°C

Time:  
10 min - 1h

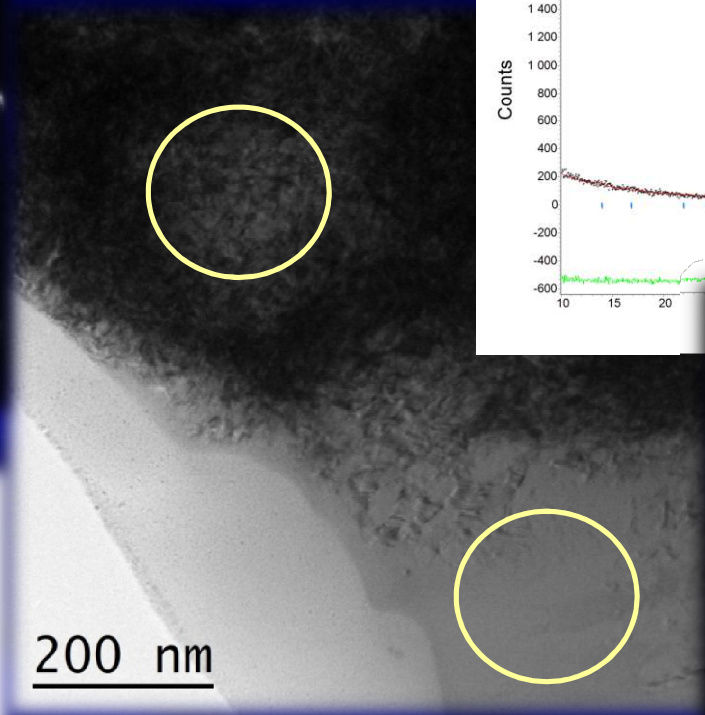
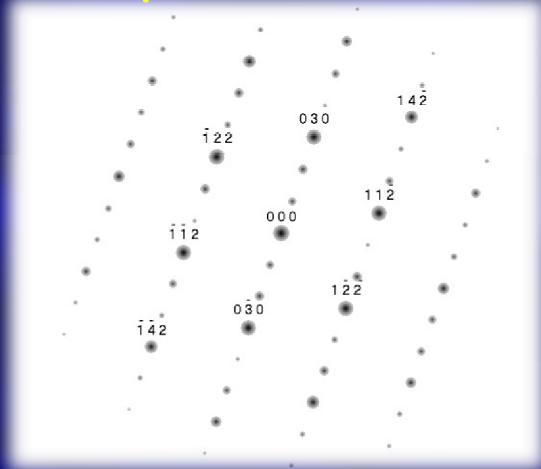
Atmosphere:  
first N - then O



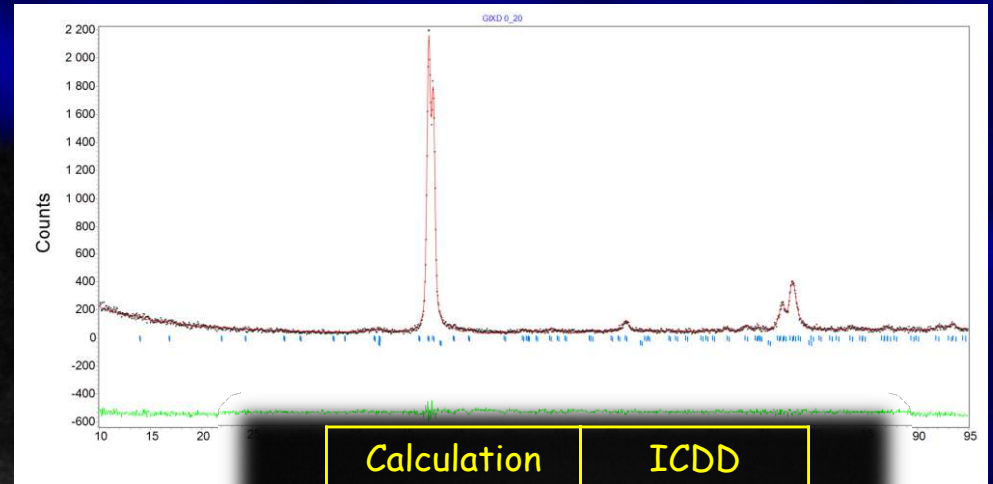
# In-plane from bottom to layer



R-phase [201]



200 nm

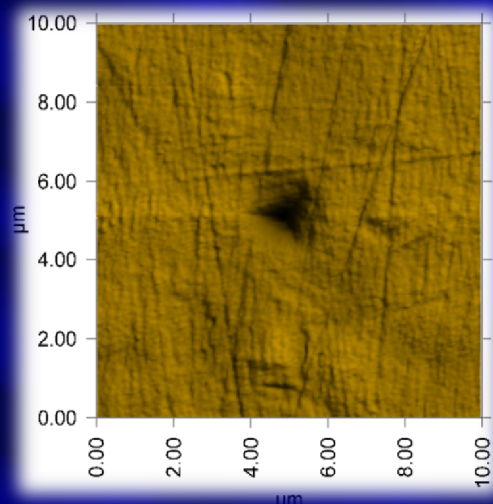


| Calculation | ICDD      |
|-------------|-----------|
| $a_0$ [Å]   | $a_0$ [Å] |
| 4,17999     | 220       |

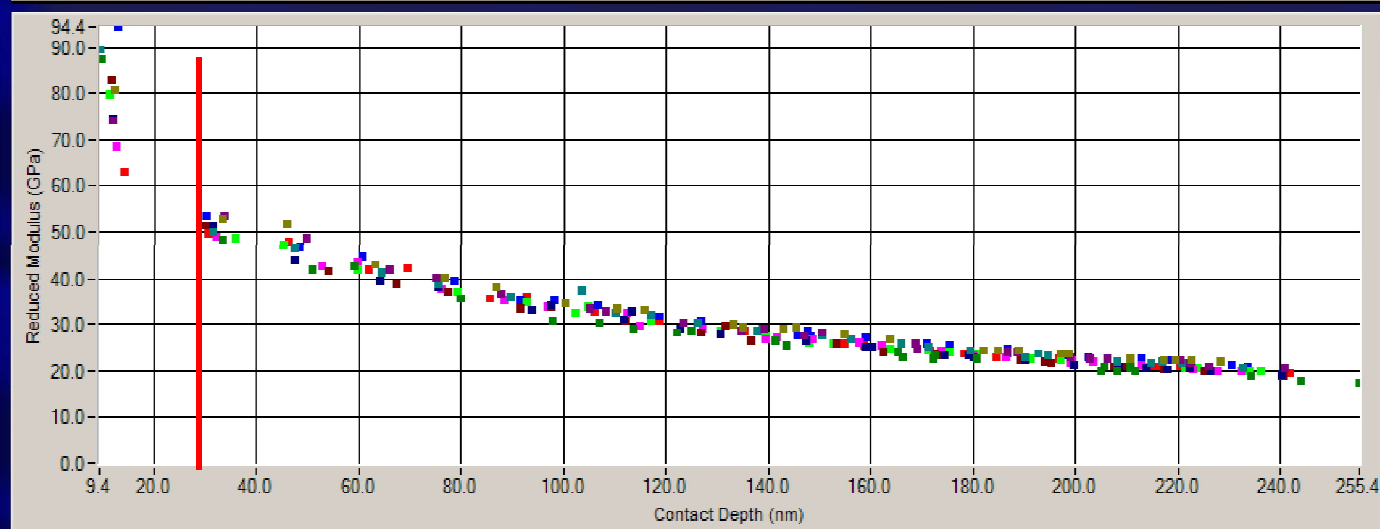
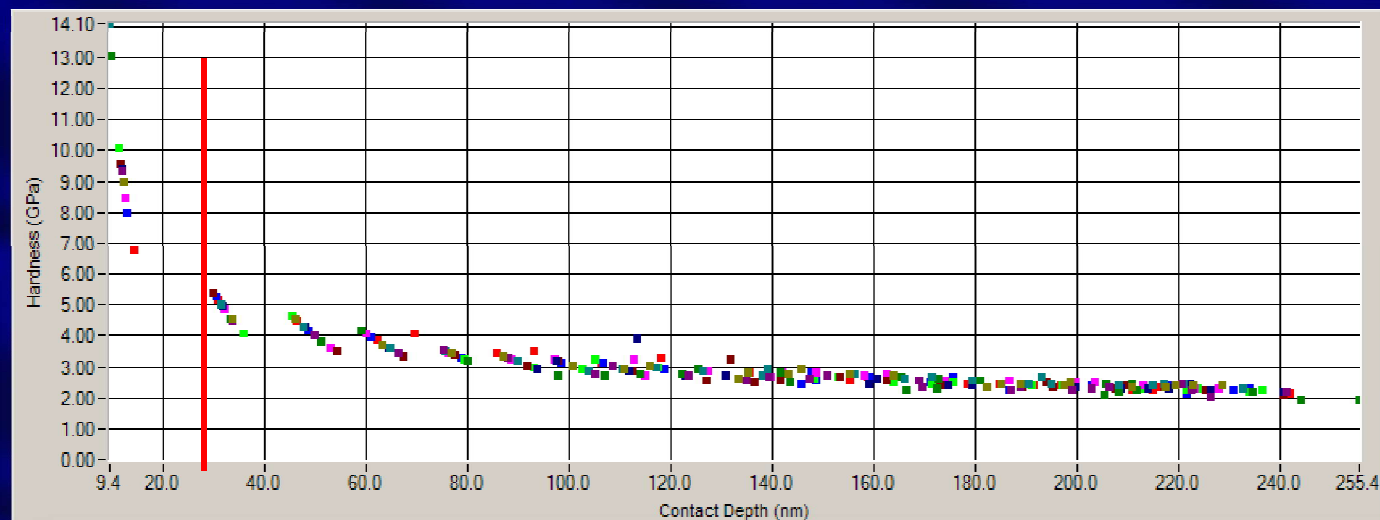


TiN

# Nitride/oxide layer - nanoindentation



Hardness  
Young Reduced  
Modulus



Penetration depth [nm]

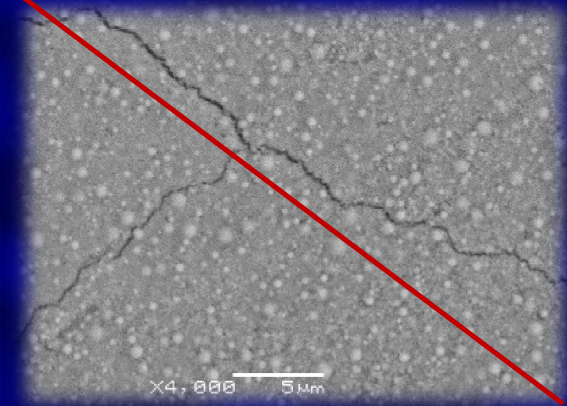
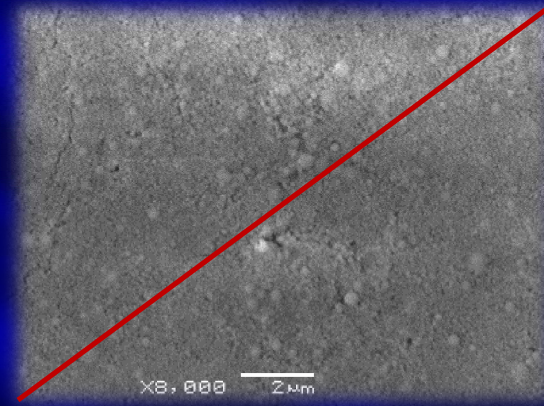
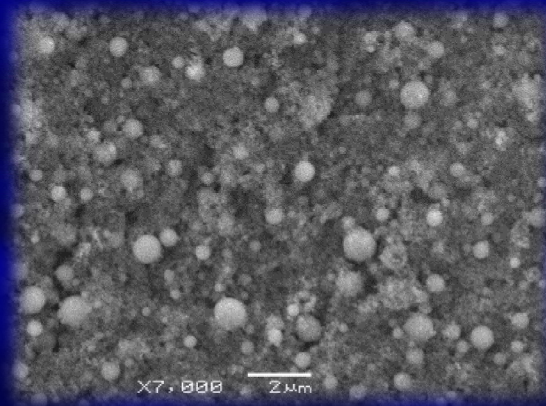
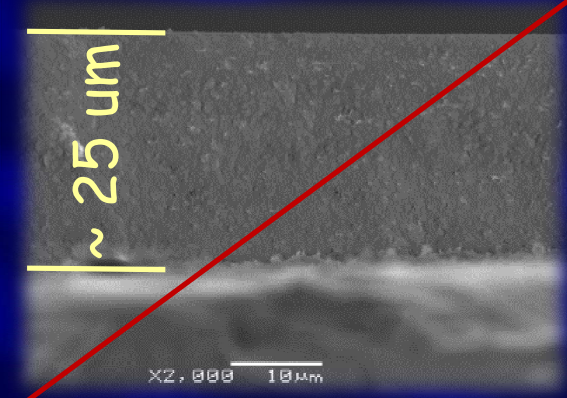
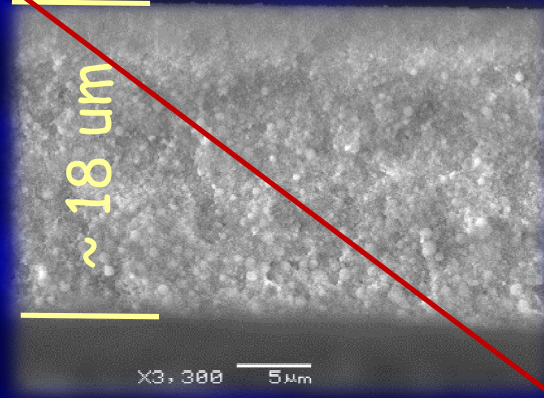
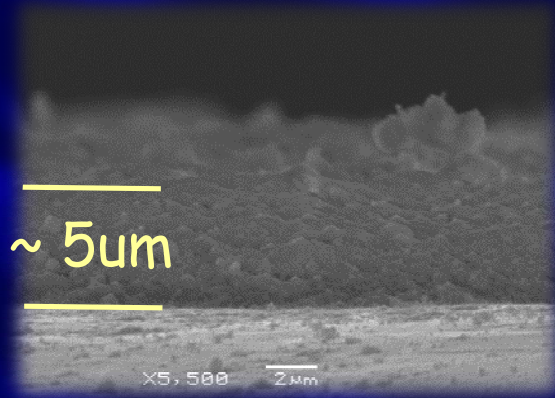
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Combination:  
HAP layer - EPD  
TiN/TiO layer - LTGD  
on NiTi alloy

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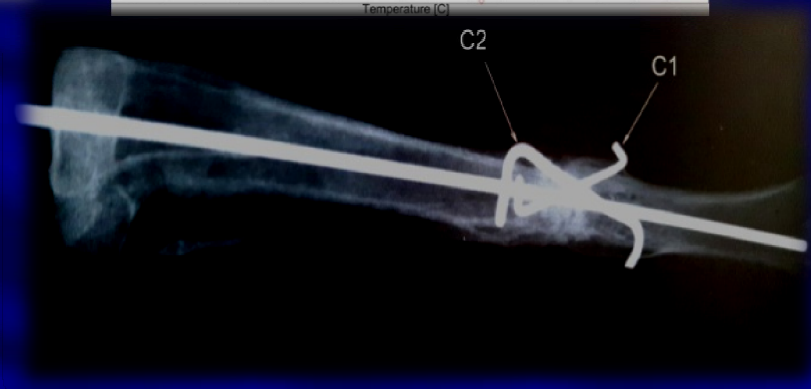
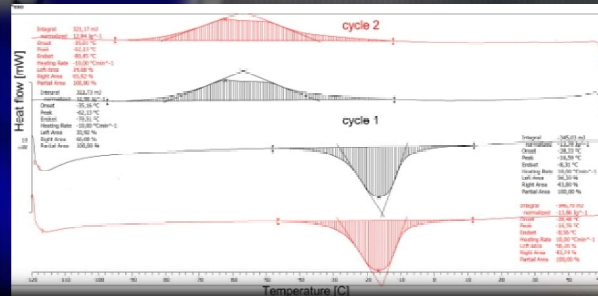
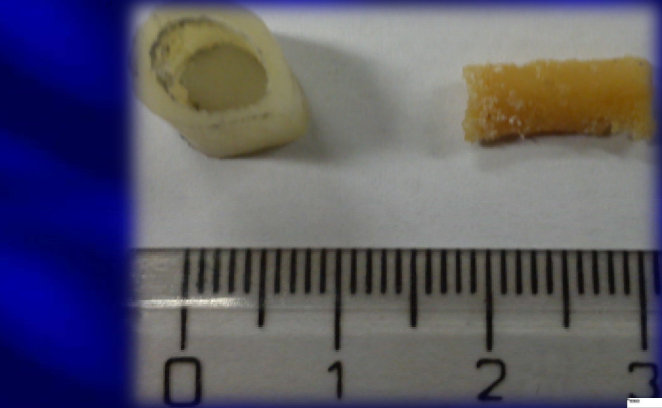
# TiN/TiO/HAP on NiTi



80V/100s

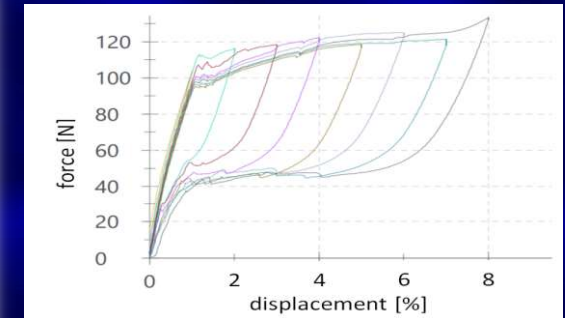
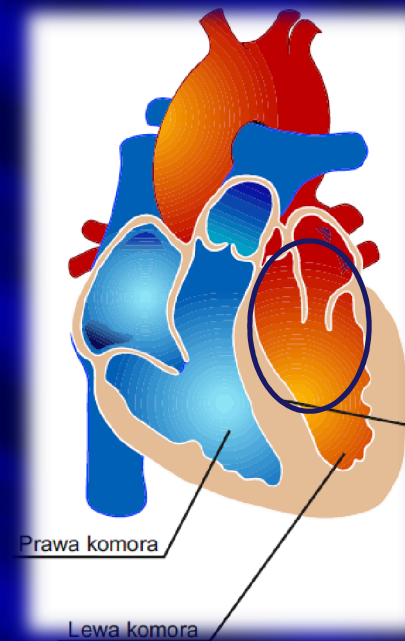
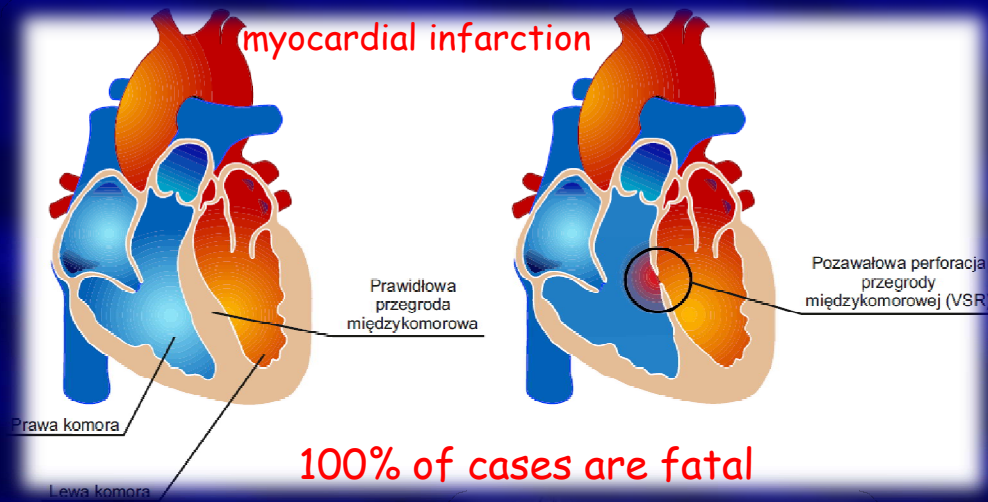
200V/60s

500V/60s

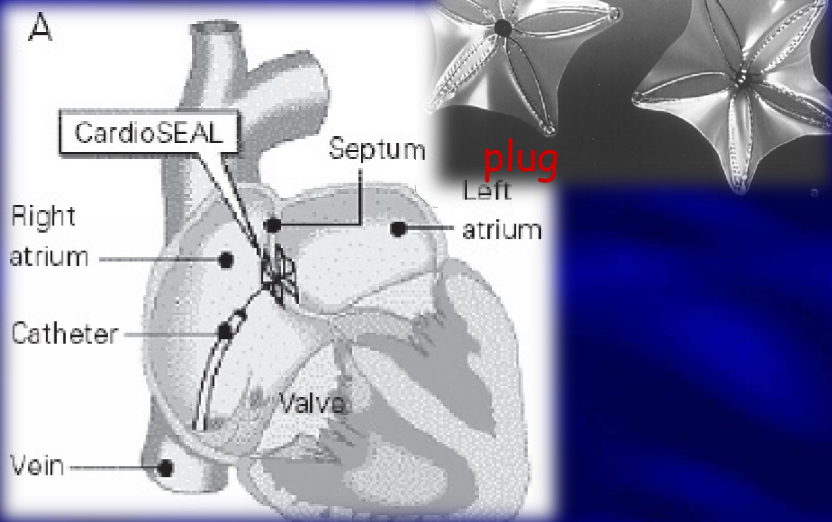




# New idea/"old" material - CardioCare 2020



device -  
healing / force  
measurement



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Institute of Cardiology, Jagiellonian University



# Conclusions

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- Martensitic transformation is still present in NiTi matrix regardless type of complex layers/sublayers/interlayers
  - The HAP layer adheres to NiTi matrix but cracks however does not splits
  - The TiN/TiO layer improves hardness
  - The HAP/TiN/TiO layer forms barrier free from Ni
-

# What about future

20 °C



55 °C



Hermaphrodite - Jean-Marc Philippe