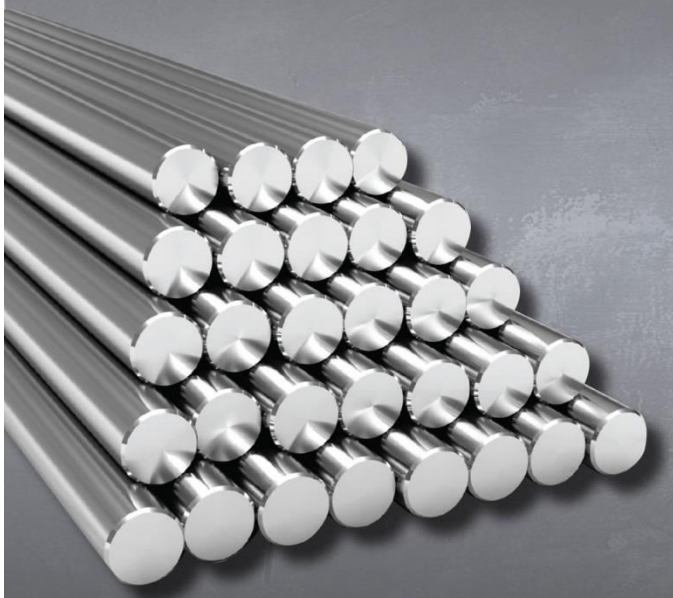
259th OMICS International Conferences

International Conference on

Smart Materials & Structures

June 15 -17, 2015 Las Vegas, USA



Exploring the Fusion of Intelligence with Materials

Operated by: Editors- Journal of Material Sciences & Engineering, Journal of Vortex Science and Technology and Journal of Nanomaterials & Molecular Nanotechnology

Hosting Organization: **OMICS International** | 5716 Corsa Ave., Suite 110, Westlake, Los Angeles, CA 91362-7354, USA, Phone: +1-650-268-9744, Fax: +1-650-618-1414

Application of electrical discharge coating to TiNi alloys surface treatment

Presented by: Shih-Fu, Ou

2015.06.15

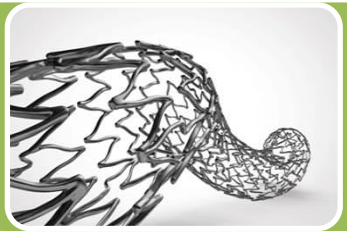
National Kaohsiung University of Applied Sciences

Contents

Smart Material

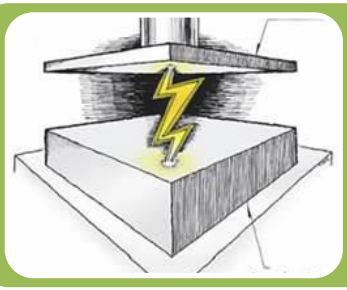
Research Objective

- Overview



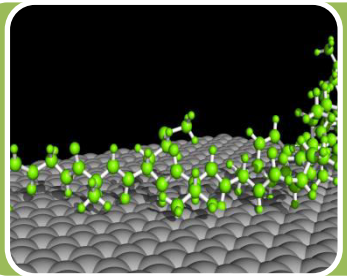
Introduction

- Nitinol
- Surface treatment of biomedical implants



Experimental setup

- Surface treatment of Nitinol
- Results



Results

Surface analysis

Biocompatibility evaluation

http://www.cxvascular.com/cn-latest-news/cardiovascular-news---latest-news/biosensors-enters-into-distribution-agreement-with-veryan-for-biomimics-3d-stent---
http://make-it-better.us/article.cfm?articleID=35
http://www.symbiosebiomaterials.be/en/technologies/genetically-engineered-peptides
http://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/9889/Telescopic-and-Microscopic-Overviews-at-LAM-2015.aspx

Research objective

1. Control the shape memory temperature of Nitinol

- The shape memory temperature can be controlled by adding alloy elements.

2. A new method for surface treatment of Nitinol

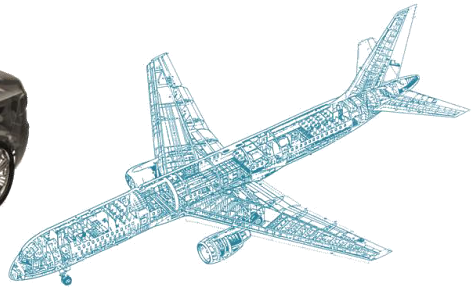
Coating a biocompatible layer on nitinol

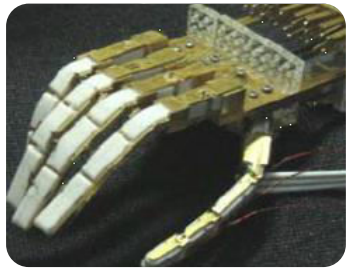
3. Evaluation of biocompatibility of the modified Nitinol

- Using in vitro test to evaluate biocompatibility

Introduction

Metallic shape memory alloy

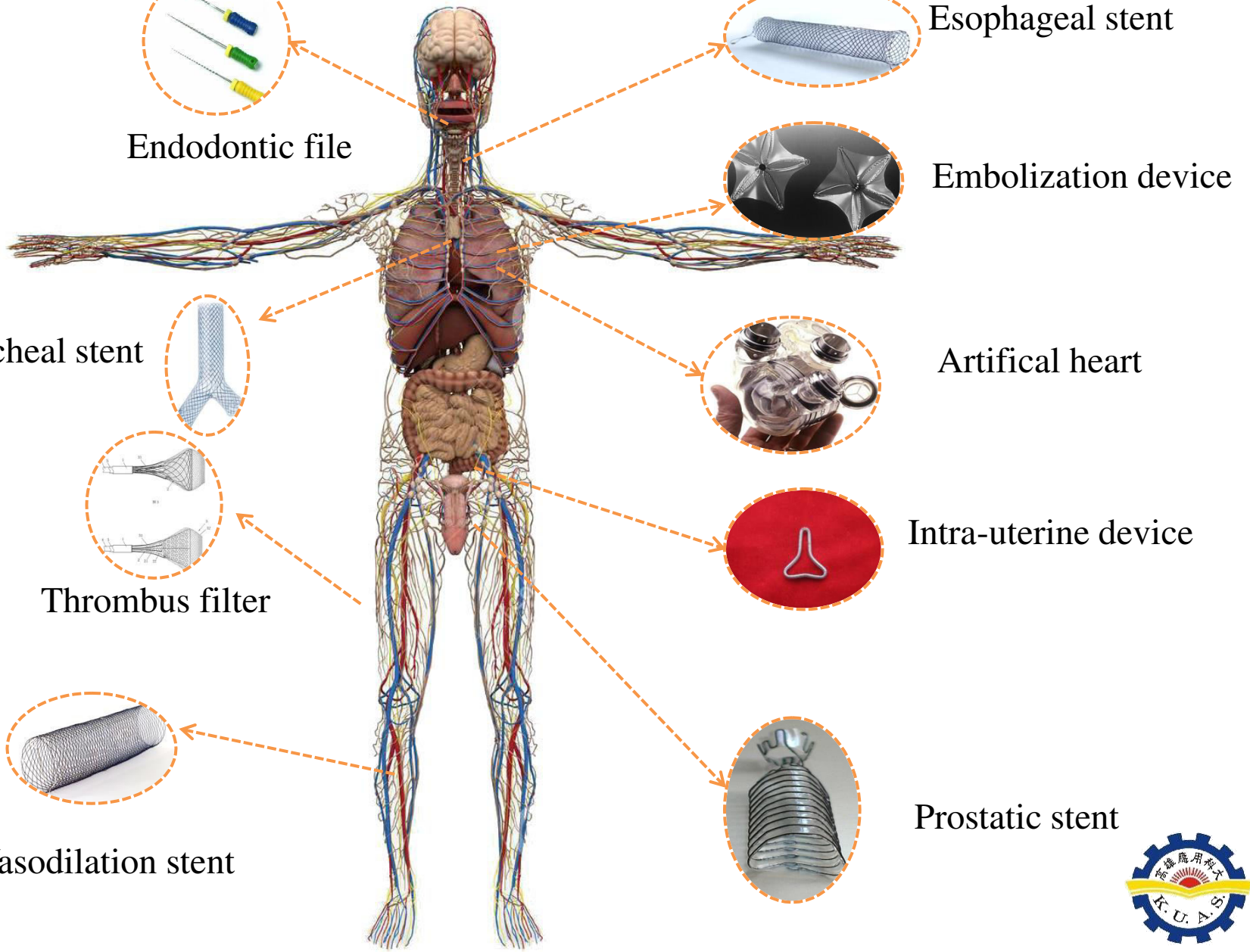


Nitinol

	Unit	NiTi	CuZnAl	CuAlNi
Fusion point	°C	1250	1050	1020
Density	g/cm³	6.4-6.5	7.5-8.0	7.1-7.2
Specific heat	J/kg K	490	440	390
Young´s modulus	GPa	23-83	80-100	70-100
Yield strength	MPa	100-130	70	40
Tensile strength	MPa	875	800	700
Corrosion resistance		excellent	good	average
Biocompatibility		excellent	poor	poor

Giroux, E. A., Maglione, M., Gueldry, A., Mantoux, J. L., 1996. Electromagnetic heating of a shape memory alloy translator. Appl Phys 29, p. 923-928.
Gümpel. P., 2004. Formgedächtnislegierungen: Einsatzmöglichkeiten in Maschinenbau, Medizintechnik und Aktuatorik, Expert Verlag, Renningen
Ronny Pfeifera*, Christian W. Müllerb, Christof Hurschlerc, Stefan Kaierlea, Volker Weslinga, Heinz Haferkampa, Adaptable Orthopedic Shape Memory Implants. Procedia CIRP 5 (2013) 253 – 258
MINIATURE FIVE-FINGERED ROBOT HAND DRIVEN BY SHAPE MEMORY ALLOY ACTUATORS

Nitinol SMA- Soft tissue application



Nitinol SMA- Hard tissue application



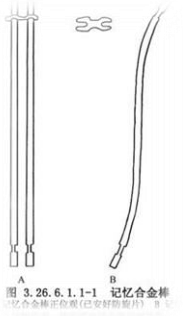
Skull plate



Orthodontic wire



Artificial cervical intervertebral joint



Scoliosis brace



Compression staple

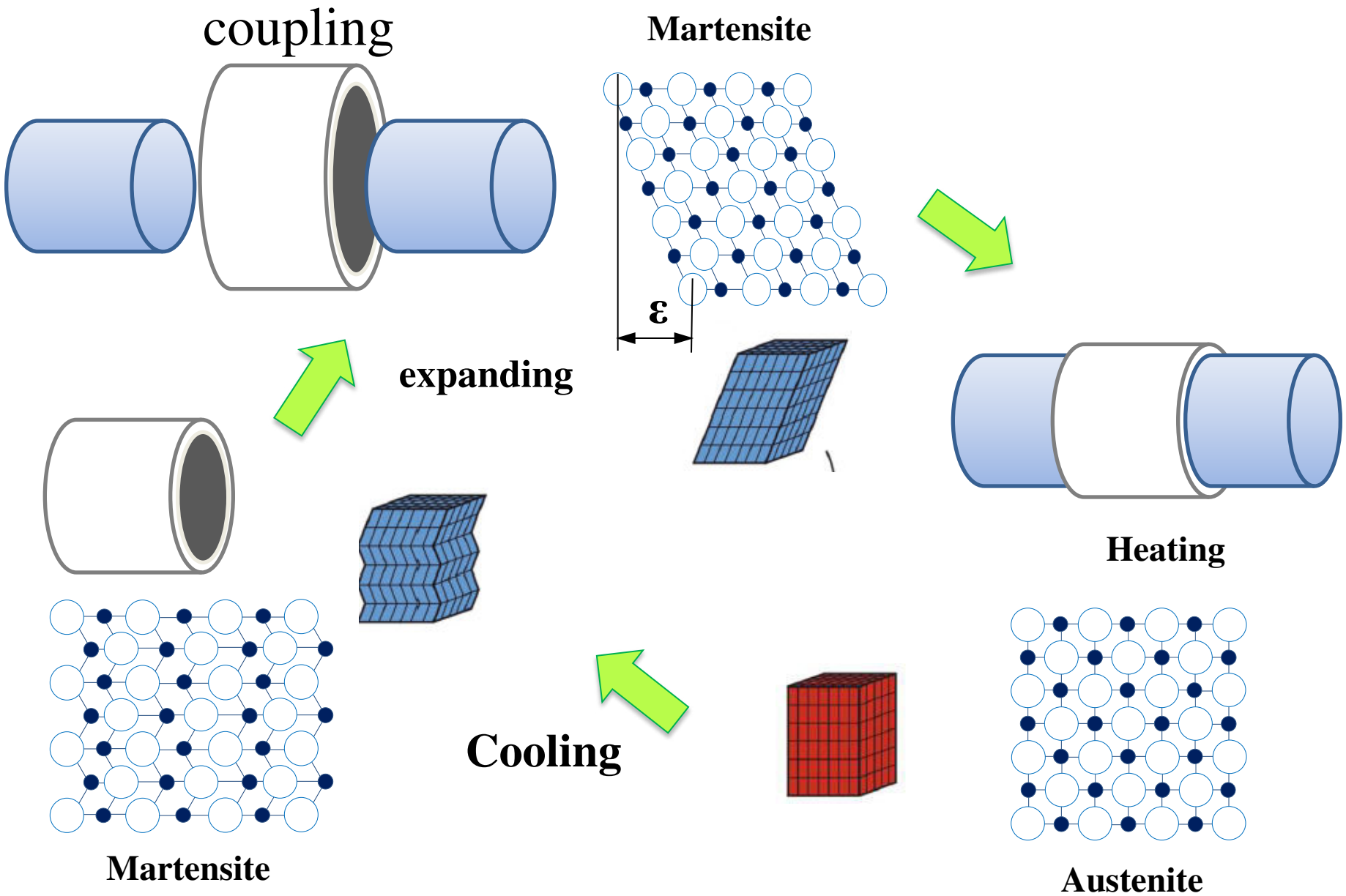


Patella entire complex



Intramedullary nail

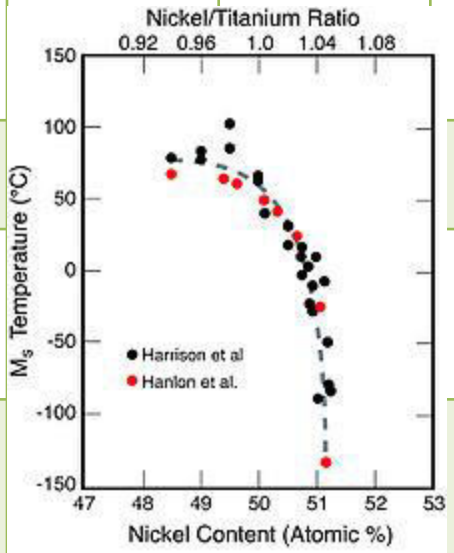
Nitinol - Shape memory effect



K Yamauchi, I Ohkata, K. Tsuchiya, S Miyazaki, Shape Memory and Superelastic Alloys: Applications and Technologies
https://www.google.com.tw/search?q=shape+memory+alloy+stent&source=lnms&tbm=isch&sa=X&ved=0CAgQ_AUoAWoVChMIrqqJjMeGxgIVFDK8Ch3XZAAY&biw=897&bih=535#imgdii=9PID44X1d_QEEM%3A%3B9PID44X1d_QEEM%3A%3B4NqCm1mD3pXkVM%3A&imgrc=9PI

TiNi based shape memory alloys

	$Ti_{50}Ni_{50}$	$Ti_{51}Ni_{49}$	$Ti_{49}Ni_{51}$	$Ti_{49}Ni_{50}Si_1$	$Ti_{50}Ni_{49.5}Mo_{0.5}$	$\mathbf{Ti_{50}Ni_{49.5}Cr_{0.5}}$
M_S (℃)	63.06	70	-40.94	-20	8.14	9.68 (M*)
A_S (℃)	73.73	110	-34.25	-1	29.14	35.2
Phase (at 25℃)	B19’			B2	B2	B19’+R
Hardness (Hv)	200			270	211	234
Shape recovery (%)	100			94	98.5	100
Phase transform ation	B2↔B19’			B2↔B19’		B2→R→B19’



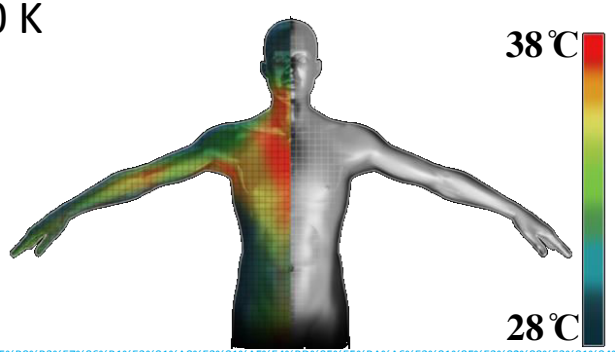
+ 0.1 at% Ni , PTT -10 K

Body temperature: 36.1℃ ~ 37.5℃

As Temp. is closer to Body Temp. is better

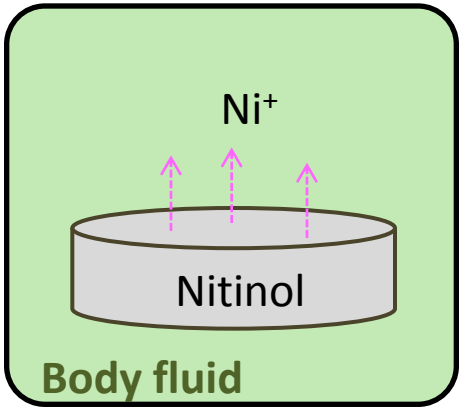
⇨ $\mathbf{Ti_{50}Ni_{49.5}Cr_{0.5}}$

A_S =35.2 ℃



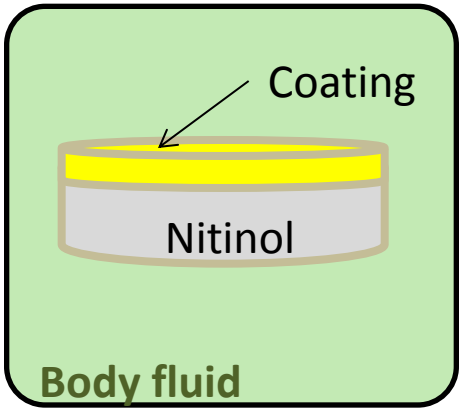
http://jijinetazan.com/%E4%BA%BA%E9%96%93%E3%81%AE%E4%BD%93%E6%B8%A9%EF%BC%81%E5%B9%B3%E7%86%B1%E3%81%A8%E3%81%AF%E4%BD%95%E5%BA%A6%E3%81%8F%E3%82%89%E3%81%84%EF%BC%9F-479

Disadvantages of Nitinol



Health concern

If the native oxide film is fractured, the release of Ni ions may cause toxic and allergic reactions.



Surface coating

An effective way to avoid Ni ions release
Improving the biocompatibility

Coating material

- Ti oxide
- Ti carbide

Coating – Titanium nitride

- High hardness (2400HV for TiN compared to 650HV for CoCr)
- Good wear resistance (Piscanec et al., 2004)
- Good corrosion resistance (Han-Cheol Choe, 2006)
- Good biocompatibility (G. Sovak, 2000)
- Reducing bacterial proliferation (Scarano A, 2003)

Purpose





Total Ankle Replacement

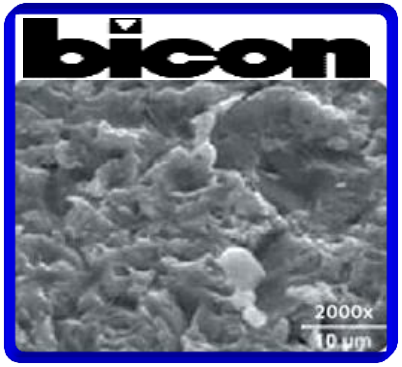


Knee Replacement

Surface treatment

Mechanical method

- **Blasting**
- Machining
- Grinding
- Polishing

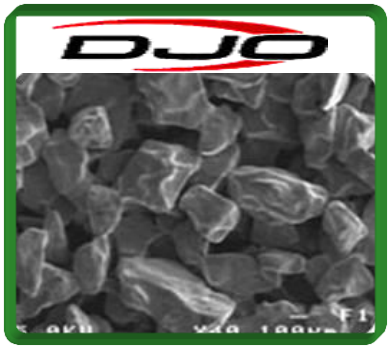


Mechanical interlock

Physical method

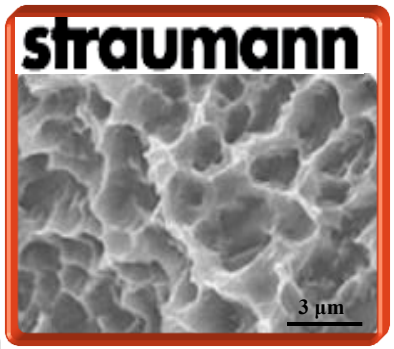
- **Plasma spray Ti**
- Ti PVD

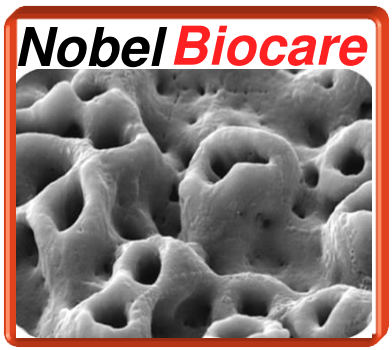




Chemical method

- **Acidic etch**
- Alkali etch
- **Anodic oxidation**
- CVD





Chemical bonding

Physical method

- **Plasma spray HA**

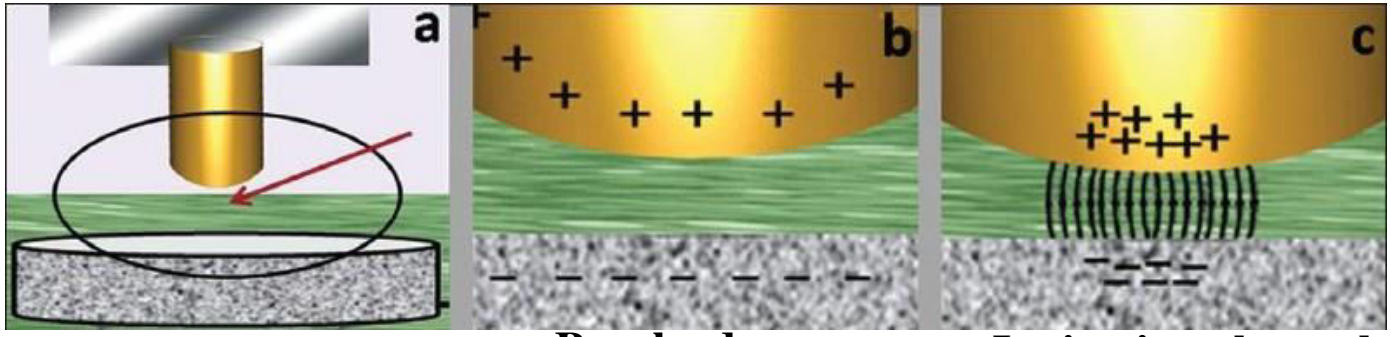




Chemical method

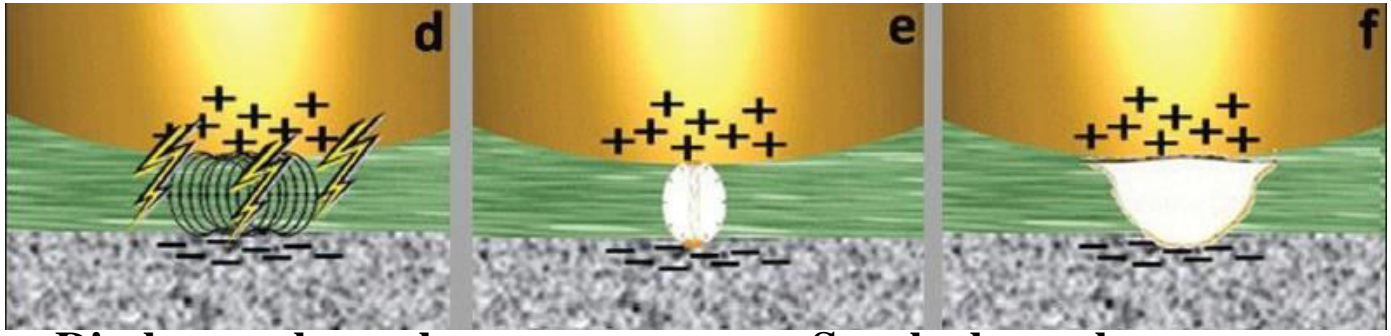
- **Sol-gel deposition**

Electrical discharge machining, EDM



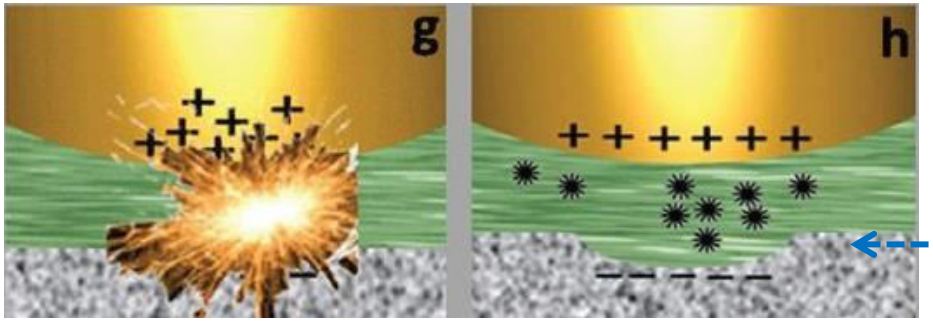
Breaks down

Ionization channel



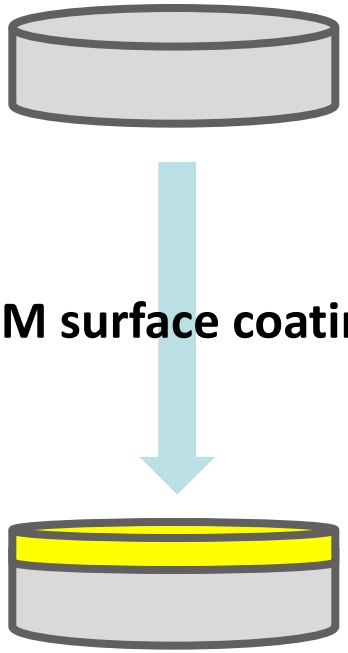
Discharge channel

Spark channel



Spark

Fluid flush



EDM surface coating

Recast layer

Spark erosion process: An overview, Journal of Dental Implants | Jan - Jun 2011 | Vol 1 | Issue 1

Experimental setup

Dry EDM - Experimental setup

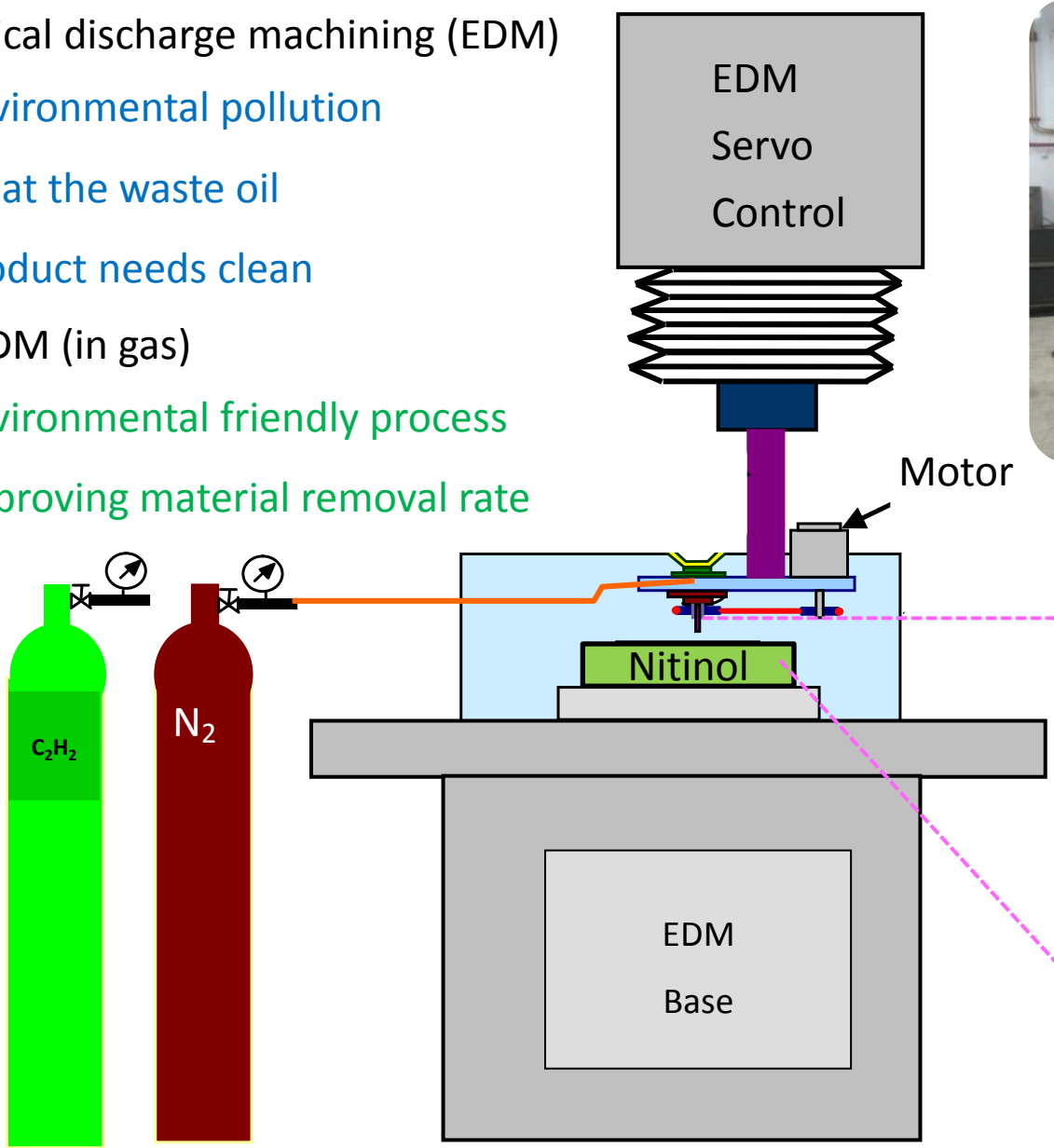
Electrical discharge machining (EDM)

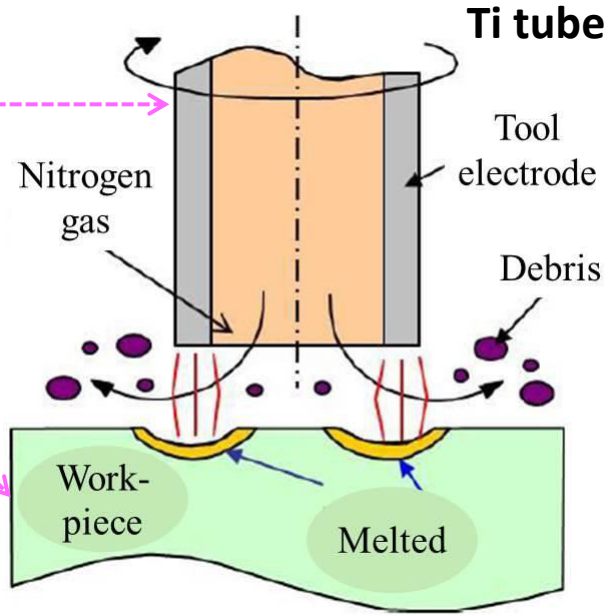
- Environmental pollution
- Treat the waste oil
- Product needs clean

Dry EDM (in gas)

- Environmental friendly process
- Improving material removal rate

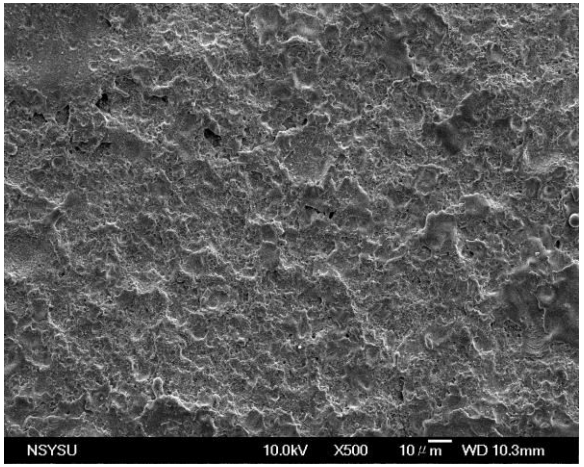


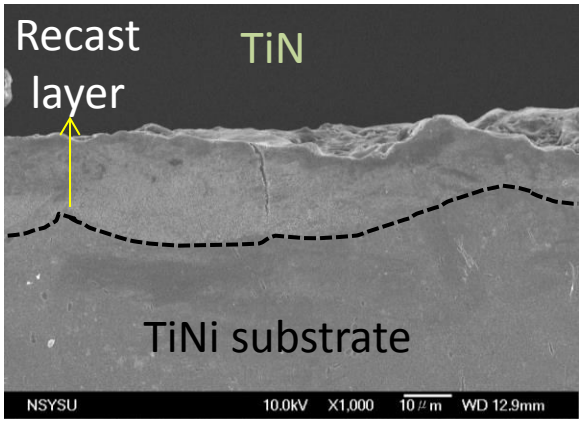




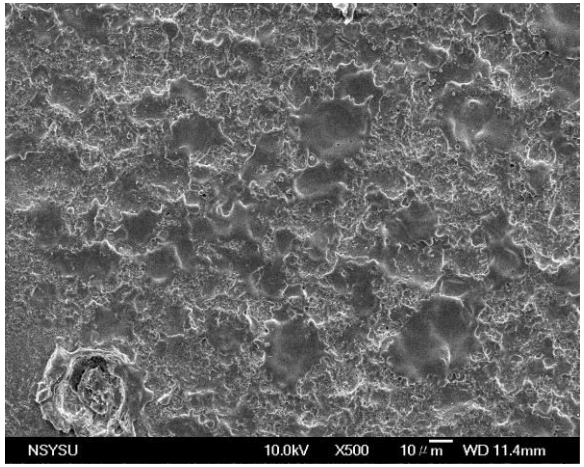
Results

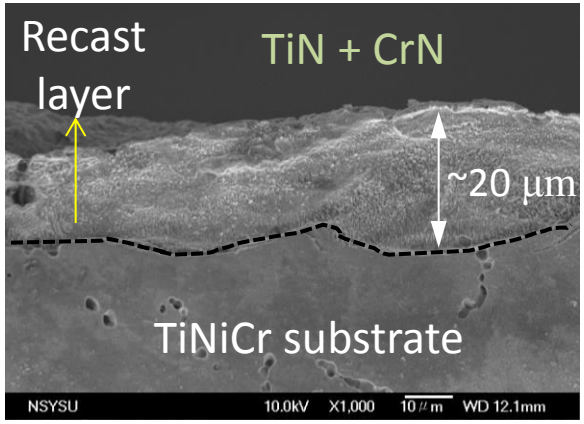
$Ti_{50}Ni_{50}$

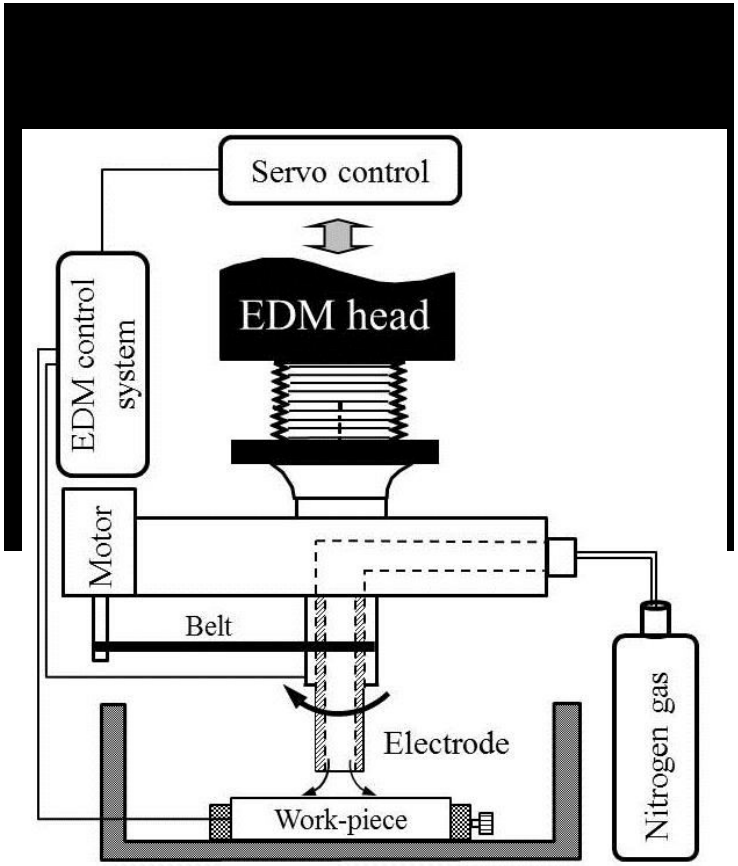




$Ti_{50}Ni_{49.5}Cr_{0.5}$

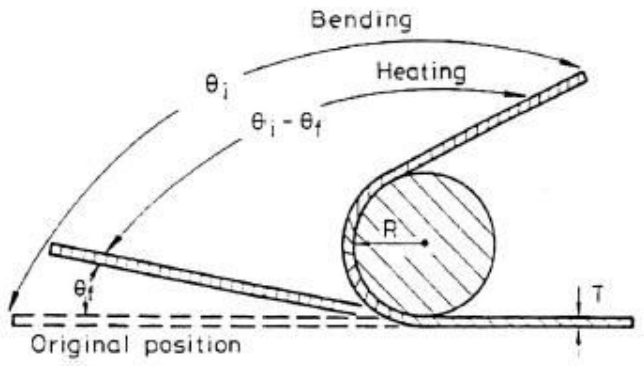






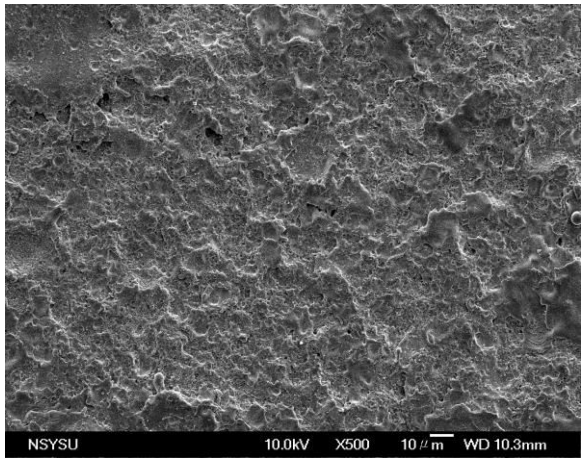
Bending Test

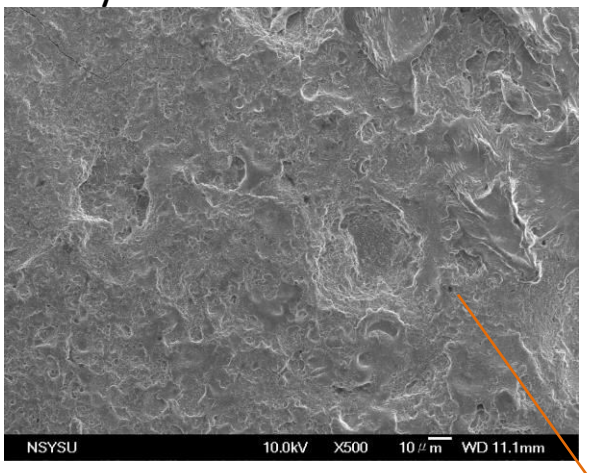
	Shape recovery, R_{SME} (%)	Hardness (Hv)
$Ti_{50}Ni_{50}$	100	207
$Ti_{50}Ni_{50}$ (EDM)	95	723
$Ti_{50}Ni_{49.5}Cr_{0.5}$	100	253
$Ti_{50}Ni_{49.5}Cr_{0.5}$ (EDM)	94	746



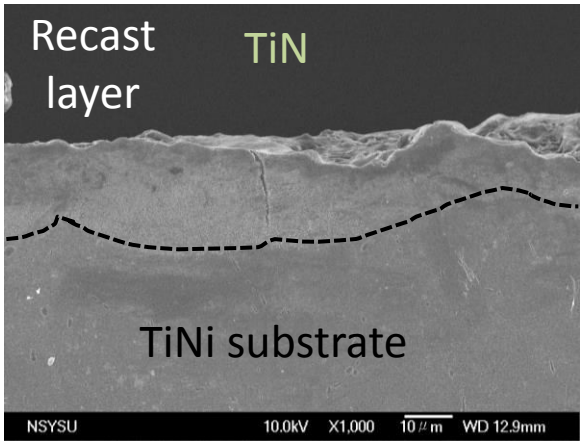
N2: 100%

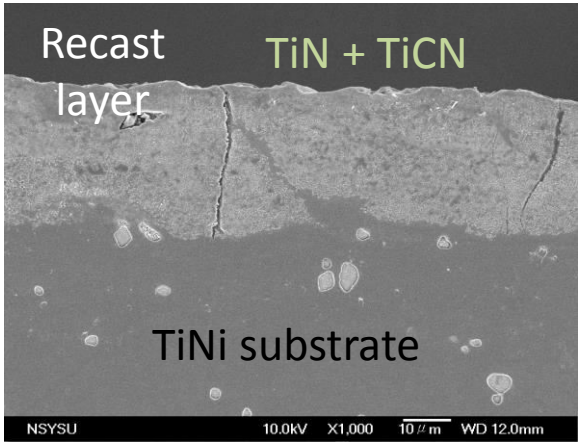
N_2: 40%
Acetylene: 60%

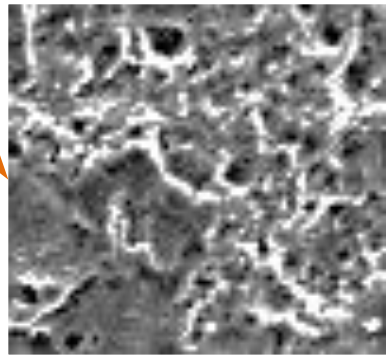












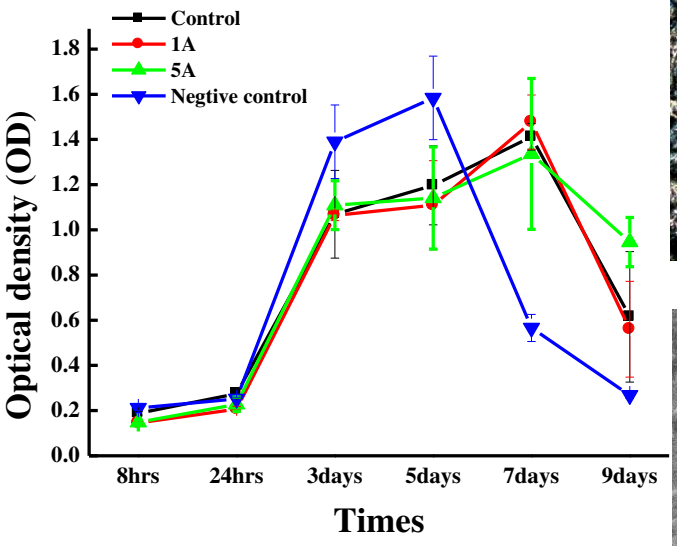
		Shape recovery, R_{SME} (%)	Hardness (Hv)
$Ti_{50}Ni_{50}$	$Ti_{50}Ni_{50}$	100	207
	EDM in N_2	95	723
	EDM in N2 + C_2H_2	89	776

In vitro tests

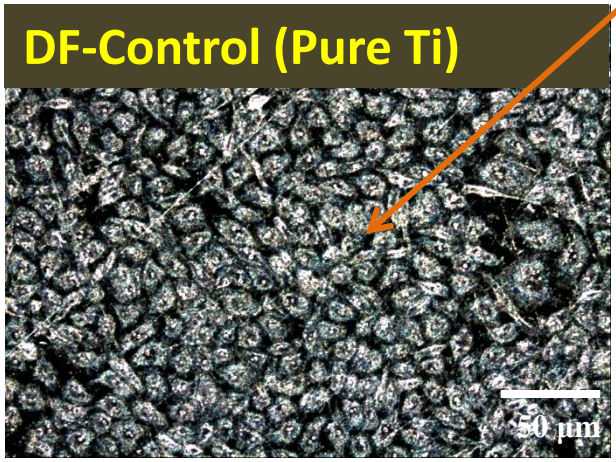
5 days incubation

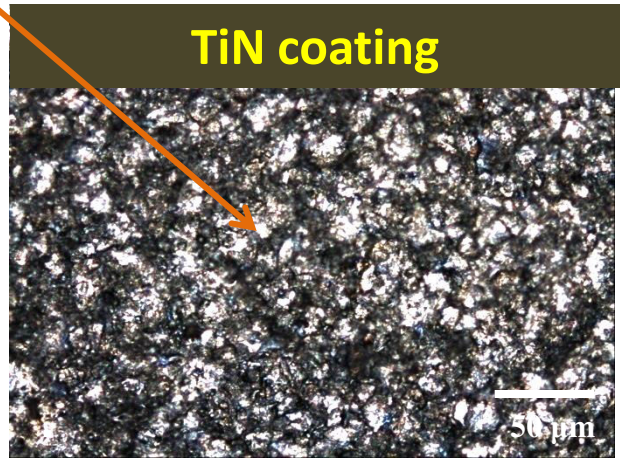
MG63 Osteoblast-like Cell

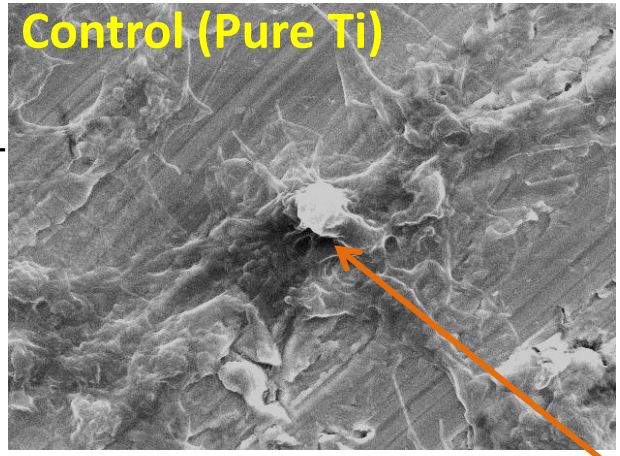
Cytotoxic test (Cell compatibility)

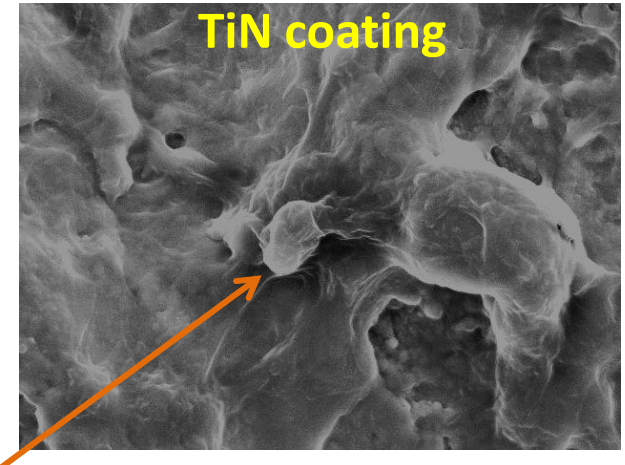


Hemocompatibility test (Blood compatibility)









Platelet

- The coating exhibited good in vitro biocompatibility and hemocompatibility as pure Ti.

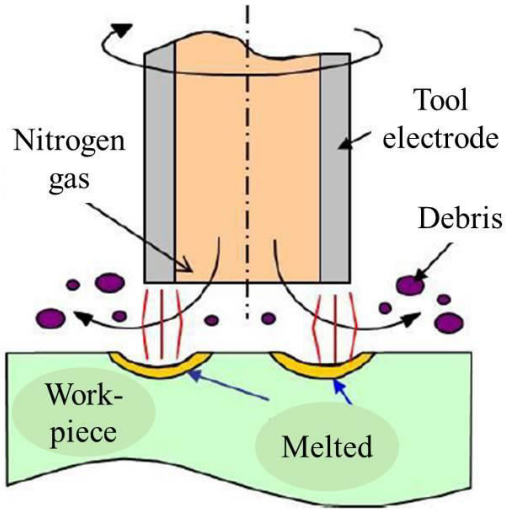
Conclusions

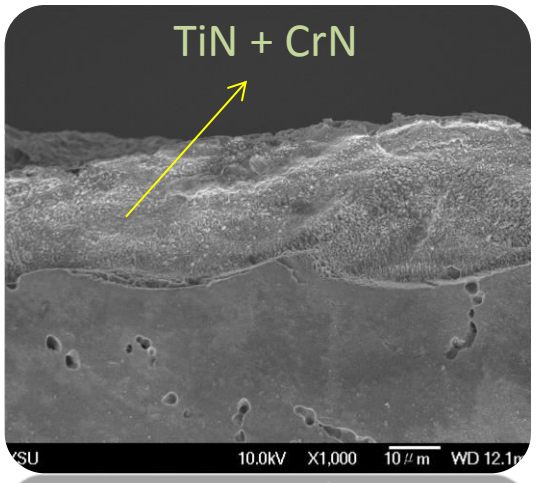
1) This study prepared $Ti_{49.5}Ni_{50}$ $Cr_{0.5}$ SMA which has a phase transformation temperature close to body temperature.

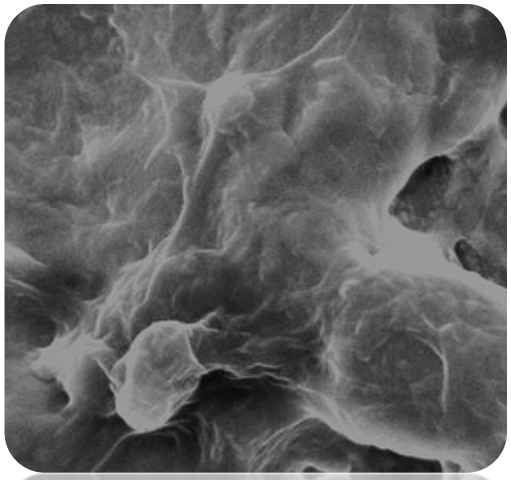
2) After EDM, the SMAs exhibited improved surface hardness while retaining good shape recovery ability.

3) The coating exhibited good in vitro biocompatibility and hemocompatibility as pure Ti.

4) The coating, comprising TiN is expected to prevent the nitinol substrate from contacting body fluid when EDMed SMAs are implanted in human body.









Surface coating Lab.

National Kaohsiung University of Applied Sciences