MOTecH Plasma

PULSED PLASMA SURFACE TREATMENT (PPST) OF METALS

FOR WEAR, CORROSION AND DIFFUSION PROTECTION

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PhD physics of materials

PULSED PLASMA SURFACE TREATMENT (PPST) RECENTLY QUALIFIED WITHIN THE OFFSHORE FOR WEAR, CORROSION AND DETRIMENTAL DIFFUSION PROTECTION (HYDROGEN, HISC)

MOTIVATION HERE:

COULD THERE BE SIMILAR POTENSIAL APPLICATIONS WITHIN THE NUCLEAR POWER INDUSTRY?

COLABORATION BETWEEN
IFE HALDEN AND KJELLER, AND MOTECH PLASMA

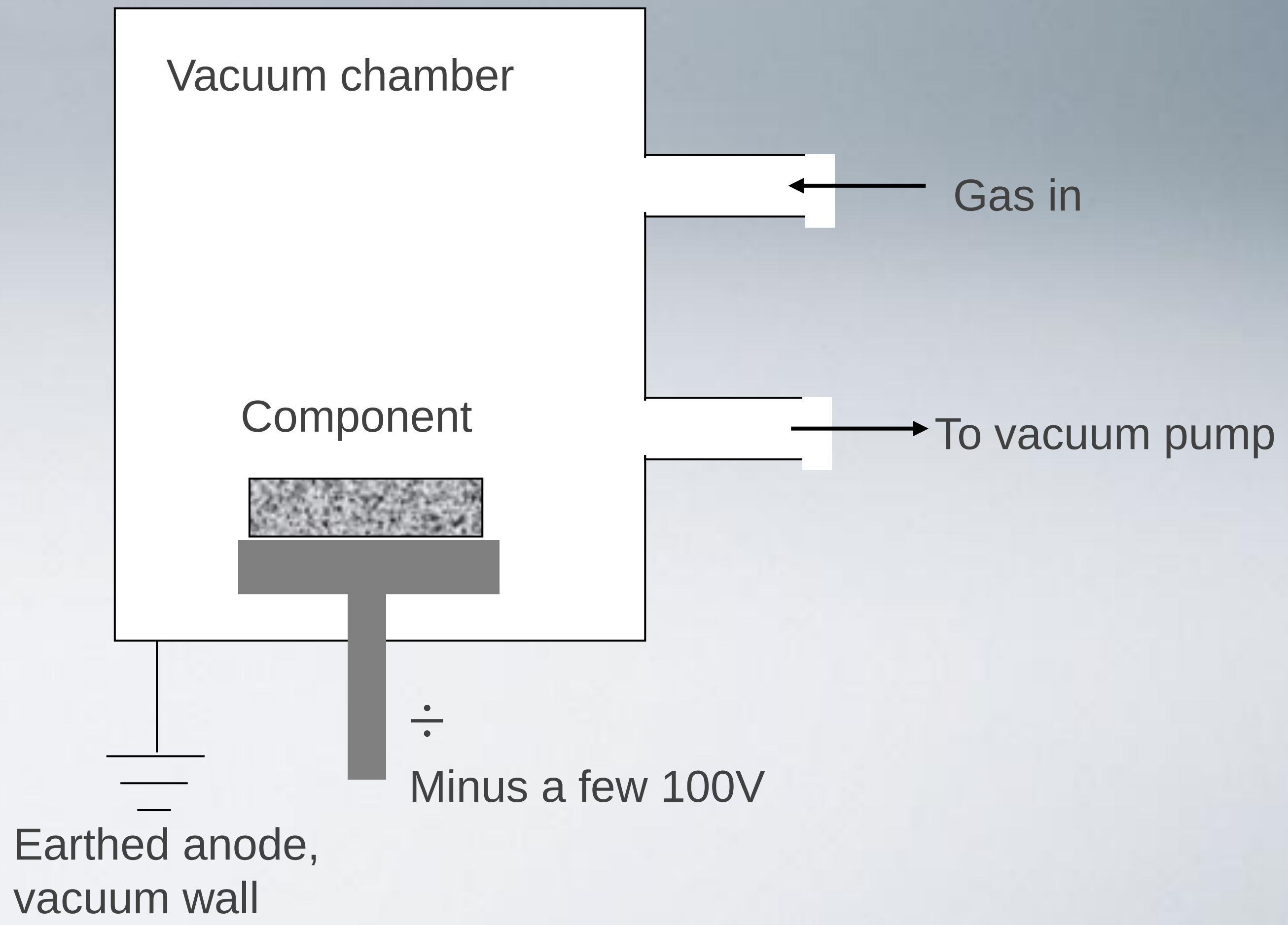
MOTecH Plasma research intensive SMB company

Plasma- and pico-technology:

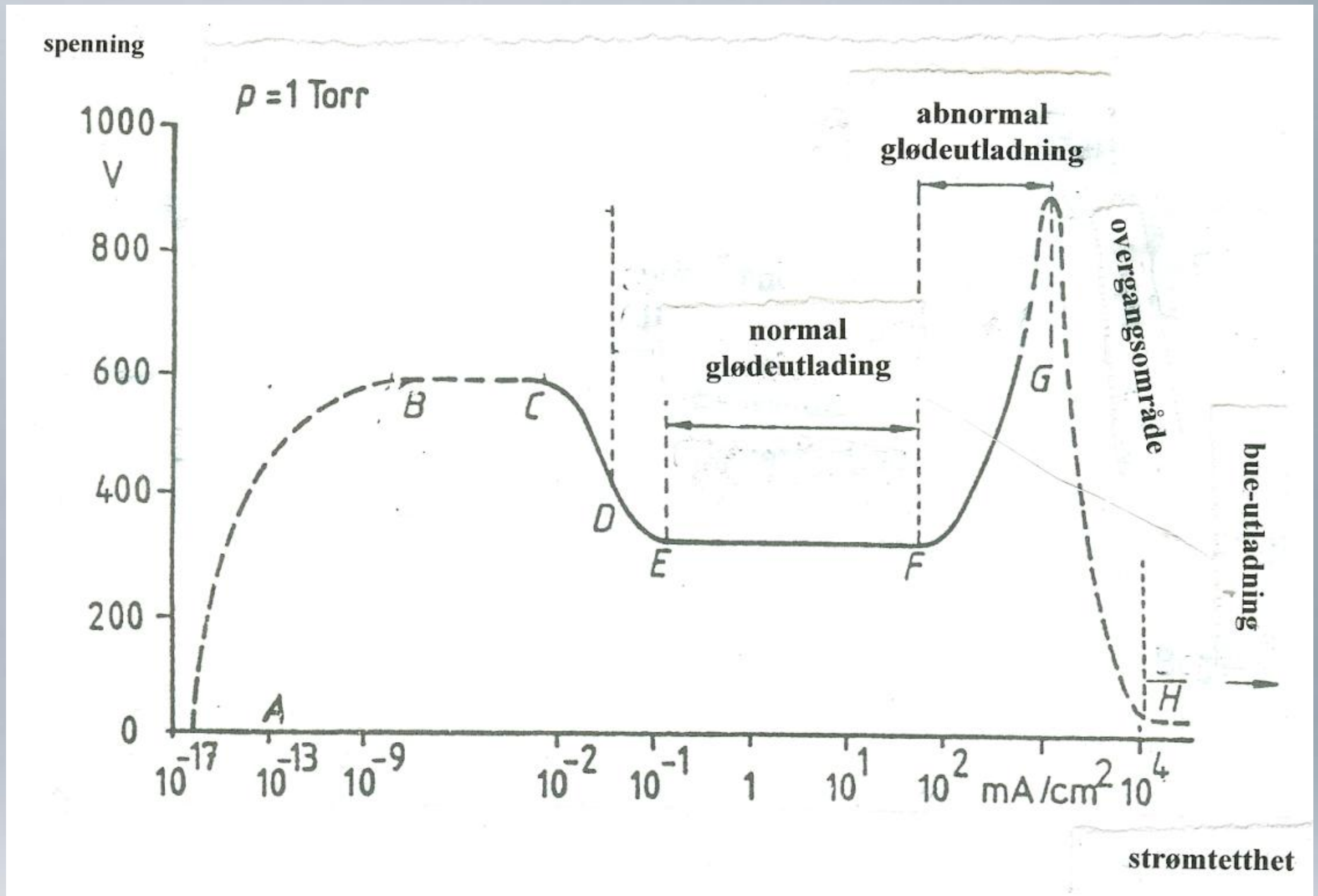
Basic principles of pulsed plasma surface treatment (PPST):

- Generally, pulsed plasma treatment is conducted in vacuum (30-500Pa) at temperatures of 300-800C.
- Various gases, e.g. containing nitrogen, carbon and/or oxygen is let into the chamber. Negative voltage connected to work piece. Gases are ionized and the positive ions ”sucked into” the suface:

Positive ions ”sucked” into base material. Voltage and current are **pulsed** in order to save energy and improve process control.



Typical voltage-current density curve in vacuum, current density vs potensial:



Area E-G is a ”glow-discharge region”.

E-F: components are only partially covered with plasma.

F-G: The whole component is covered by the plasma.

THE PULSED PLASMA TREATMENT OPERATES IN THIS REGION.

Basic principles:

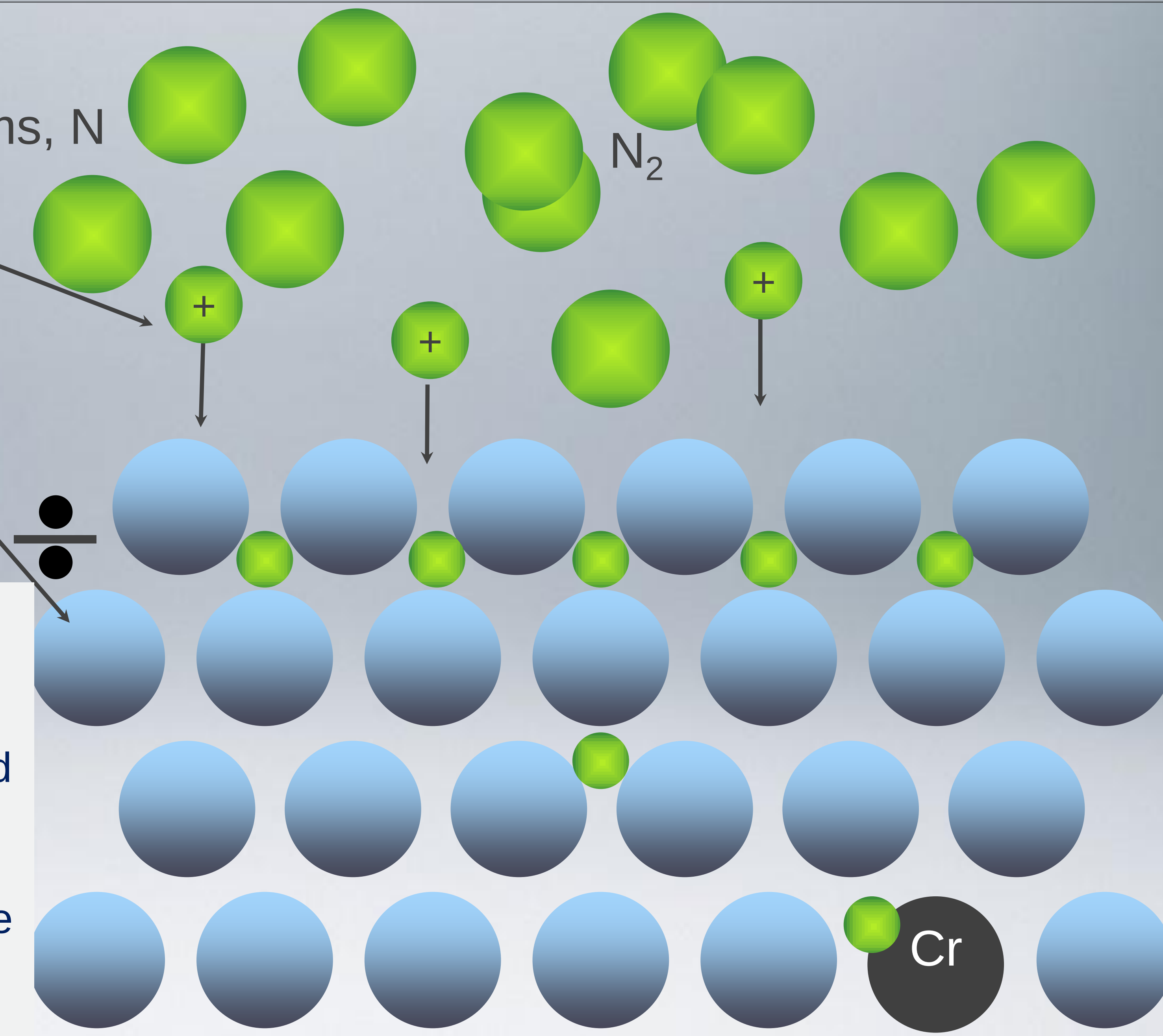
In the vacuum chamber we have a mixture of positive ions, free electrons, atoms (e.g. N) and stable molecules, e.g.N_2

Neutral atoms, N

Positive ions, e.g. C^+ or N^+

Ions < 1/4 size of atom!

A negative voltage, e.g. -470V



Three reactions make take place, depending on how the process is run:

1. Atoms may diffuse into the surface and remain in solid solution (interstitials)
2. Atoms may react with carbide or nitride formers and form precipitates, e.g. hard CrN particles.
3. N (or C) CONVERTS the base material into a new structure. In carbon steels this is a compound layer, in stainless and inconels we have S-phase(s).

Standard treatment of carbon and low alloy steels. Special gas oxidation

Surface layer serves as barrier for hydrogen diffusion (e.g. HISC protection)

Thermodynamics (Fe-N-C phase diagram) show that an intermettallic Fe_xN_y "COMPOUND LAYER" may form if we add 1-2% carbon to the gas. This is done by adding some methane (CH_4) to the nitrogen plasma.

A very hard "skin" or COMPOUND LAYER is formed on top of the Diffusion zone, typically 5-20 microns.

Diffusion zone gives mechanical support to the hard and wear resistant compound layer. Hence, the part will tolerate high line- or point loads. (avoid so-called eggshell-effect).

Core material remain unchanged.

Postoxidation, few microns

Compound layer, 2-20 microns.

Intermetallic $Fe_{2-3}N$ and/or Fe_3N_4

Diffusion zone
nitrides or nitrogen
in solid solution.

Graded structure gives good
mechanical support
for the compound layer

Core material
is unchanged

Pulsed plasma treatment in practice.

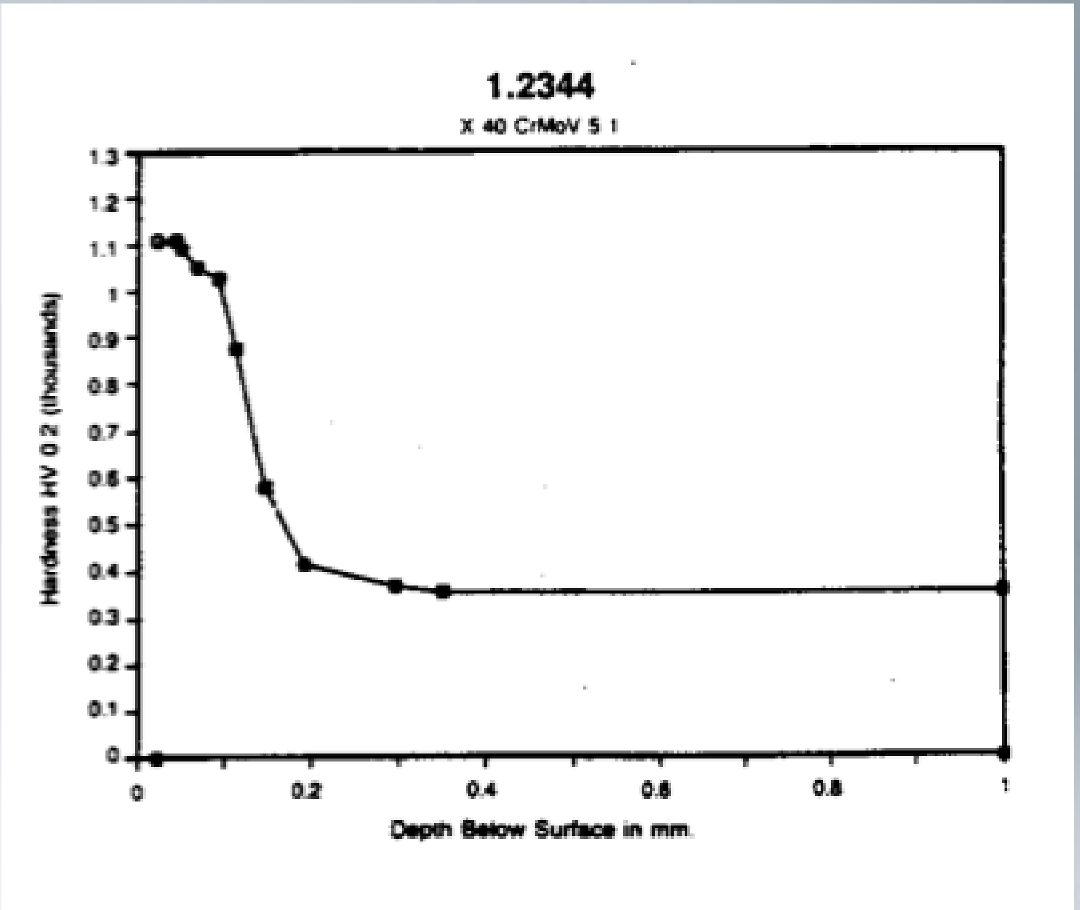
Ex. hardness curve.

Vickers hardness: Diamant pyramide pressed inn into surface. Sice of indent related to hardness. E.g. tool steel (H13: 0.4C, 5.3Cr, 1.3Mo, 0.9V) in Al-industry.

Typical hardness curve where
The diamond pyramid is loaded
with 200g (HV0.2).

Graded structure and hardness
Gives excellent wear
properties.

Case depth is defined as the
Point where the hardness (HV)
Is 50HV above core hardness.



Cross-section (SEM and TEM). Case depths may vary from

5-25 microns for all stainless steels and inconels in question. Examples:

Typical case depth of inconels is 15 microns:

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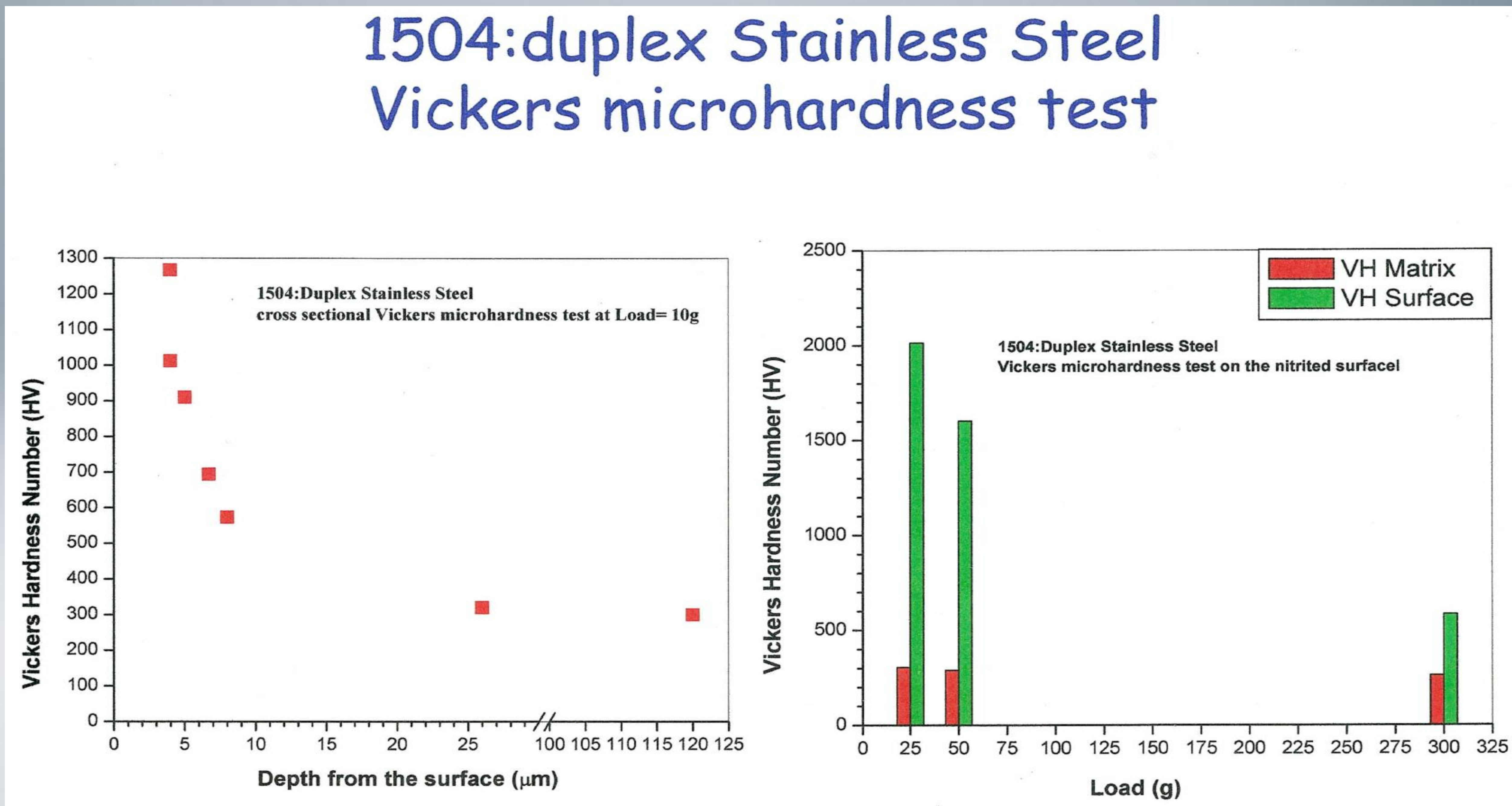
SURFACE TECHNOLOGY AND ADVANCED MATERIALS

PULSED PLASMA SURFACE TREATMENT

Microhardness profile and surface hardness as a function of loads:
Case depth 0.01-0.03mm. Microhardness HV0.01 > 1500. These are typical values for low temperature treatment of all stainless steels (AISI316, duplex…..) and inconels etc.



Anti-galling tests.

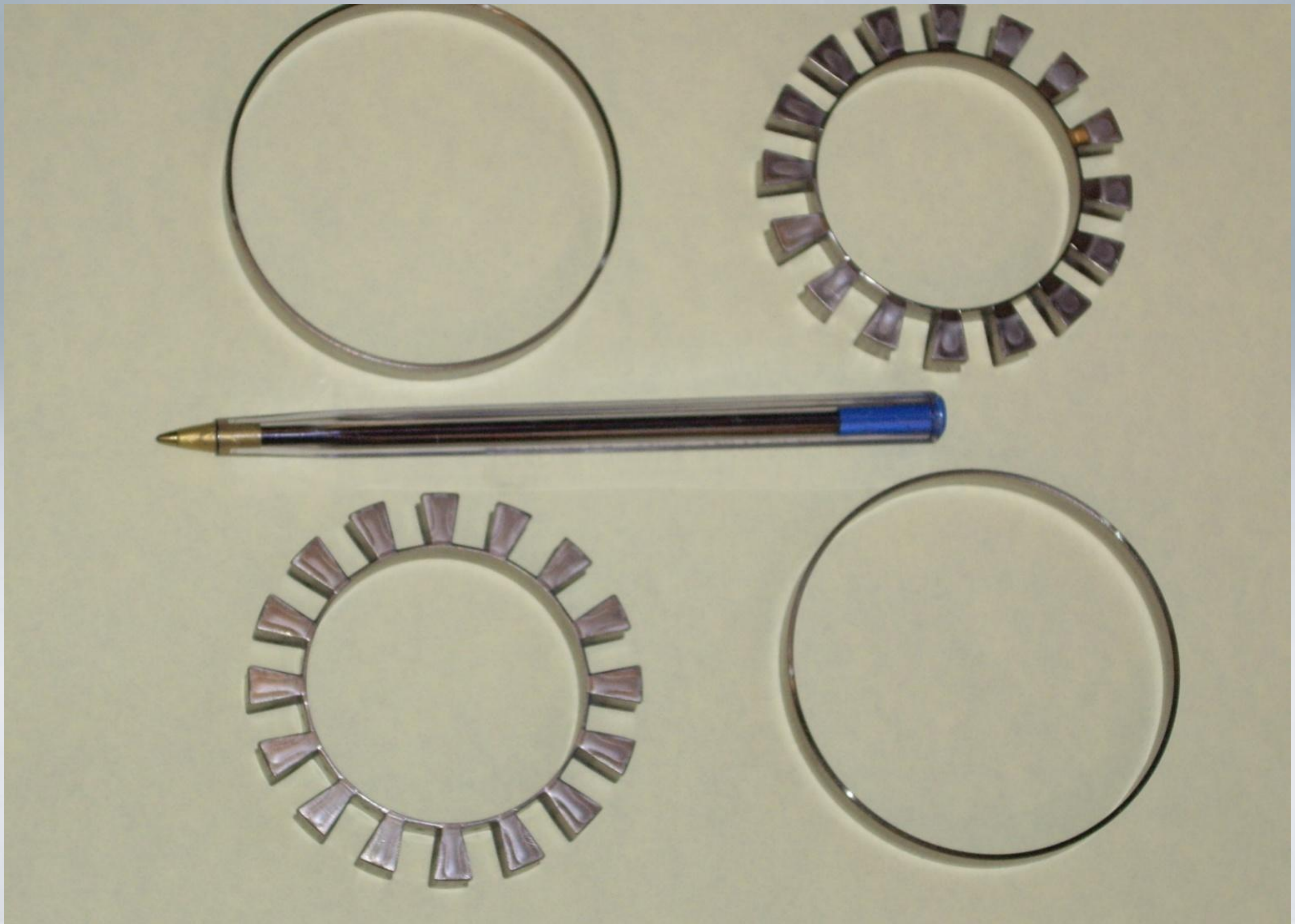
PPST is extremely efficient agains galling. Important for many applications!

Various tests by Tekniker/Spania, Mokveld/Holland og Steinsvik/Norway.

Ex.: Inconel metal-metal seals, 690 bars, 400 cycles. No wear!

Anti-galling properties proportional to case depth!

Excellent dimensional, surface and shape stability.
Ball bearing parts with thin rings.



MOTecH Plasma, pulsed plasma technology

CAN DO HIGH TEMPERATURE MATERIALS PHYSICS AND CHEMISTRY AT LOW TEMPERATURES. MAY OPEN FOR NEW AND EXCITING APPLICATIONS WITHIN VARIOUS INDUSTRIES, INCLUDING NUCLEAR INDUSTRY

UPGRADING OF SURFACE PROPERTIES LIKE WEAR, CORROSION, AND BARRIERS AGAINST DETRIMENTAL DIFFUSION (E.G. HYDROGEN),

WHILE PRESERVING CORE PROPERTIES LIKE FRACTURE TOUGHNESS, CREEP, DUCTILITY…

Historical:

Hydro turbines (Kværner Energy).
Erosive-corrosive wear (wet sand erosion).

MOTecH Plasma

Unique furnace,
world largest.
(450kVA plasma,
150kVA heating).

Volume:
dia 5.5m x 3.5m,
1000m^2, 40 tonns!

Runner, martensite
(165M; 16Cr,5Ni)

Improved corrosion
of carbon steels.