NV PROCESS

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AIR WATER INC.

- Profile (As of March 31, 2014) -

Established : **September 24, 1929**

Head Office : **Chuo-ku, Osaka**

Number of Employees : **9,558 (Consolidated)**

Paid-in Capital : **32,263 Million**

Net Sales in FY2013 : **641,256 Million (Consolidated)**

Ordinary Profit in FY2013 : **36,275 Million (Consolidated)**

AIR WATER'S BUSINESS FIELDS


Industrial Businesses


Medical Businesses

AIR WATER INC.


Energy Businesses


Other Businesses

Chemical Businesses

Logistics Businesses

NV Metal Surface Treatment

NV METAL SURFACE TREATMENT BUSINESS

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E-mail: info-nv-h@awi.co.jp

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AIR WATER (THAILAND) CO., LTD.
Amata Nakorn Industrial Estate
Tel: 038-468-130

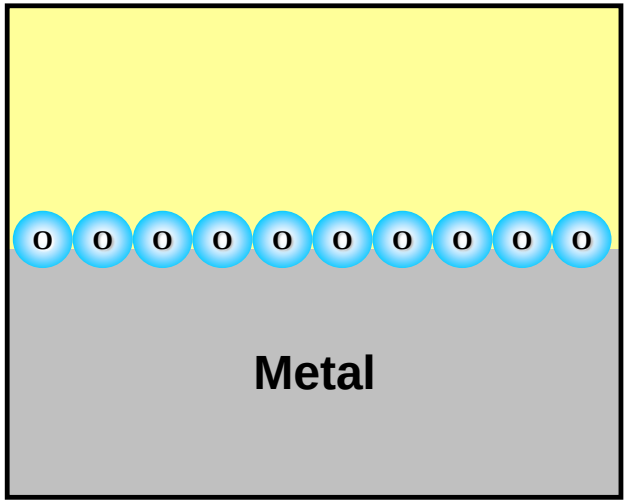
NV PROCESS (Contents)

1. NV Nitriding

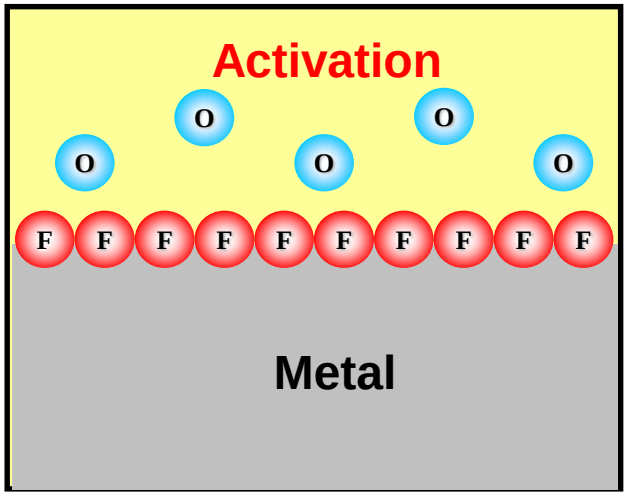
NV PROCESS

Principle of NV Nitriding

NV Nitriding = **Activation** + **Gas Nitriding**

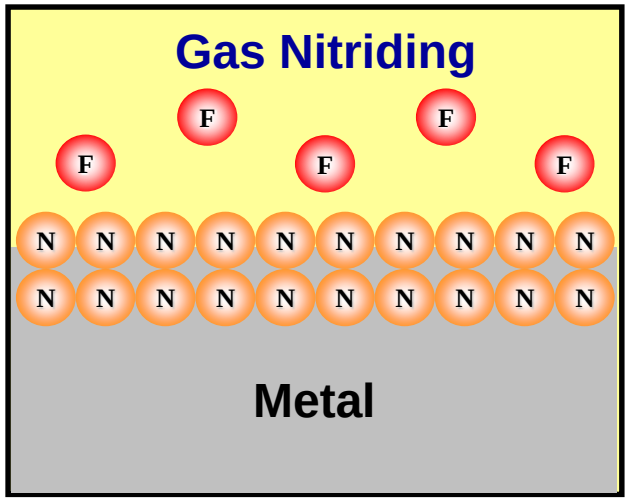


Metal surfaces is covered by Oxide



Oxide is changed to Fluoride

→ Nitrogen invade and diffuse from the activated surfaces.

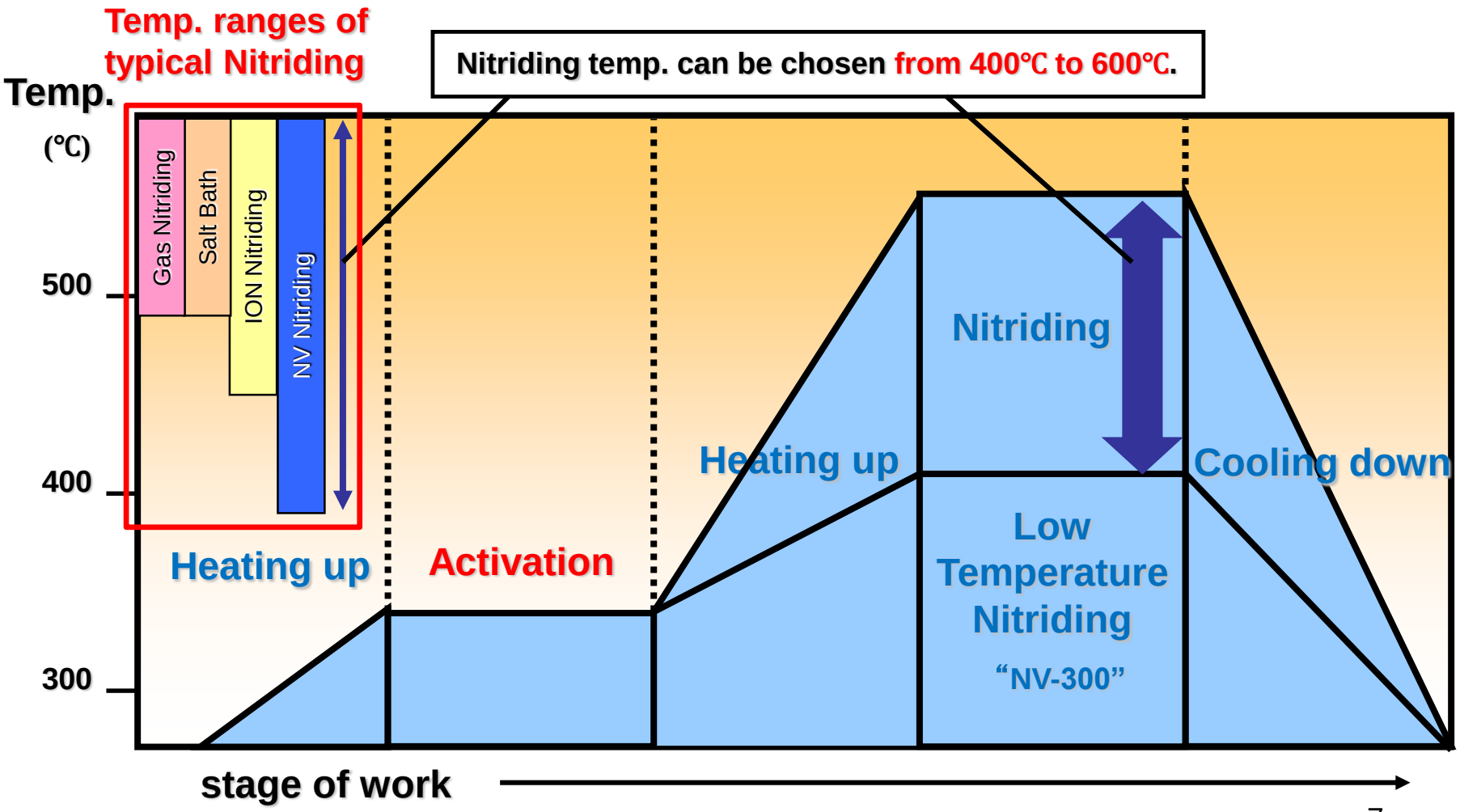


Metal surfaces will be active by the reduction of fluoride.

※ NV Nitriding is patented technology in major countries

Process Chart of NV Nitriding

- **Temperature and mixture ratio of gases are flexible by Activation Process**



2. Advantages of NV Nitriding

NV PROCESS

Advantages of NV Nitriding

- With the metal surface activation treatment, we have succeeded in greatly advancing the concept of conventional gas nitriding technology.

① The types of metals suitable for nitriding have greatly expanded, from low grade steel to nickel base alloys.

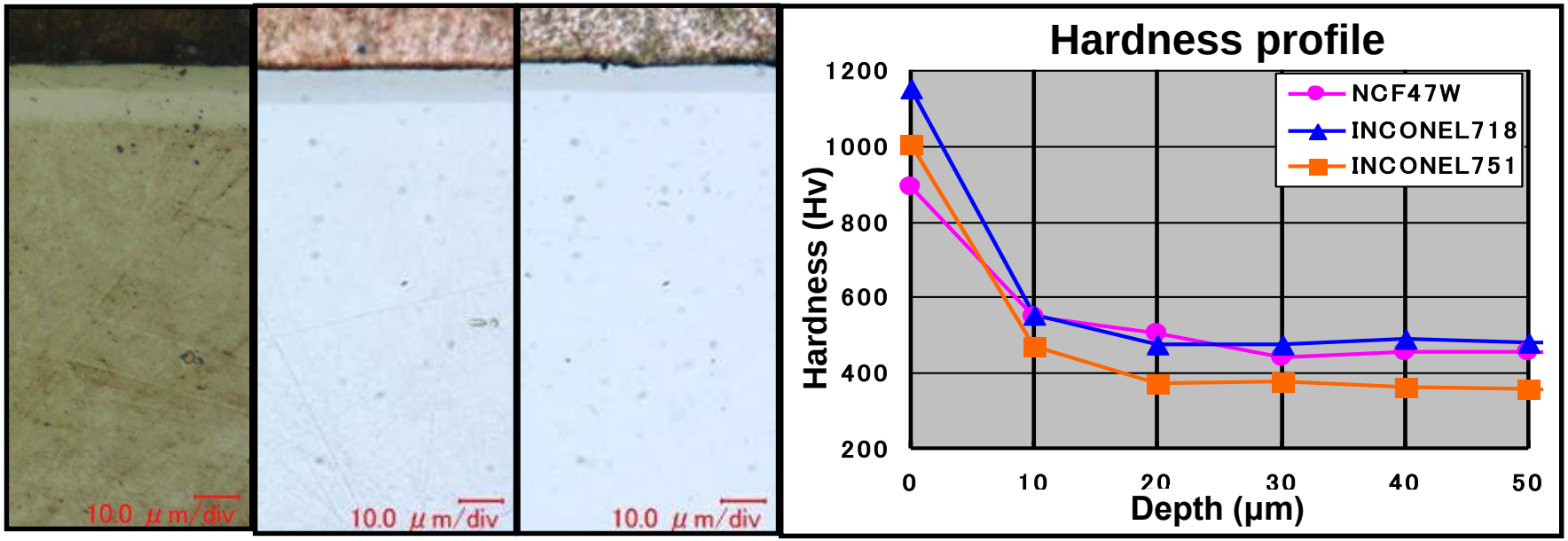
② It is possible to apply stable Nitriding under low temperature.
(Nitriding at the temperature of latter of 300℃ is available)
→ Minute change in shape and roughness with treatment

③ Nitriding condition is so flexible. Nitriding by low N-potential can be applied easily.
→ The thickness of compound layer or hardness of Nitriding layer is controllable.

④ Nitriding layer can be controlled according to the using condition of the customer.

Accommodation to Nickel base Alloys

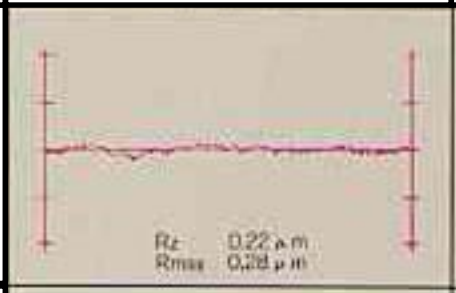
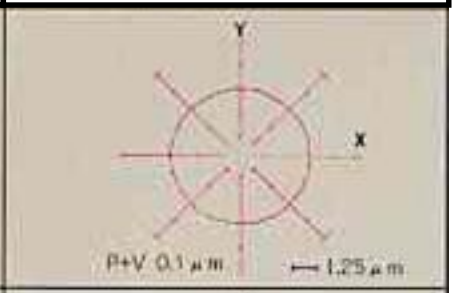
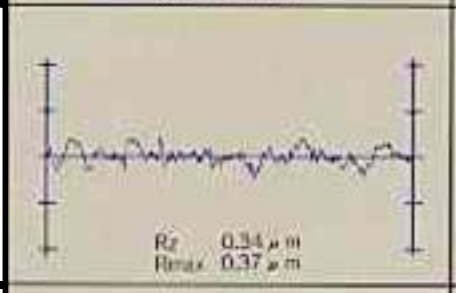
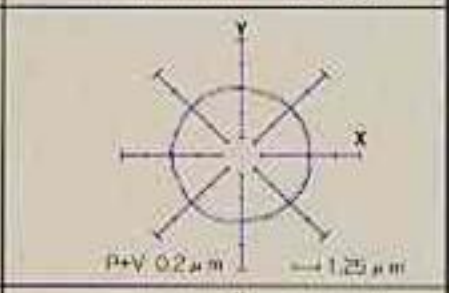
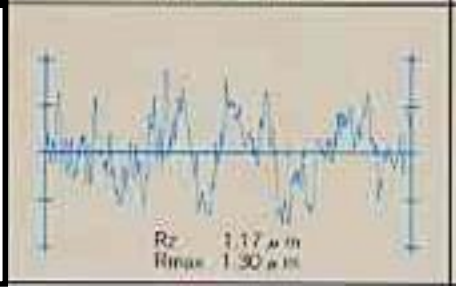
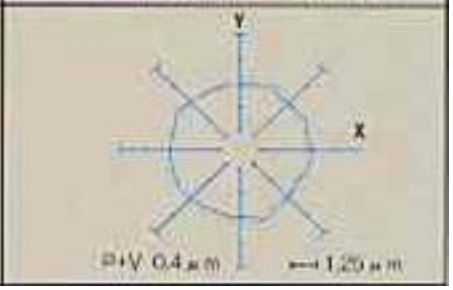
- **It is possible to apply Nitriding to Nickel base Alloys as a mass production.**
  Wear resistance is improved in high temperature atmosphere without chipping.



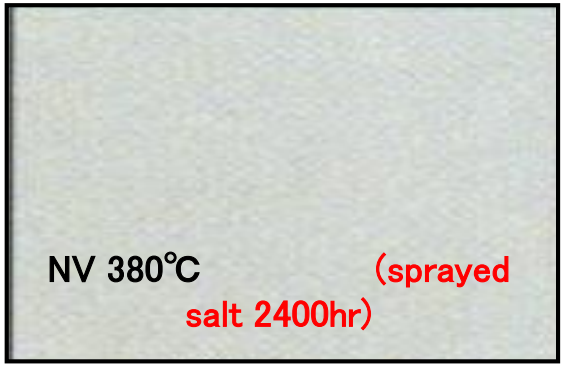
（Left : NCF47W, Center : INCONEL718, Right : INCONEL751 ）

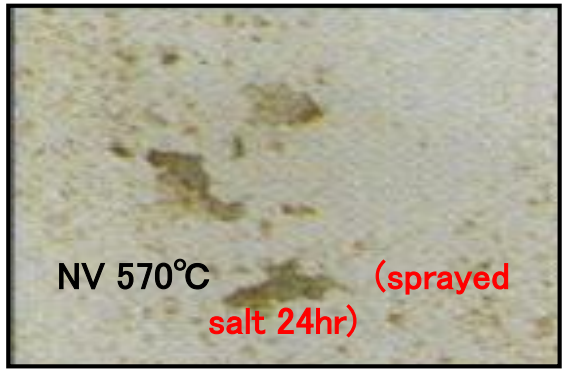
Effect of low temperature Nitriding

- **NV Nitriding is possible to realize minute change in shape and roughness.**

SUS316	Roughness	Roundness
Row material		
NV 380℃		
NV 570℃		

Appearances after salt spray test（SUS316）





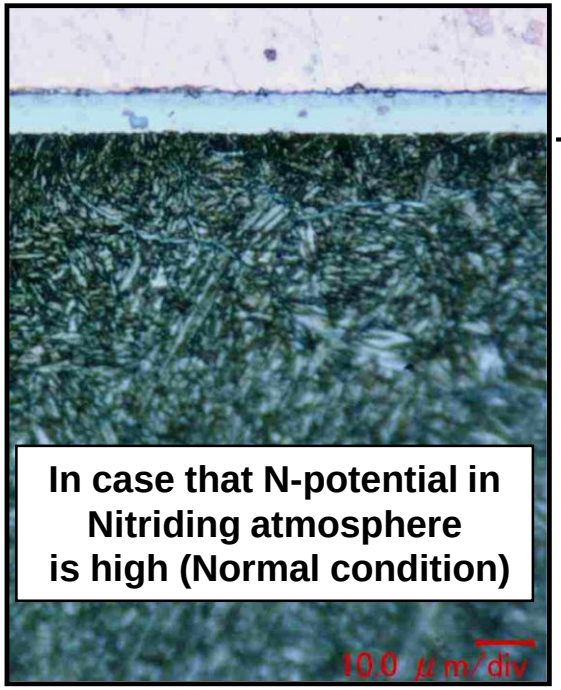
Control of compound layer

= Example of SCM435 =

- **Nitriding layer without compound layer which has been difficult by conventional Nitriding methods can be realized by NV Nitriding. NV Nitriding can make harder surface of diffusion layer compared with other Nitriding methods.**

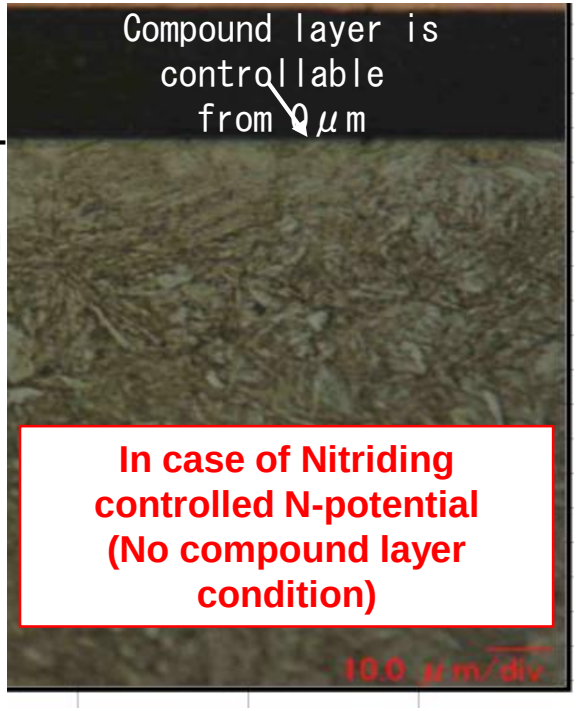
Compound layer

Nitriding layer without compound layer is impossible in case of normal condition



In case that N-potential in Nitriding atmosphere is high (Normal condition)

Diffusion layer



In case of Nitriding controlled N-potential (No compound layer condition)

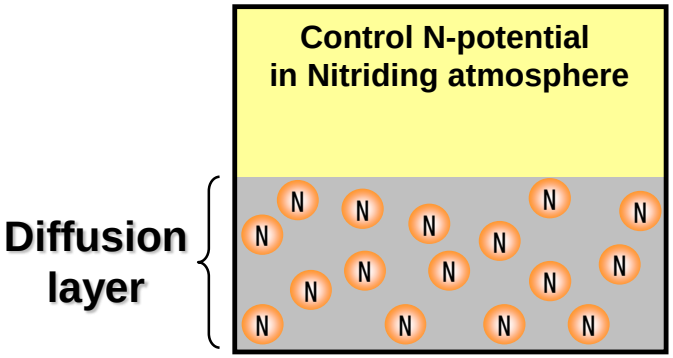
NV Nitriding can make both types of Nitriding layer.

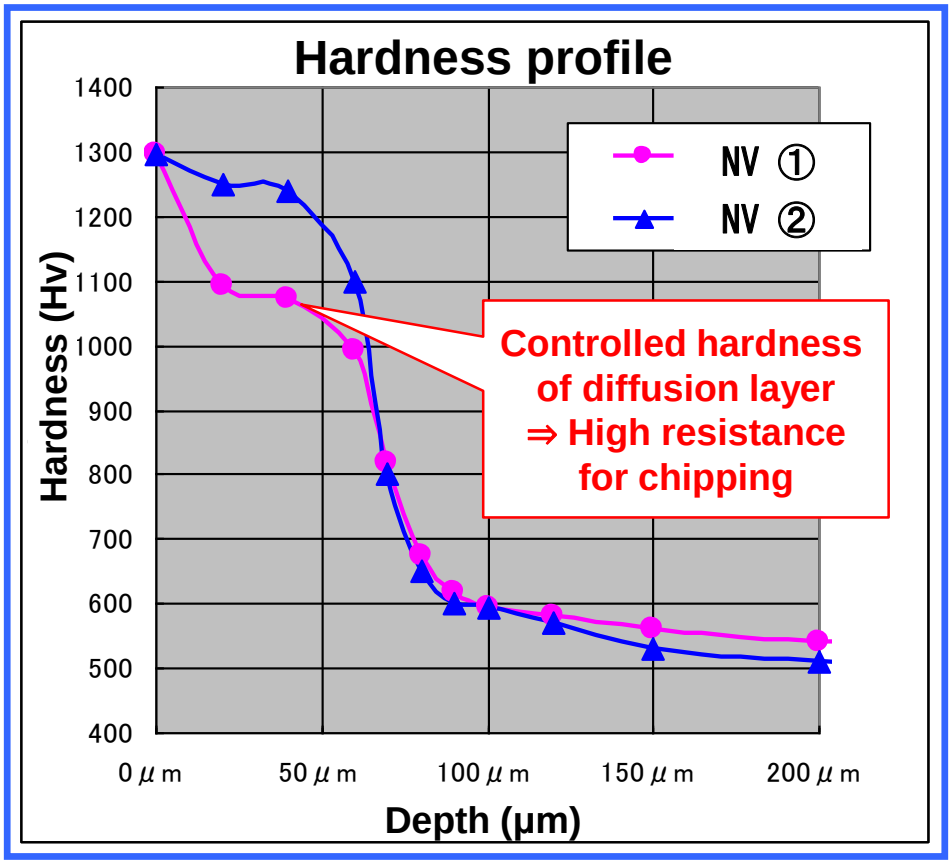
Control of hardness of Nitriding layer

＝ Example of SKD61＝

- **Hardness of Nitriding layer is controllable by NV Nitriding, even if it is difficult to control by conventional Nitriding methods.**

NV Nitiriding can make various types of hardness profiles by Nitriding controlled N-potential, this is realized by activation process.





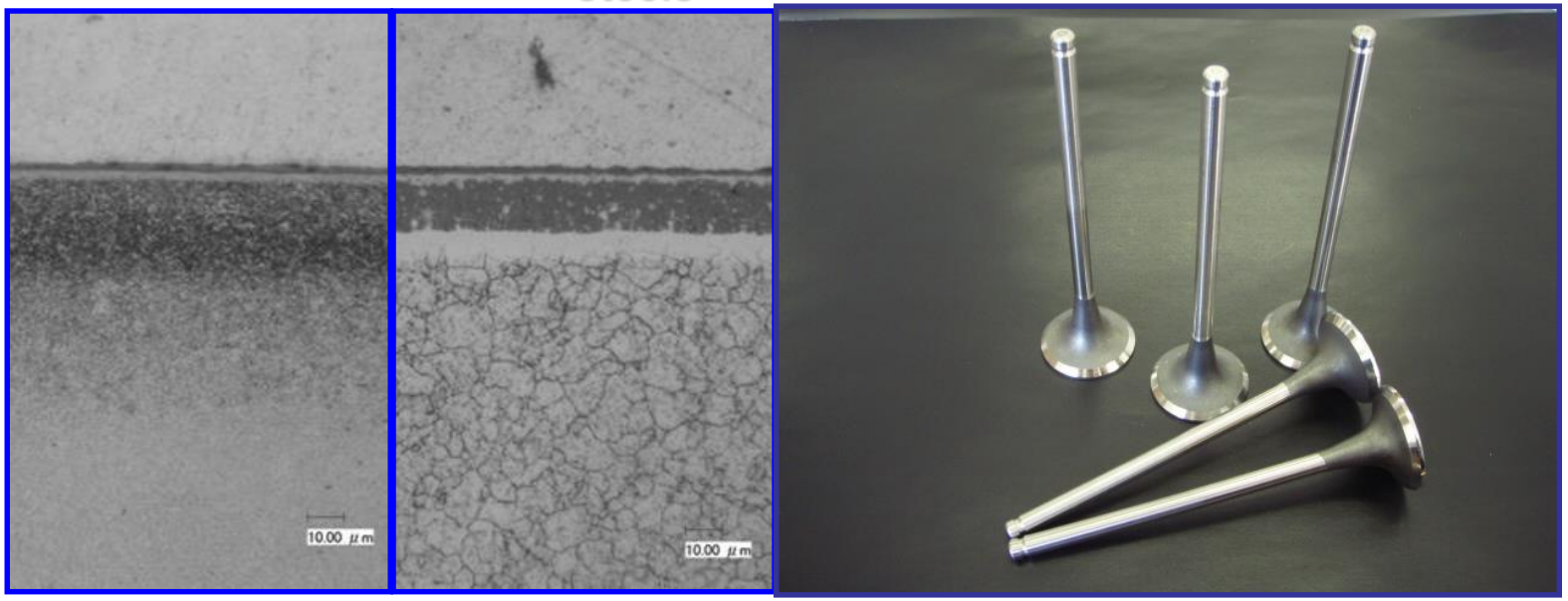
3. Samples applied NV Nitriding

NV PROCESS

Engine valves

＝ Heat- resistant stainless(SUH35, SUH11) ＝

- **Advantages of NV Nitriding**
  【Auto motive parts】
  ① Cost, delivery ； Low Nitriding cost and short lead time are realizable by high capacity furnace or on-site system
  ② Environment ； Environmentally friendly technology without cyanide
  ③ Wear resistance ； Stable Nitriding layer on the surface of stainless steels

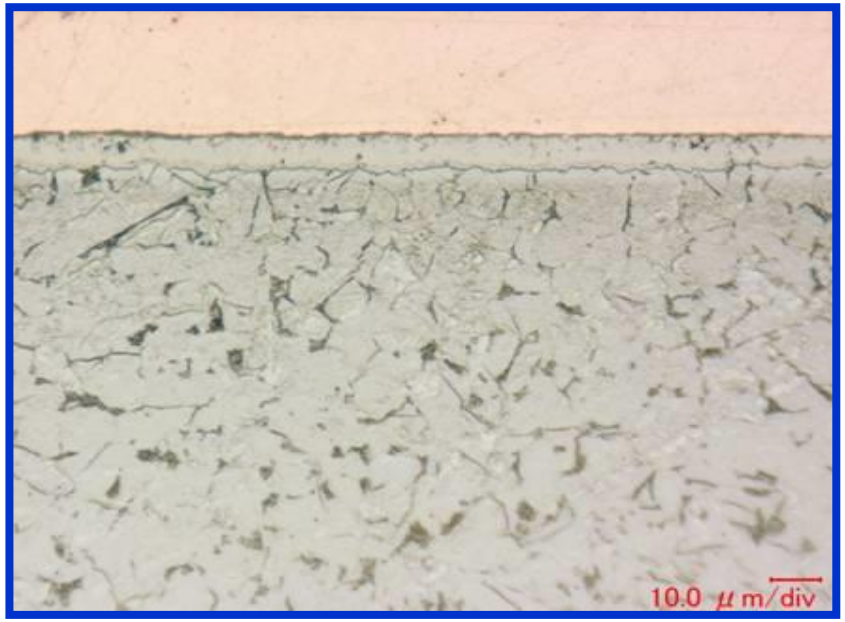


（Left; SUH11, Right; SUH35）

Bearing retainers

＝ SPCC ＝

- **Advantages of NV Nitriding**
  【Auto motive parts】
  ① Prevent welding and scoring ； 1.5 times in comparison with salt bath Nitriding. 3 times in comparison with raw material.
  ② Cost, quality ； It is possible to make stable layer under setting as a stack



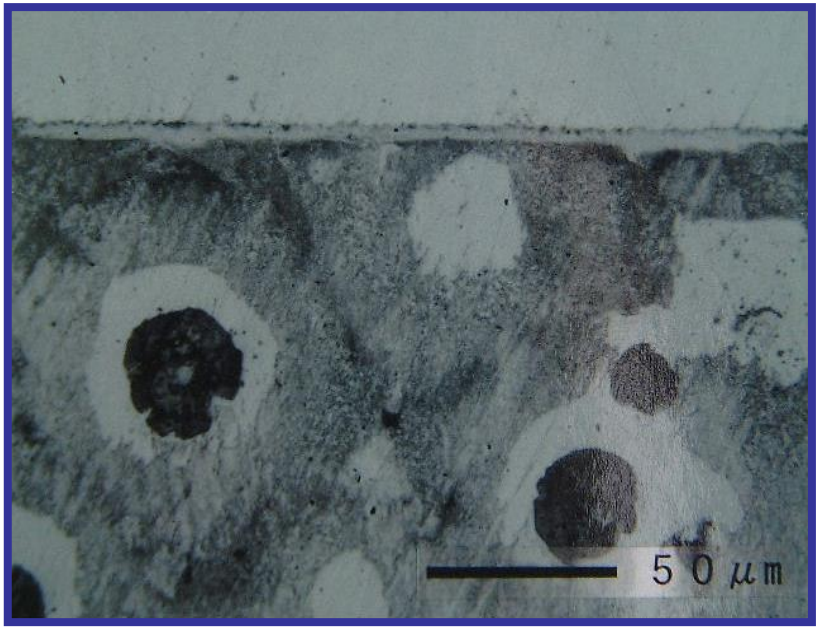
（Nitriding structure of SPCC）

（Bearing retainer）

Shafts for rotary compressor

＝ Ductile cast iron(FCD600) ＝

- Advantages of NV Nitriding
  【Air conditioner parts】
  ① Wear resistance; Wear resistance under new refrigerant is available
  ② Accuracy of dimension; Keeping accuracy of dimension by low temperature Nitriding

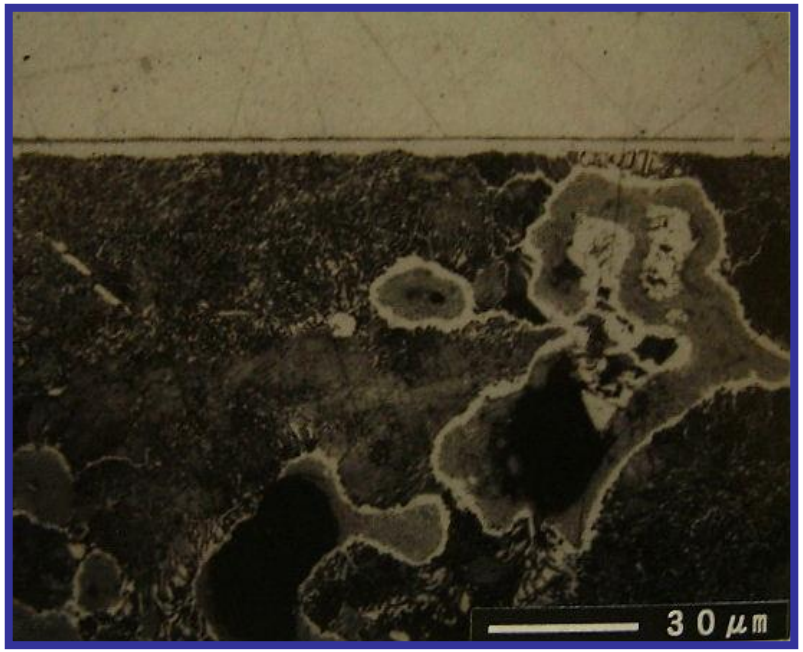


（Nitriding structure of FCD600）

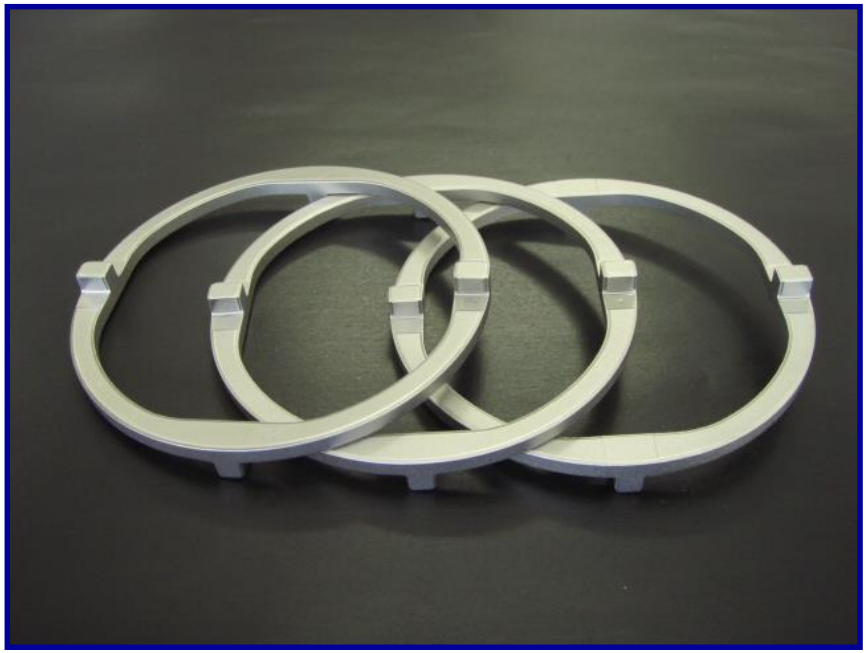
Oldham's rings for Scroll Type Compressor

＝ Sintered iron ＝

- Advantages of NV Nitriding
  【Air conditioner parts】
  ① Nitriding for Sintered iron；It is possible to make stable Nitiriding layer without influence from sintering additive
  ② Accuracy of dimension；Low temperature Nitriding is possible by activation
  ③ Wear resistance；Effect of high quality Nitriding layer



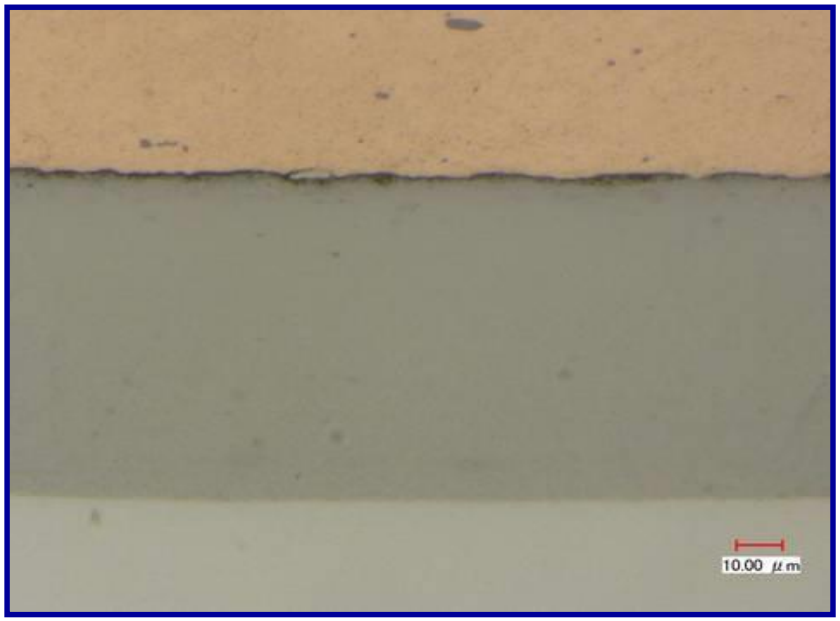
（Nitriding structure of sintered iron）



Variable turbo charger parts

＝ Austenitic stainless ＝

- **Advantages of NV Nitriding**
  【Auto motive parts】
  ① Uniformity；Uniform Nitriding layer is realizable even if shape of parts is complex
  ② Wear resistance；Effect of tough Nitriding layer without porous structure

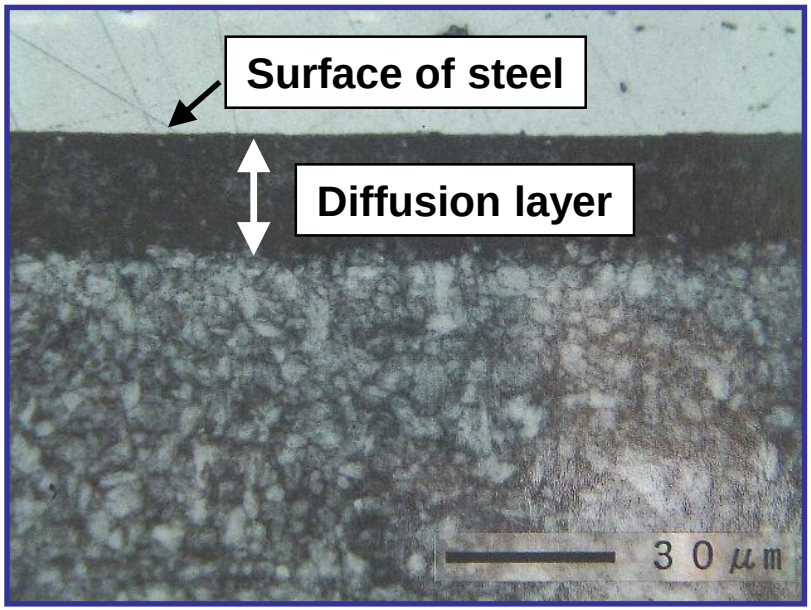


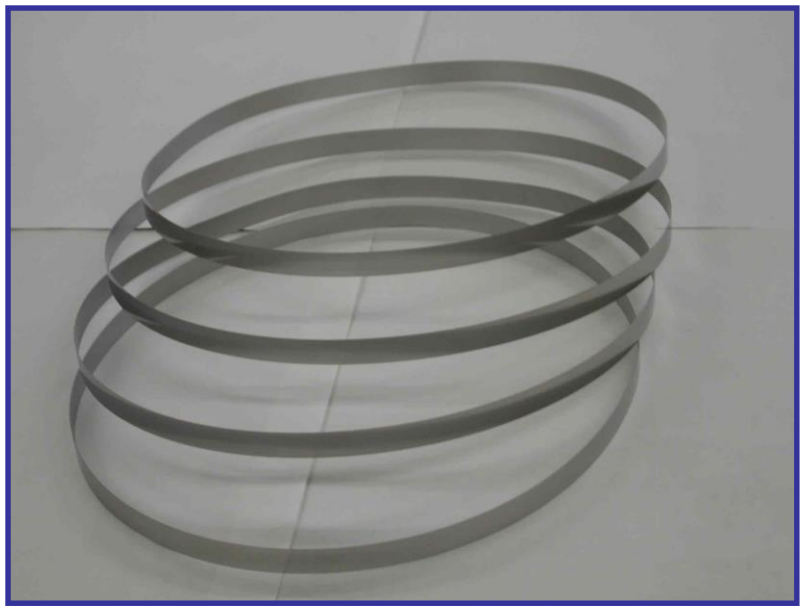
（Nitriding structure of austenitic stainless steels）

Steel belts

＝ Marageing steel ＝

- **Advantages of NV Nitriding**
  【Auto motive parts】
  ① No compound layer; No embrittlement problem against thin plate parts
  ② Uniformity; Uniform Nitriding layer, depth and hardness, is realizable
  ③ Fatigue strength; Enriched fatigue strength by Nitriding ⇒ 100 times in comparison with raw material



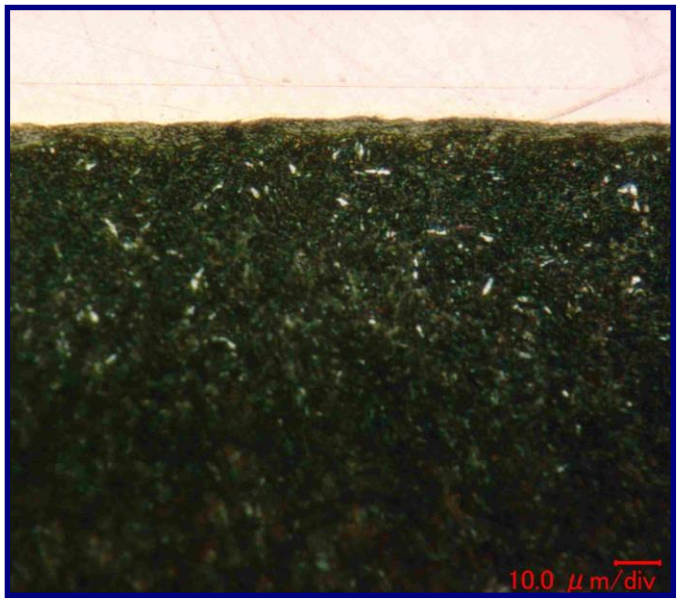


（Nitriding structure of Marageing steels）

High strength springs

＝ Spring steel ＝

- **Advantages of NV Nitriding**
  【Auto motive parts】
  ① Fatigue strength; Nitriding layer without compound layer has toughness. Core hardness can be kept by low temperature Nitriding.
  ⇒ NV Nitriding can makes 20% higher fatigue strength parts than conventional Nitriding methods
  ② Uniformity; Uniform Nitriding layer can be made on the surface area which contacted each parts.

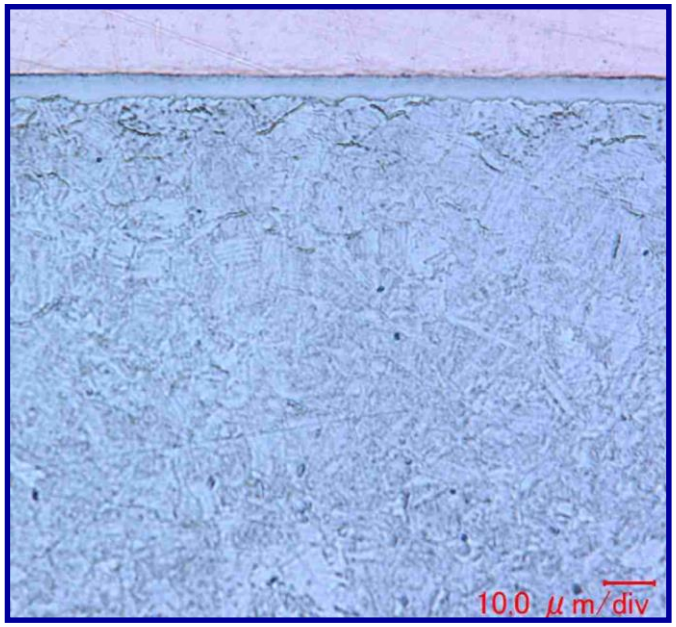


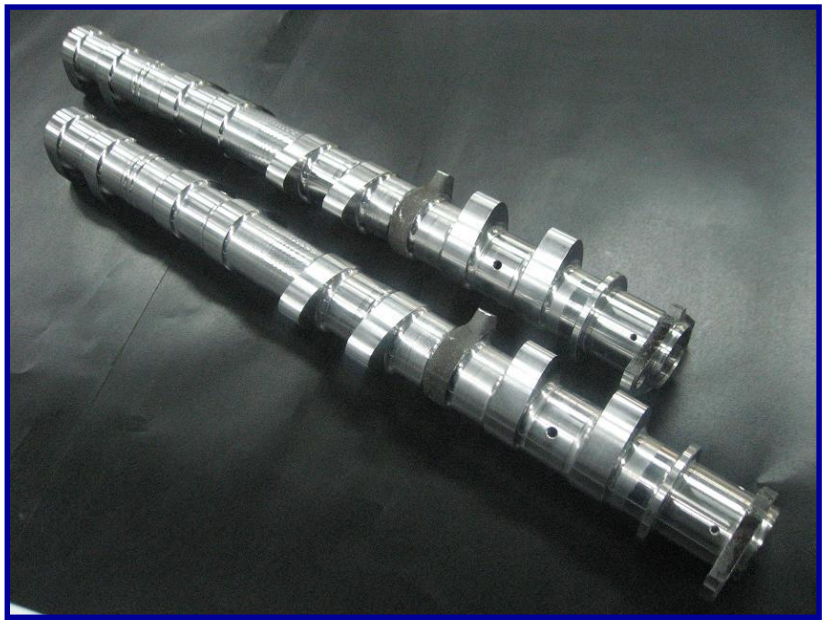
（ Nitriding structure of Spring steels ）

Camshaft

＝ SCM420 ＝

- **Advantages of NV Nitriding**
  【Auto motive parts】
  ① Minute strain；NV Nitriding can make Nitriding layer, which has as high wear resistance as conventional methods, by low temperature Nitriding
  ② Controlled layer；Optimum depth of Nitriding layer to realize both wear resistance and toughness can be applied by NV Nitriding



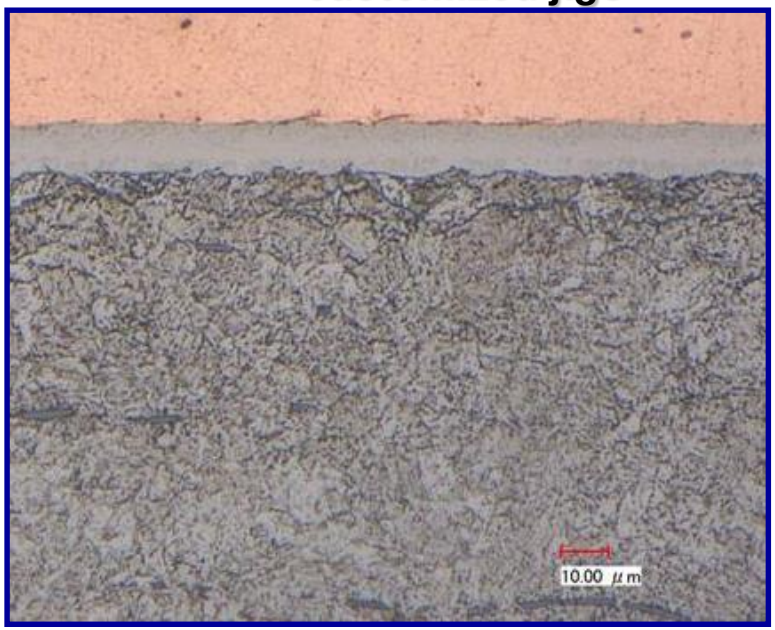


（Nitriding structure of SCM420）

Crankshaft

＝ Alloy steel ＝

- **Advantages of NV Nitriding**
  【Auto motive parts】
  ① Minute strain；NV Nitriding can make Nitriding layer, which has as high wear resistance as conventional methods, by low temperature Nitriding
  ② Cost；Low Nitriding cost is realizable by high capacity furnace or customized jigs

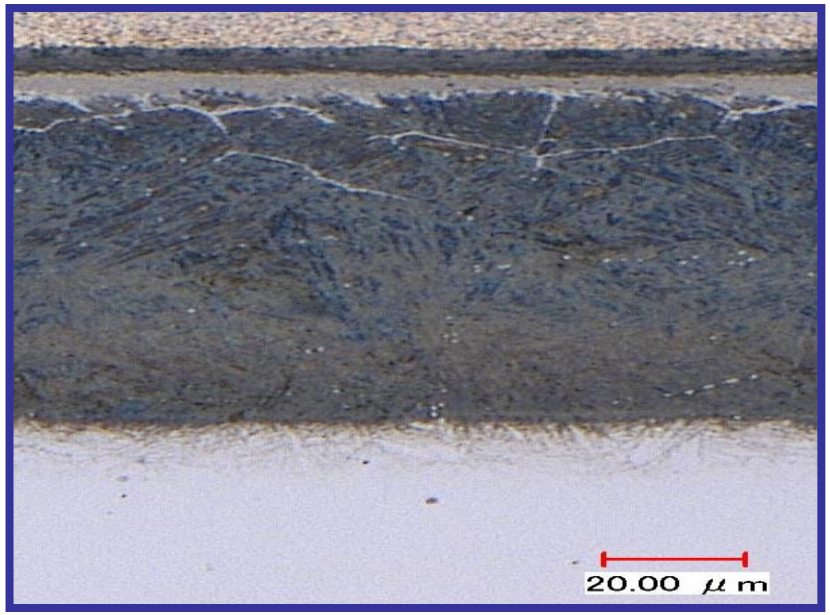


（Nitriding structure of alloy steels）

Textile machinery parts

＝ Martensitic stainless ＝

- **Advantages of NV Nitriding**
  【Textile machinery parts】
  ① Wear resistance ； Hard and non-porous compound layer made by NV Nitriding can improve wear resistance
  ② Oxidizing layer ； NV Nitriding can make Oxidizing layer on the surface of Nitriding layer. It is more effective for prevention of welding and scoring than conventional Nitriding layer.

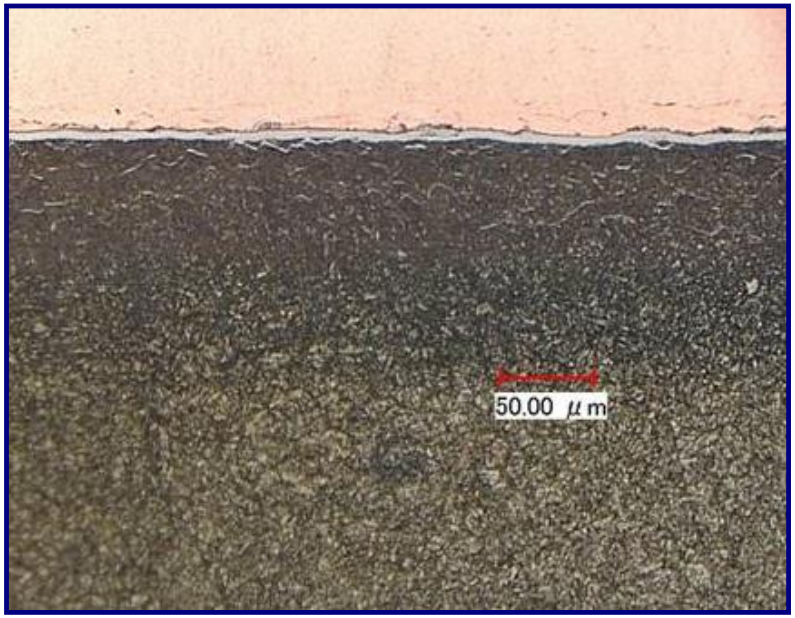


（Nitriding structure of martensitic stainless steels）

Aluminum extrusion Dies

＝ Alloy tool steel (SKD61) ＝

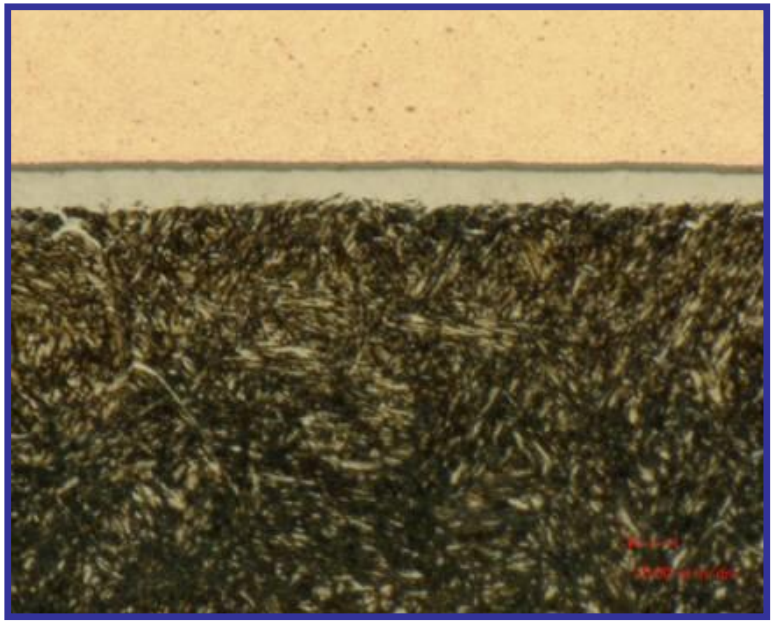
- **Advantages of NV Nitriding**
  【Tool, Mold and Die field】
  ① Wear resistance; 1.5 - 2 times in comparison with salt bath Nitriding.
  ② Chipping resistance; High toughness layer by controlled hardness profile
  ③ Cost, delivery; No transportation cost and short lead time are realizable by on-site system



Forging Dies

＝ Alloy tool steel (SKD61) ＝

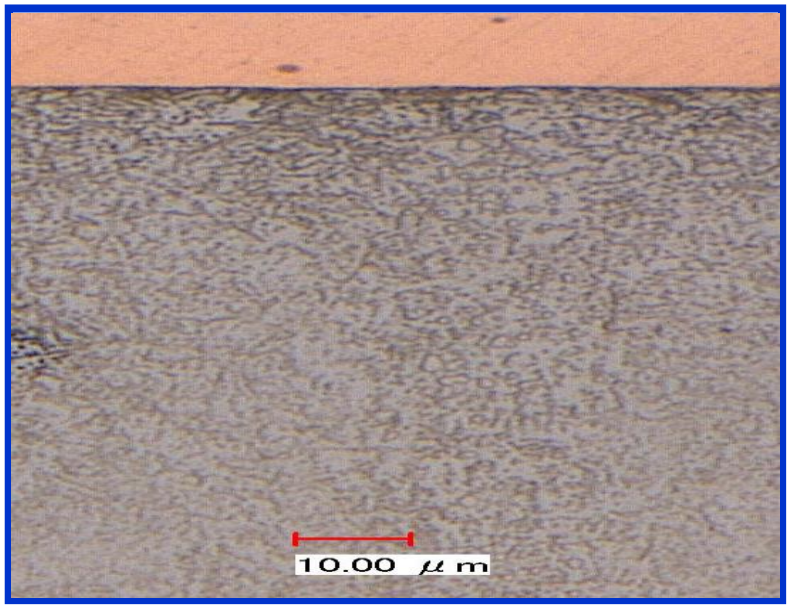
- **Advantages of NV Nitriding**
  【Tool, Mold and Die field】
  ① Wear resistance；1.5 times in comparison with conventional gas Nitriding.
  ② Prevent welding and scoring；Stable prevention of welding and scoring can be realized by Uniform compound layer



Plastic injection mold

＝ Alloy tool steel (SKD11) ＝

- **Advantages of NV Nitriding**
  【Tool, Mold and Die field】
  ① **Uniformity**; **Uniform Nitriding layer is realizable even if shape of parts is complex or low temperature Nitriding is applied**
  ② **Toughness**; **Nitriding layer without compound layer has high toughness**
  ③ **Accuracy of dimension**; **Keeping accuracy of dimension and core hardness by low temperature Nitriding**



（Nitriding structure of SKD11）

4. NV Nitriding for Die-casting Dies (NVX for Insert) (NVF for Pin)

NV PROCESS

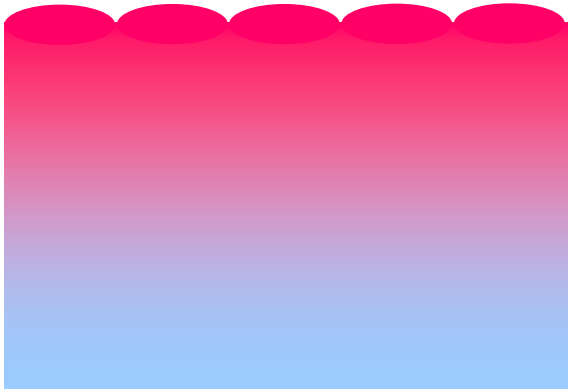
Principle of generation of Heat-check

Put aluminum melt → Temperature on the surface of die rise

Surface

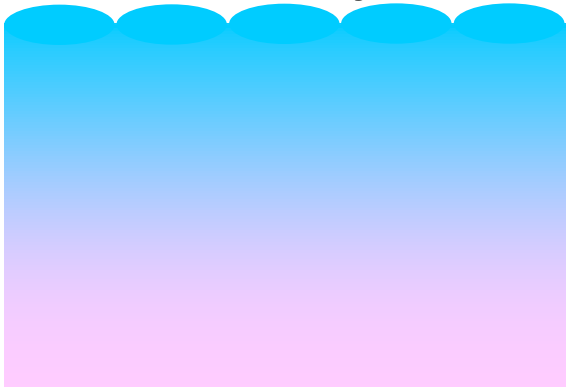
Inside

Compressive stress rise on the surface → Plastic strain

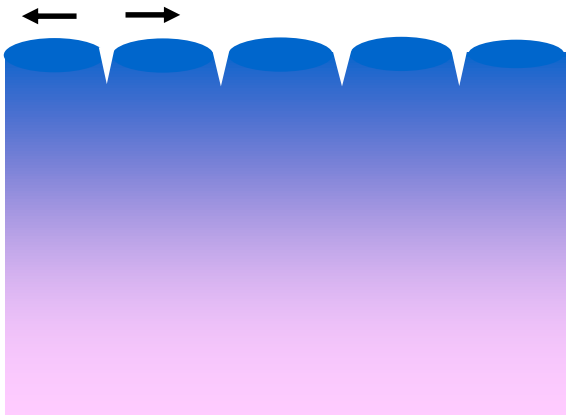


High temperature

Spray lubricant → Temperature on the surface of die drop suddenly



Tensile stress concentrate on the concave area → Heat-check



Low temperature

For prevention against Heat-check

- **Cause of Heat-check is tensile stress concentration during cooling down**

【Preventive metods】

① Plastic strain is needed to be decreased during heating up

⇒ Strength of dies in high temperature should be kept

⇒ Diffusion layer of nitrogen is effective to keep strength during heat cycles.
(However, excessive hardening worsen, because of embrittlement)

② Compressive stress should be provided against tensile stress

⇒ Nitriding which can generate high compressive stress on the surfece is effective. (Compound layer worsen, because it may cause crack)

【Attention points for Nitriding】

① Thin compound layer is better for crack prevention and welding to modify dies)

② Surface hardness should be optimized in balance between compressive stress and toughness)

③ Diffusion layer should be kept optimum hardness deeply

Hardness control by NV Nitriding

【 Hot die steel】

- **It's possible to control hardness of diffusion layer, even if it was difficult by conventional Nitriding methods.**

  ① Adjustable ranges of condition are limited in case of conventional Nitriding methods

  ② NV Nitriding can control gases composition flexibly by effect of activation process, therefore hardness of diffusion layer can be easily designed by control of invasion and diffusion of N and C atoms.

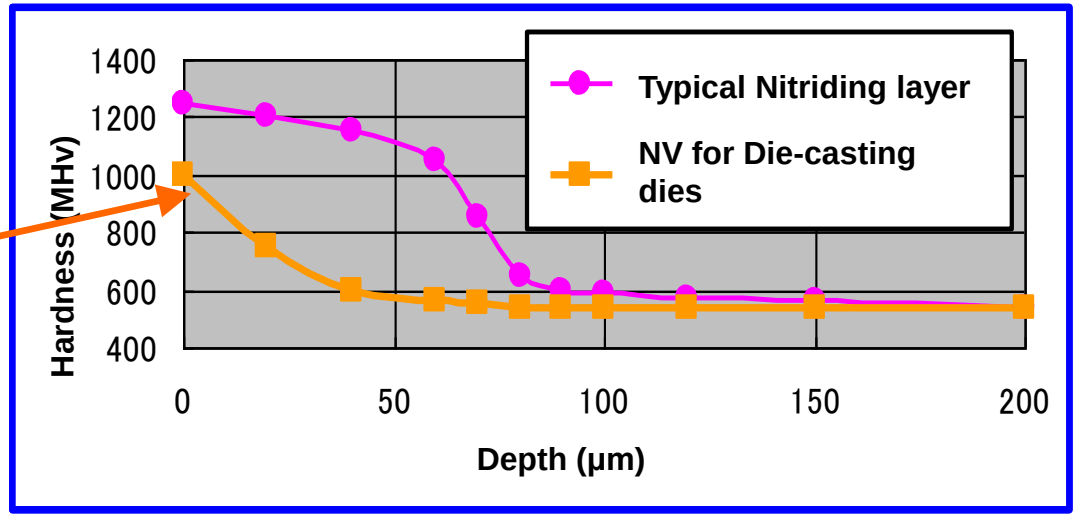
  ⇒ This is the patented technology

Hardness profile for

Die-casting dies

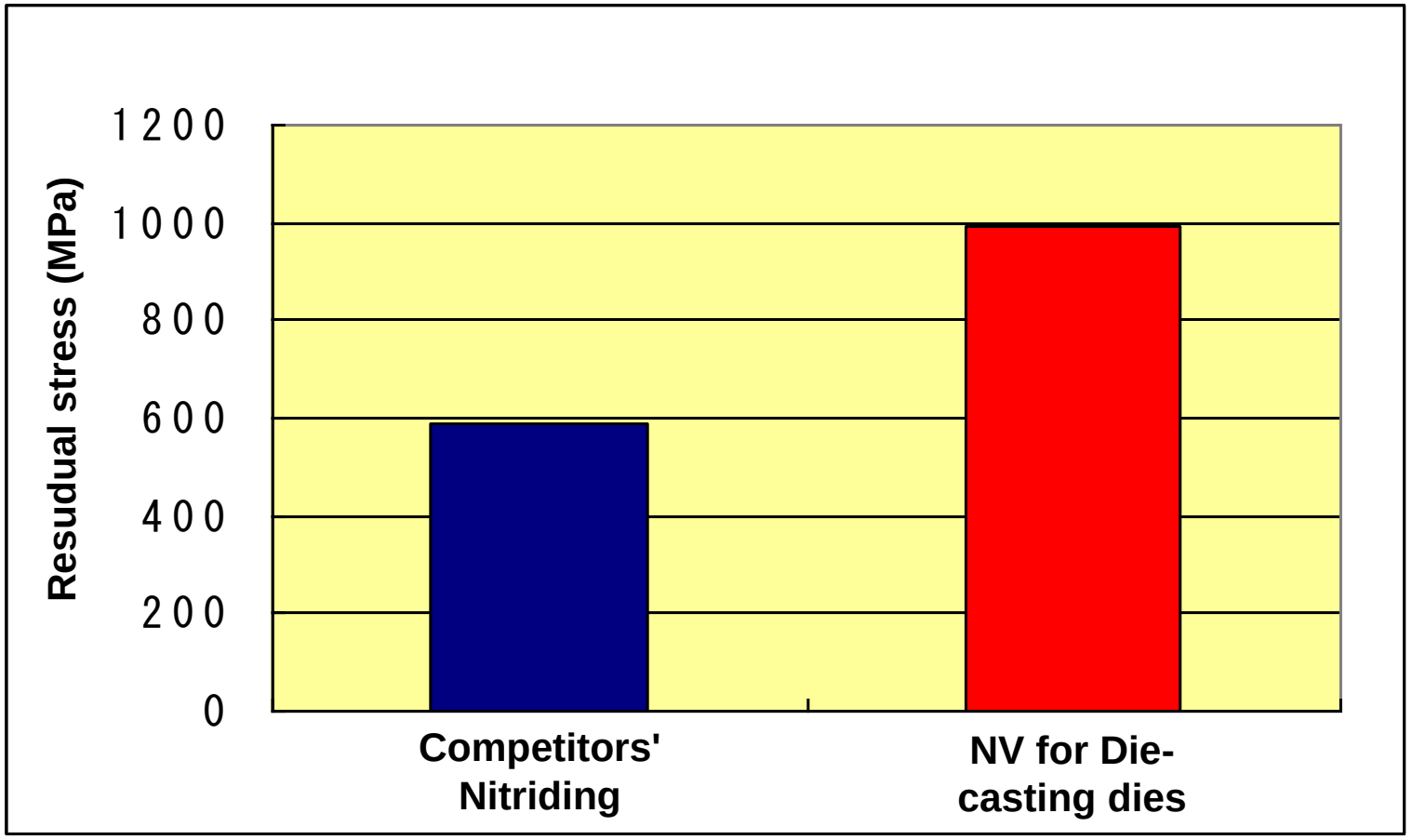
High hardness is only surface area

⇒For wear resistanse and preventation against Heat-check



Residual compressive stress

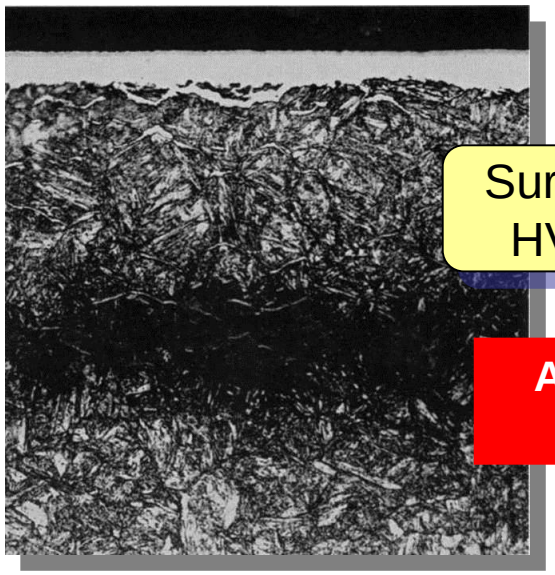
- **Compressive stress is provided against tensile stress to prevent Heat-crack. Residual compressive stress provided by NV Nitriding for Die-casting dies is 60% higher than the one provided by competior's surface treatment for Die-casting dies.**



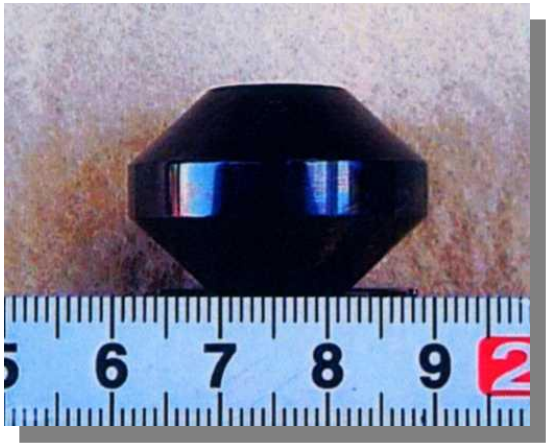
Result of Heat-Cycle test

- **Comparison with nomal Nitriding sample**

Normal Nitriding sample



NV for Die-casting dies



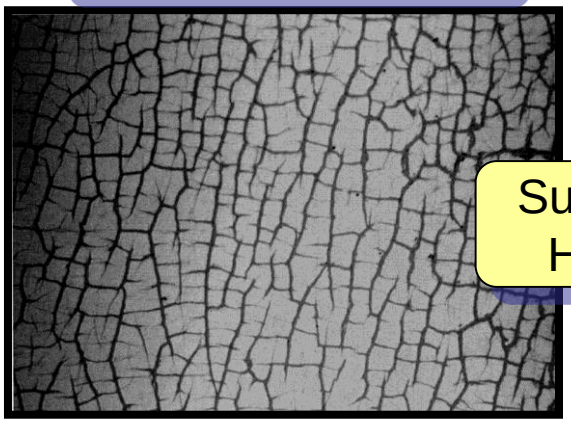
Surface hardness
HV1000～1100

Adjustable as same level

Result of Heat-Cycle test

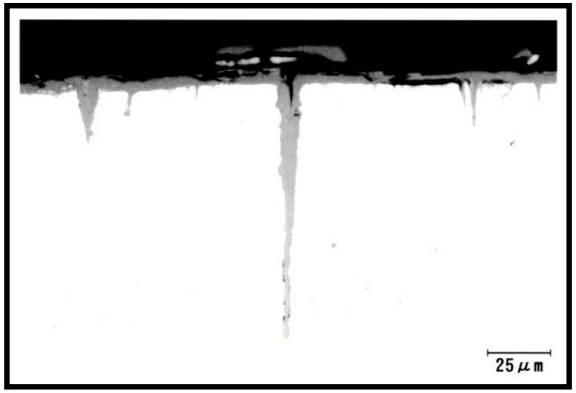
- **Surface after Heat-Cycle test ([600℃ ⇔Room temp.] 300 times)**

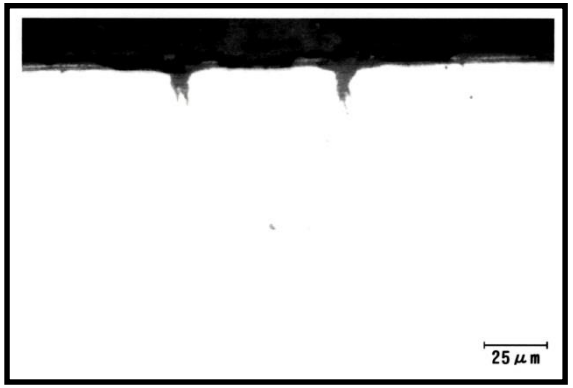
Normal Nitriding sample



Surface hardness
Hv1000～1100

NV for Die-casting dies



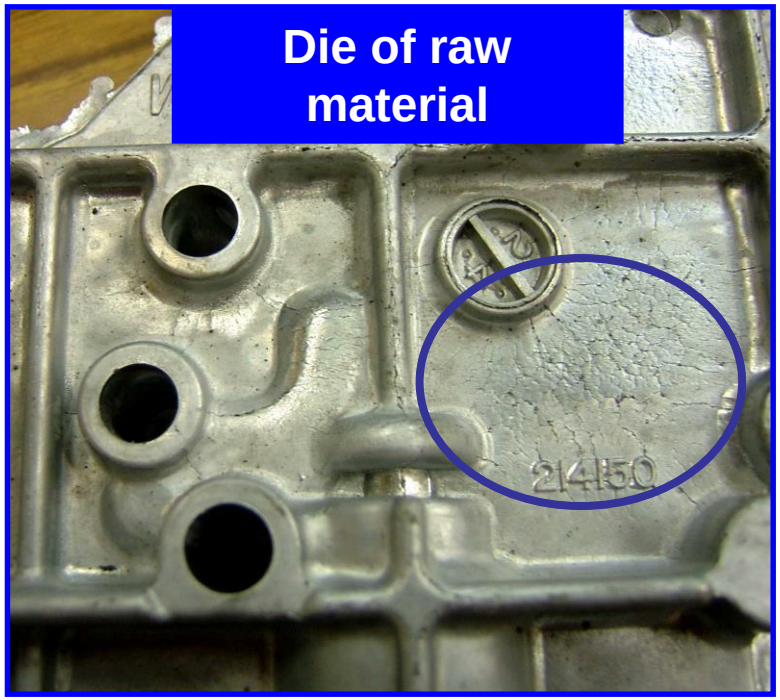


Sample crack deeply. There are rough crack on the surface

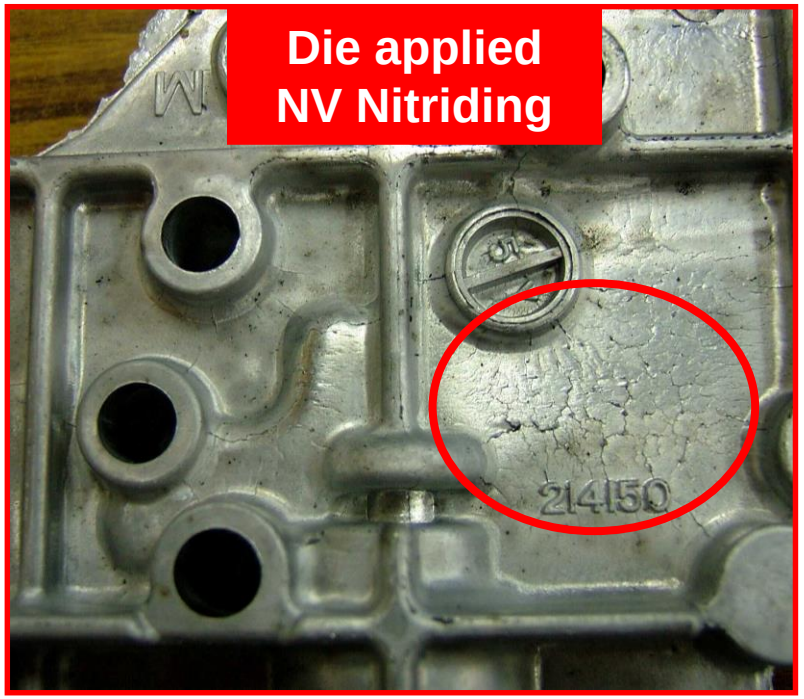
Development of crack can be prevented. There are only minute Heat-check.

Comparison with die applied only quenching and tempering

- **Point : Level of Heat-check is nearly same even die casted about 30,000 shots more than die of raw material. NV Nitriding is effective for life time of die due to no breakage.**



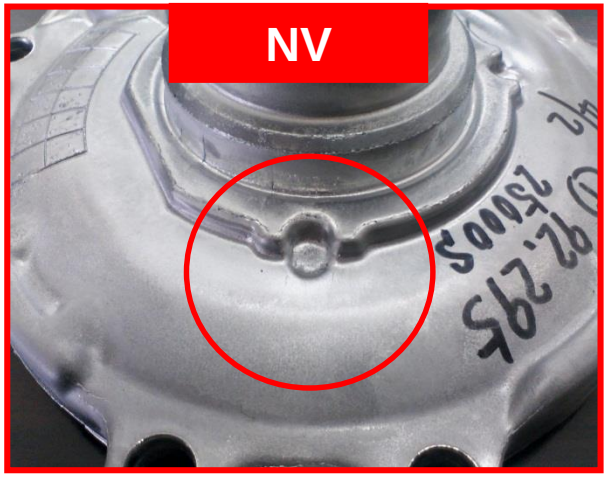
After 18,345 shots

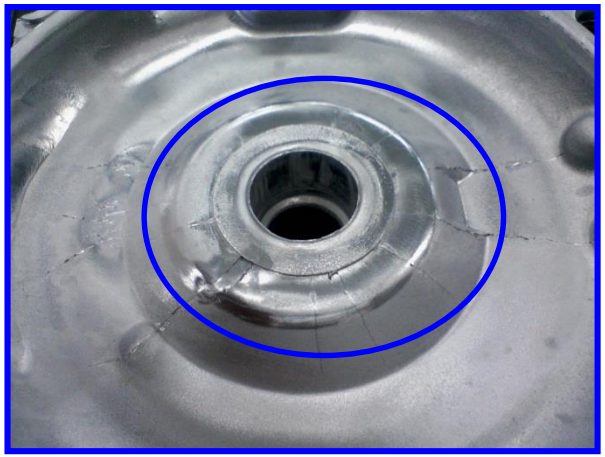


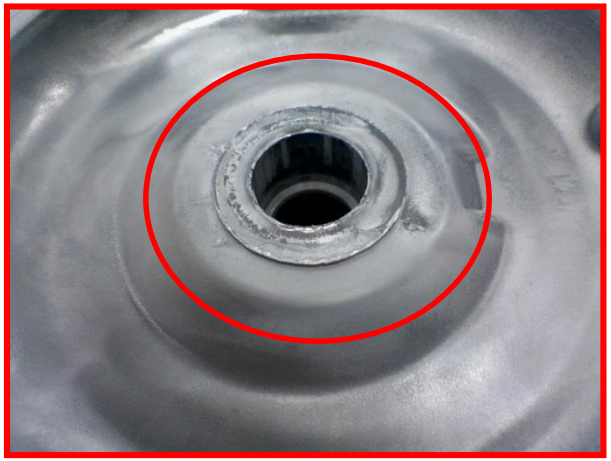
After 47,684 shots

Comparison with competitor's surface treatment

- **Point : These are the surfaces of die after casting 90,000 shots. Surface treatment has been applied 3times until 90,000 shots. Level of Heat-check is better than competitor's surface treatment.**

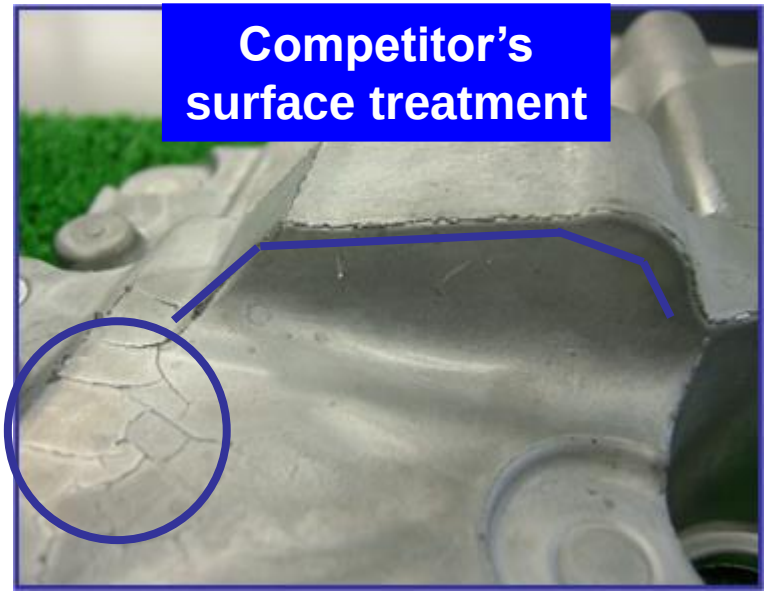




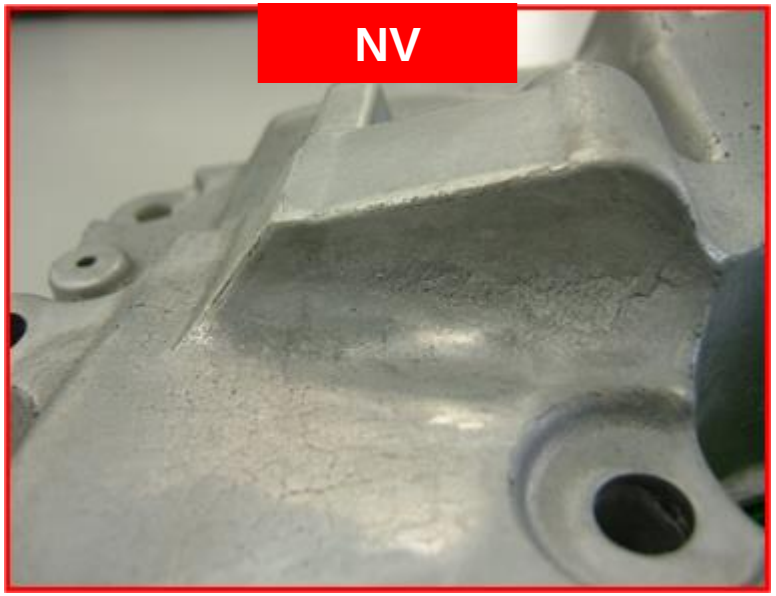


Comparison with competitor's surface treatment

- **Point : NV Nitridng can realize improvement of 30% of life time.**



After casting 90,000 shots



After casting 120,000 shots

5. NV Nitriding for Forging Dies (NVF)

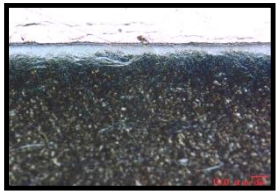
NV PROCESS

Feature of NV Nitriding for forging dies

1. **Uniform Nitriding layer**

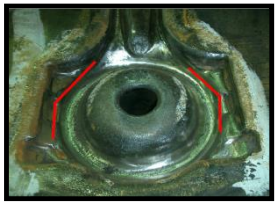
– Uniform Nitriding layer is realizable by NV Nitriding even if shapes of dies are complex.

2. **Prevention of welding and scoring**



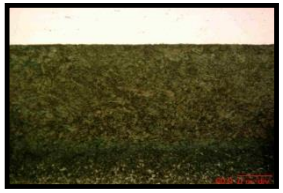
– Improvement of sliding frictional behavior, prevention of welding and scoring can be realized by uniform compound layer and oxide layer on the surface.

3. **Shock resistance and crack resistance**



– Improvement of shock resistance can be realized by hardness control of Nitriding layer. (It is also possible to avoid softening core hardness by low temp. Nitriding

4. **Modification (re-sink)**



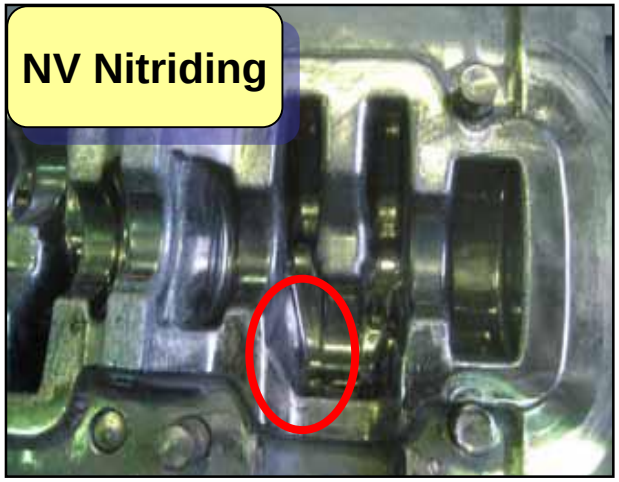
– Modification (re-sink) of dies is available by masking Nitriding or control of Nitriding layer.

Umiform Nitriding layer

Uniformity of NV Nitriding (SKD61 equivalent)

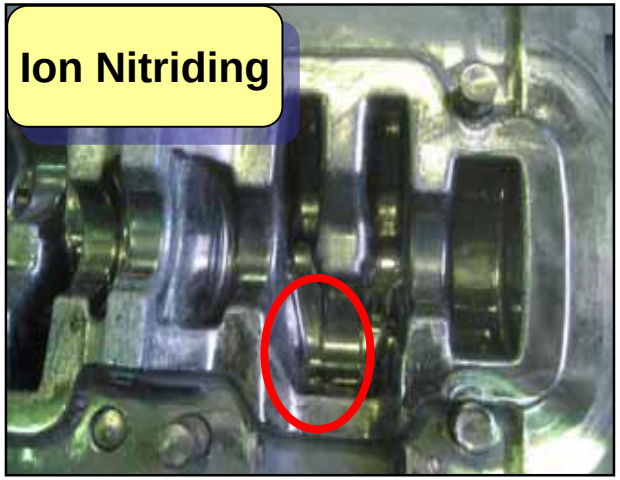
Surfaces of die

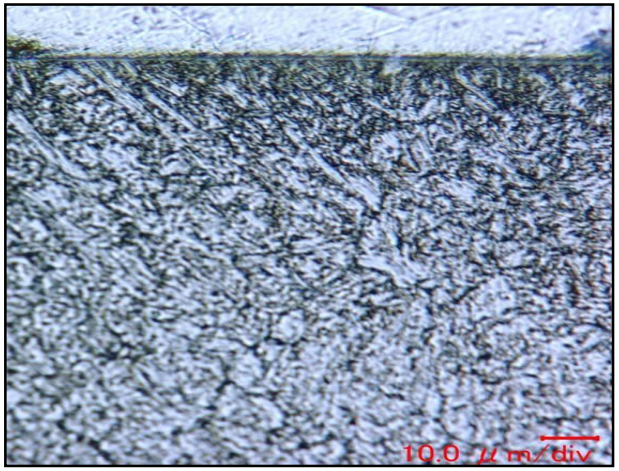
Micro structure (×600)



← Uniform compound layer（ε-layer）

Diffusion layer (CrN precipitate）



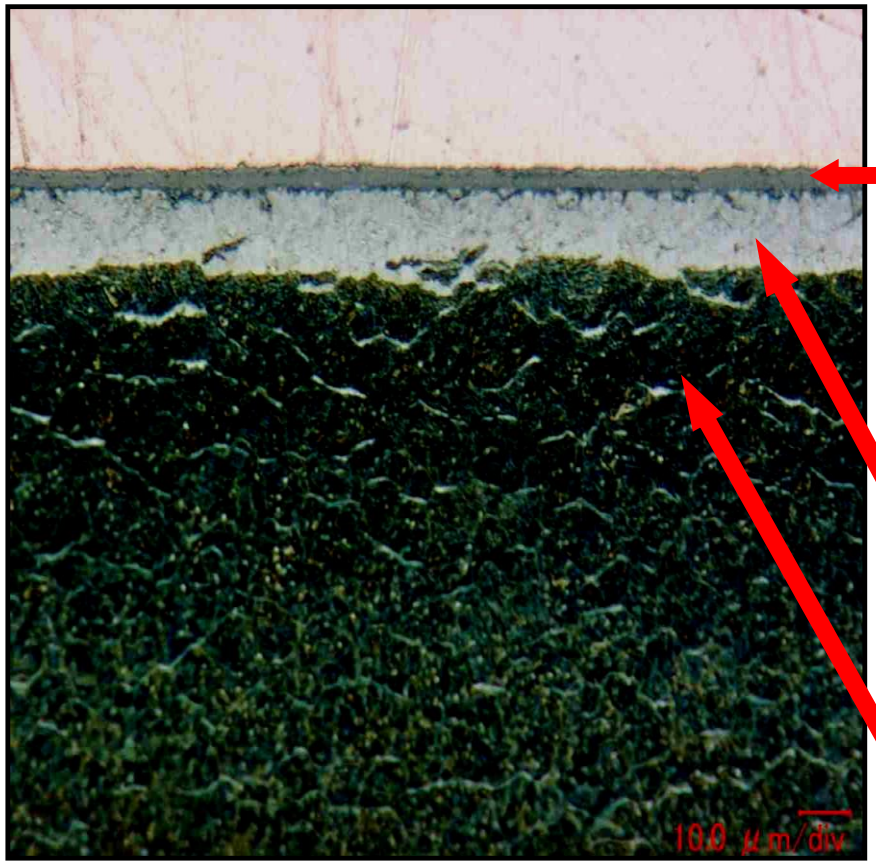


Slight Nitriding layer

In case of complex shape, Nitriding layer is unstable

Sliding frictional behavior, welding and scoring

- Sliding frictional behavior and prevention of welding and scoring can be improved by existence of uniform compound layer and Fe3O4 on the surface which is made by NV Nitriding for forging dies



- Fe_3O_4
  Effective for bedding-in pattern, prevention of welding and scoring, retention of release agent (Impovement sliding frictional behavior)

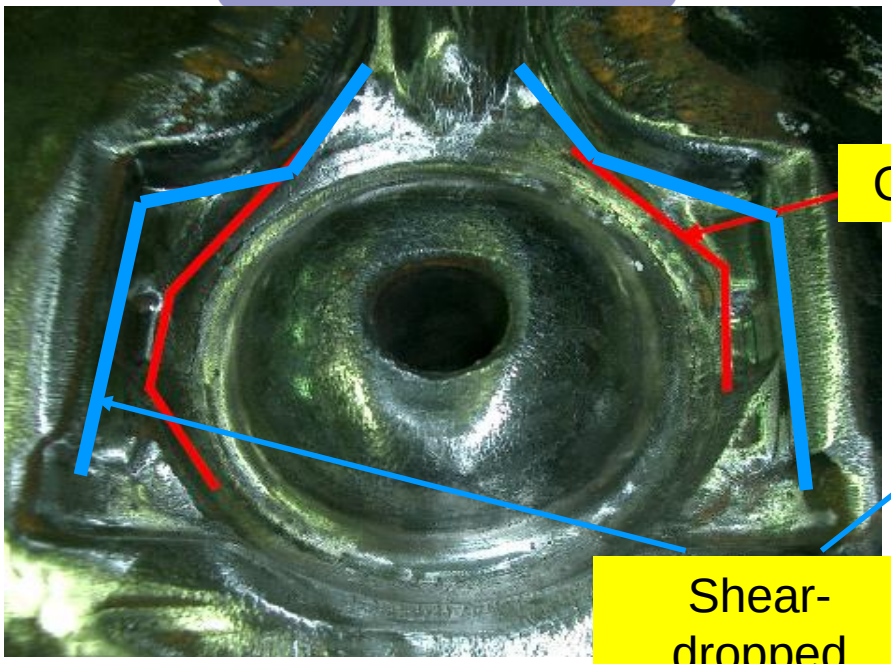
- Uniform ε-layer（Fe_3N）
  Effective for wear resistance, prevention of welding and scoring

- Fe（Solute N）＋Fe_4N
  Effective for toughness of surface area

Shock resistance

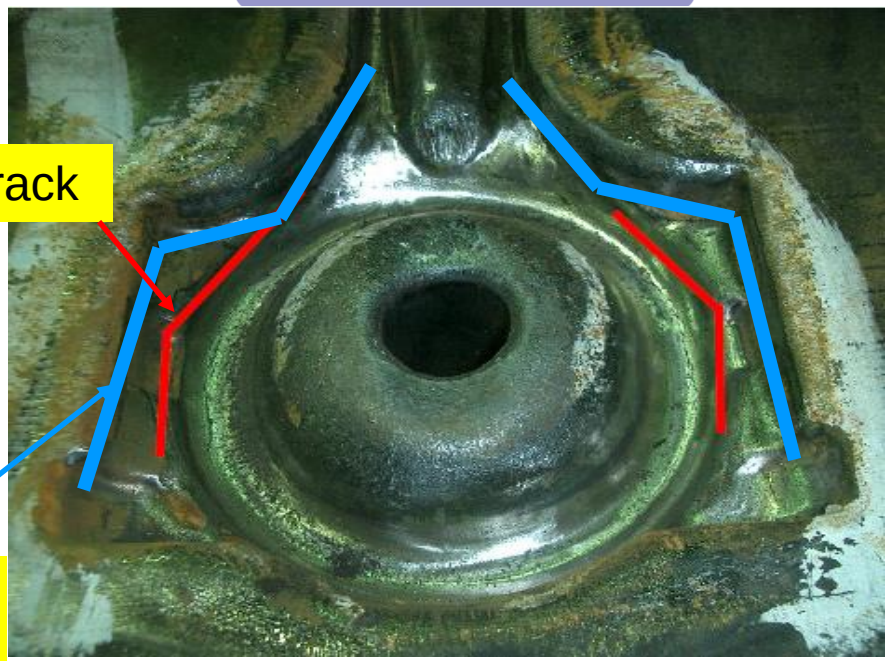
Improvement of die life or continuous forging without maintenance is possible

NV Nitriding



10,500 shots

Salt Nitrosulphurizing



6,500 shots

Die life is above, but shear-dropped is occurred after following shots.

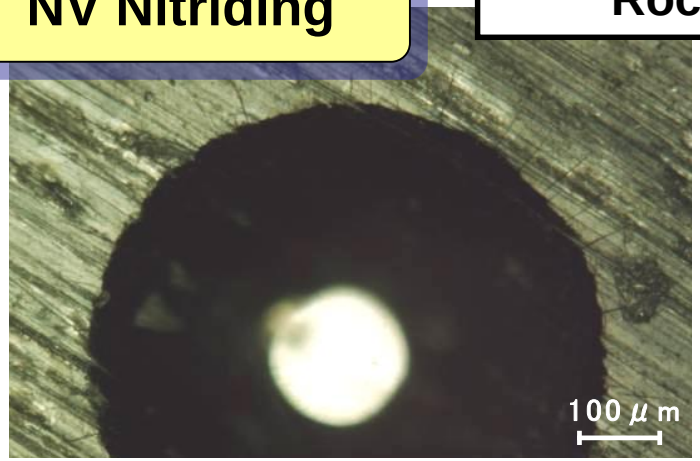
Dies applied NV: 8,500 shots Salt Nitrosulphurizing: 3,000 shots

Crack resistance

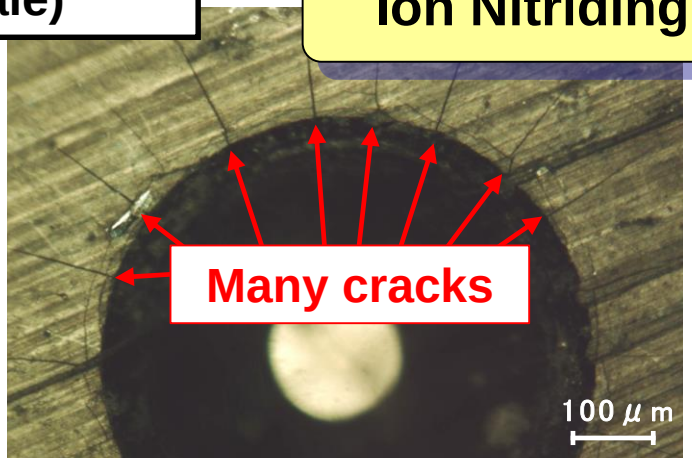
- Toughness of hardened layer can be improved

Toughness evaluation by Rockwell (C-scale)

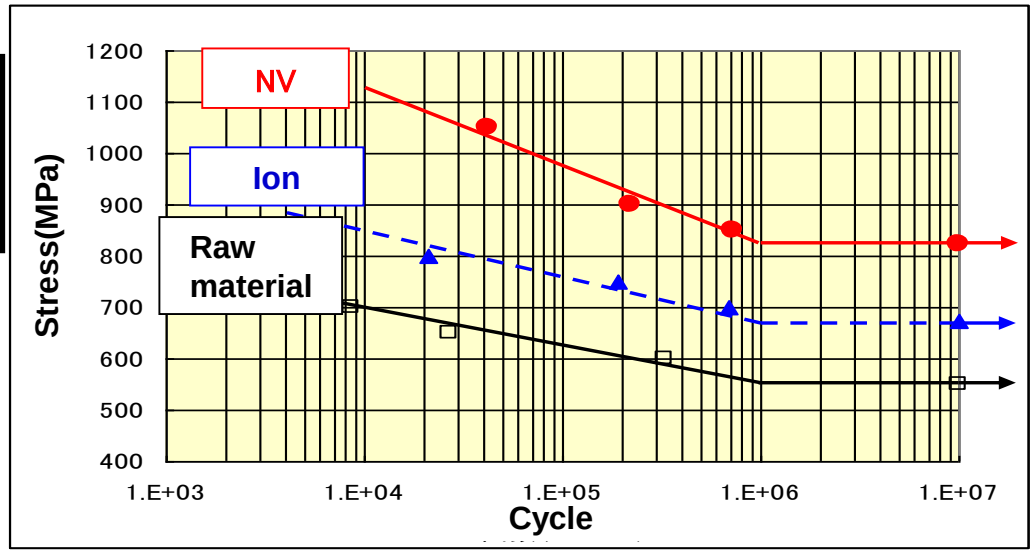
NV Nitriding



Ion Nitriding



Rotary bending fatigue testing



Fatigue strength is so improved by relieving embrittlement ⇒Crack resistance is improved under loading repeated stress