Stainless Steels

Basic Information

Structure

1. Definitions
2. Corrosion in Stainless Steel
3. Types of Stainless Steel
4. Applications & Limits
5. Summary
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7. Discussion

1. Definitions

What is Stainless Steel?

1. Definitions

1.1 Stainless Steel

Stainless steel does not stain, corrode, or rust as easily as ordinary steel (it stains less), but it is not stain-proof.
http://www.stainless-online.com/why-stainless-steel-stainless.htm

1.2 Corrosion

Corrosion means the disintegration of a material into its constituent atoms due to chemical reactions with its surroundings.
http://en.wikipedia.org

1. Definitions

Corrosion resistance depends on:

- chemical composition of the steel
- heat treatment
- environmental conditions:
  temperature, humidity, acids, ...
- applied mechanical stress
- surface preparation: polished vs. brushed

1. Definitions

What makes Steel Stainless?

1. Definitions

12% Cr

Cr_2O_3 film

2. Corrosion in Stainless Steel

- types / mechanisms

- examples

2. Corrosion in Stainless Steel

2.1 Uniform Corrosion

- in acids, basics, salt melts
- usually rather slow
- can be estimated and considered in design
- has to be watched → chemical industry
- increased by sulfur
- decreased by nickel
- minor problem with stainless steels

2. Corrosion in Stainless Steel

2.1 Uniform Corrosion

2. Corrosion in Stainless Steel

2.2 Pitting Corrosion

- formation of small pits
- in media containing Cl^- or Br^- - ions
  → marine conditions, chemical industry
- high corrosion rates within the pit, none outside
- increased by S, C, P
- decreased by Mo, N

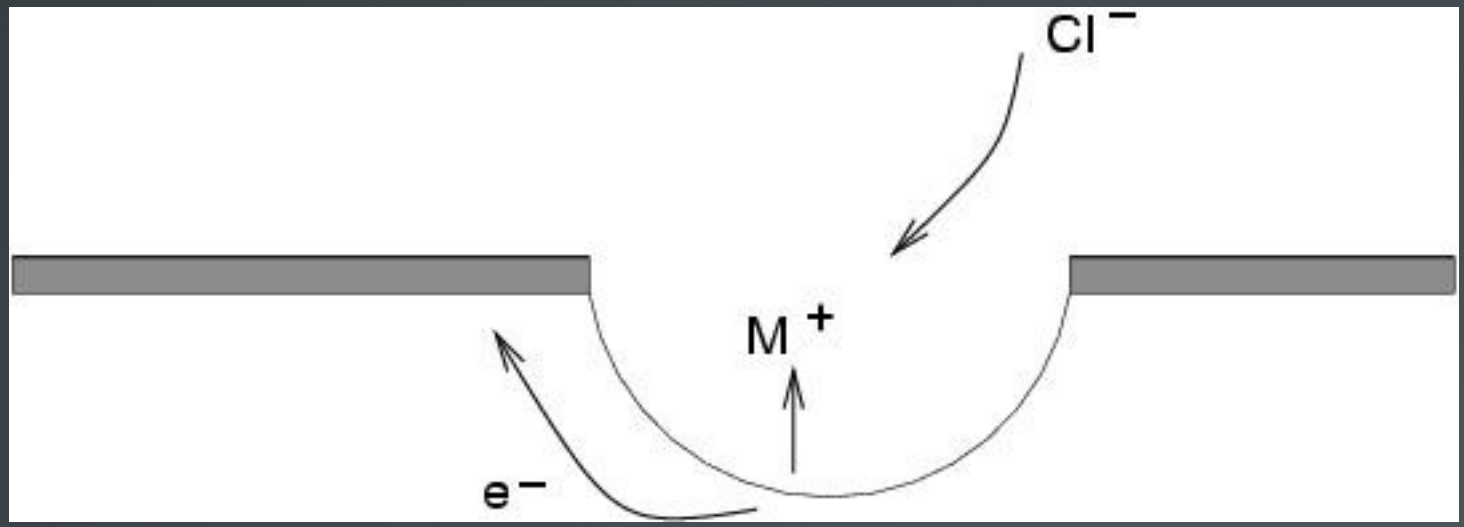
pitting index for Austenite:

PI = %Cr + 3.3 %Mo + 30 %N

positive: PI > 40

2. Corrosion in Stainless Steel

2.2 Pitting Corrosion



mechanism of pitting corrosion

2. Corrosion in Stainless Steel

2.2 Pitting Corrosion

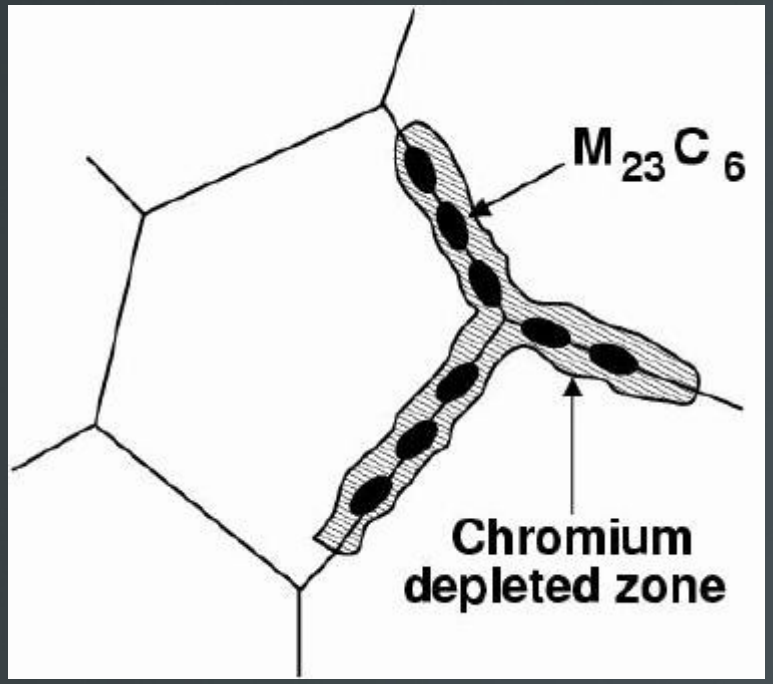
2. Corrosion in Stainless Steel

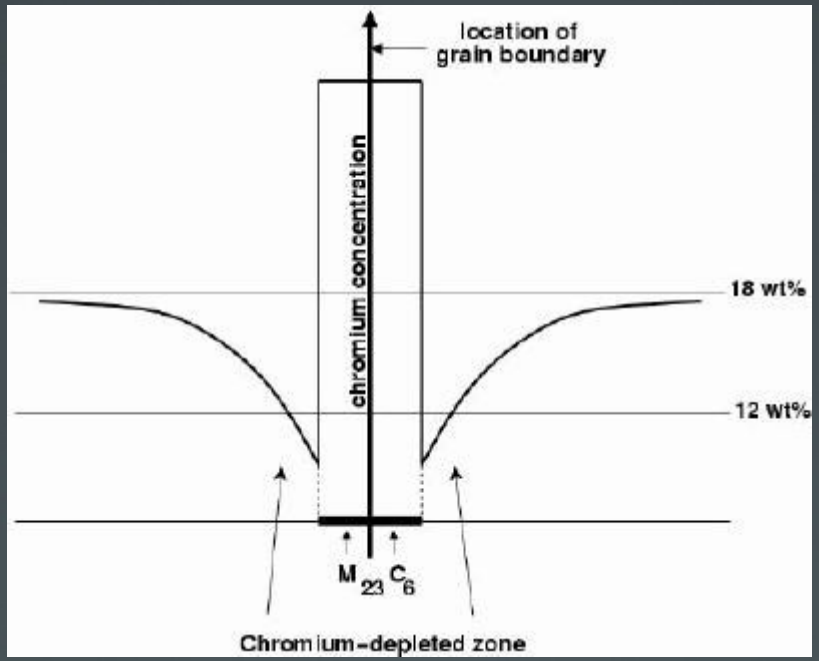
2.3 Sensitization

- in austenitic steels
- particularily in weld assemblies (”weld decay”)
- also in heat treatment of austenitic steels
- leads to grain decohesion → embrittlement
- cause: precipitation of Cr-carbides ($Cr_{23}C_6$, Cr_7C_3)
  via diffusion at about 800°C
- solute Cr-content locally below 12% → corrosion
- additionally: carbides very brittle
- can lead to sudden failure

2. Corrosion in Stainless Steel

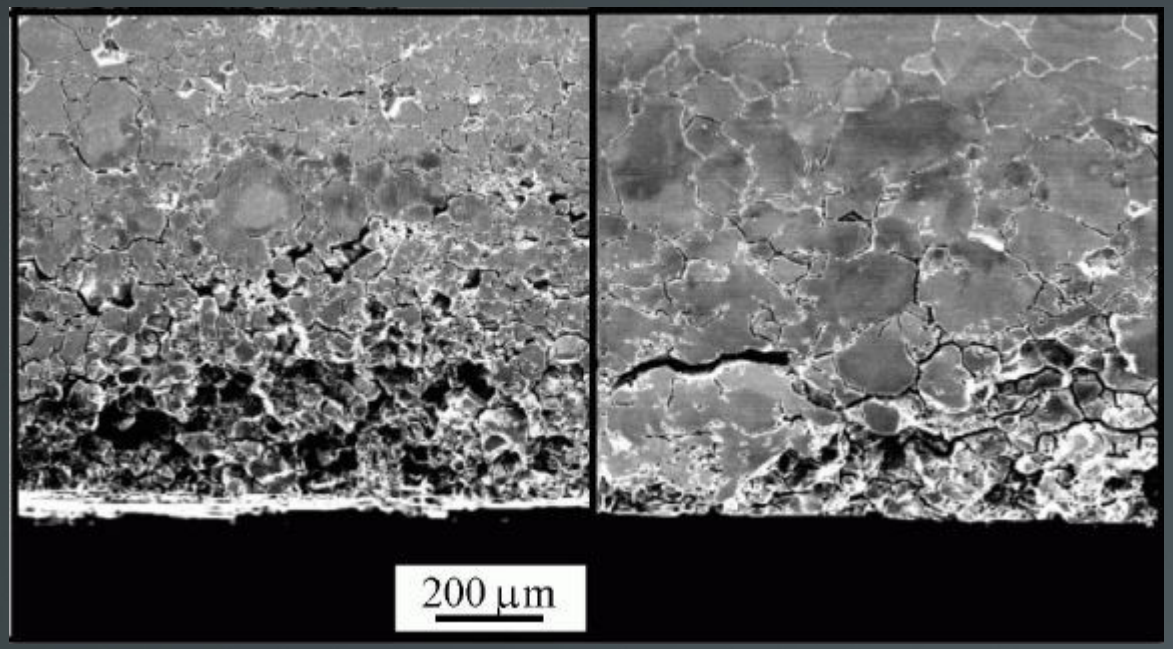
2.3 Sensitization





2. Corrosion in Stainless Steel

2.3 Sensitization



2. Corrosion in Stainless Steel

2.3 Sensitization

remedies:

- proper heat treatment with rapid cooling
- lowest possible carbon content
- stabilization with solutes (Nb, V, Ti)
- carbide solution treatment (after welding)

3. Types of Stainless Steel

- four main types
- important properties
- microscopic structure

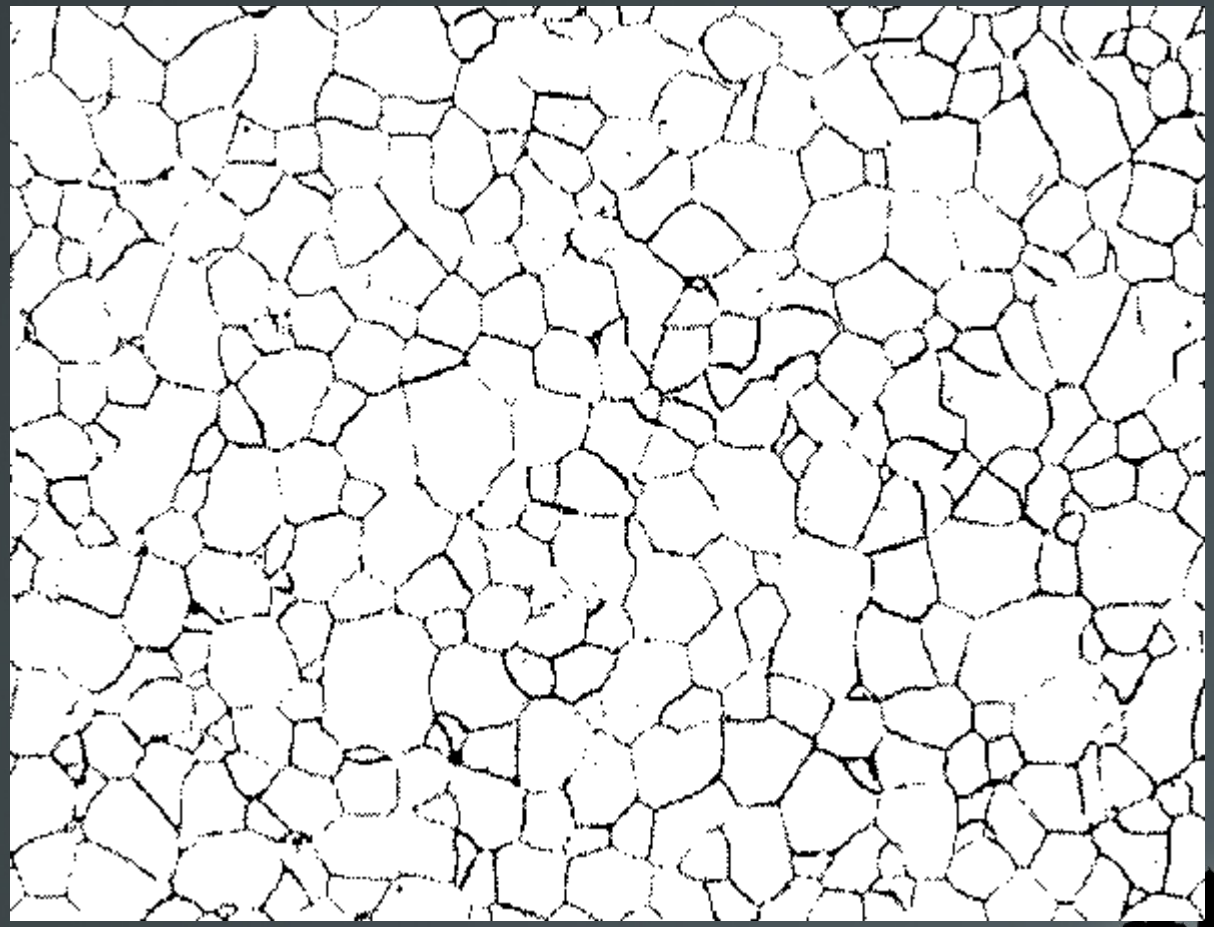
3. Types of Stainless Steel

3.1 Ferritic Stainless Steels

- bcc structure, low strength, high ductility
- good toughness and corrosion resistance
- 13% to 30% Cr, < 0.1% C
- no austenitic phase tranformation

→ not hardenable

3. Types of Stainless Steel

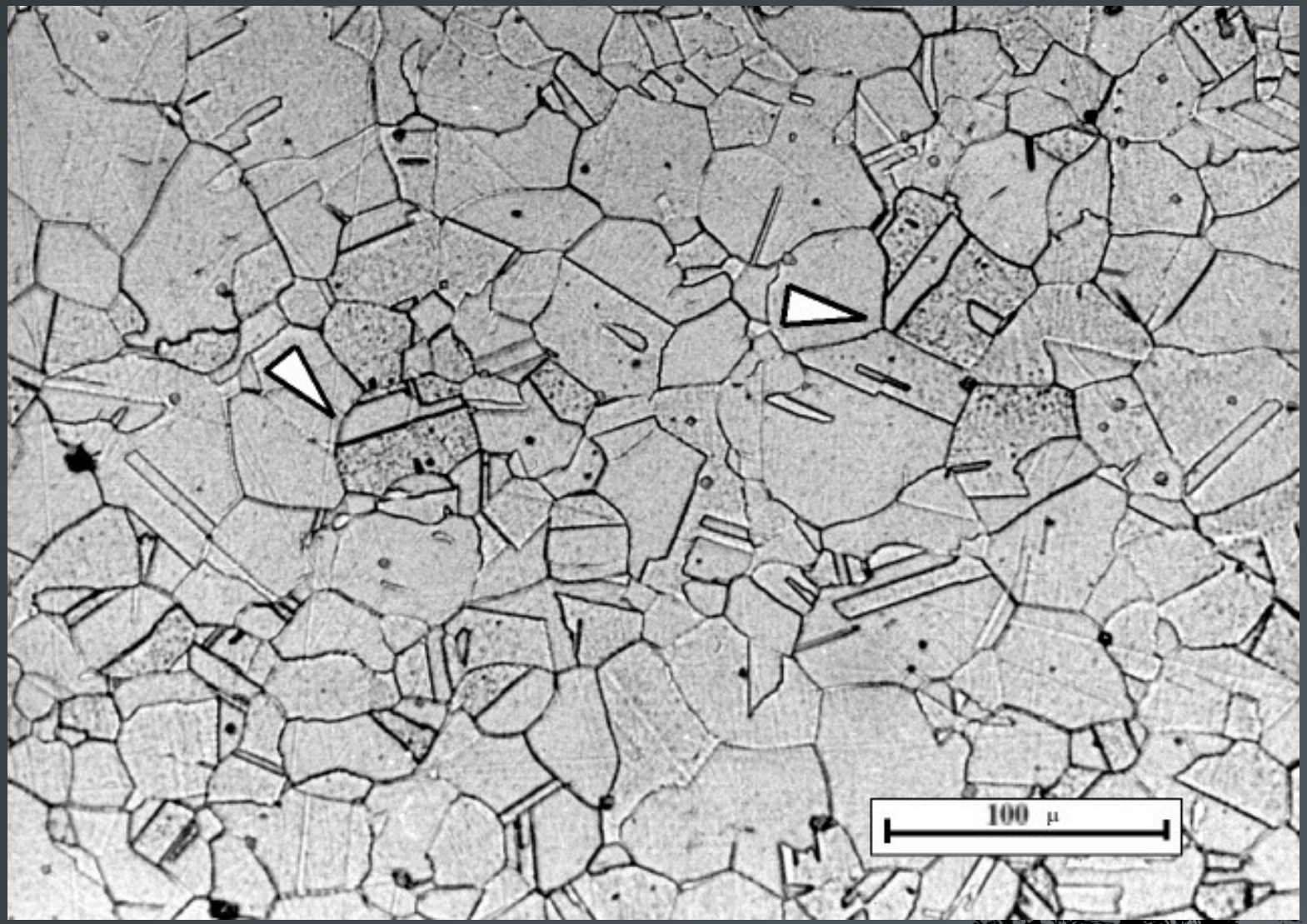


3. Types of Stainless Steel

3.2 Austenitic Stainless Steels

- at least 18% Cr and 8%Ni
- fcc structure
- best toughness, very good ductility
- no low temperature embrittlement
- non-magnetic
- most used stainless steels
- not hardenable

3. Types of Stainless Steel

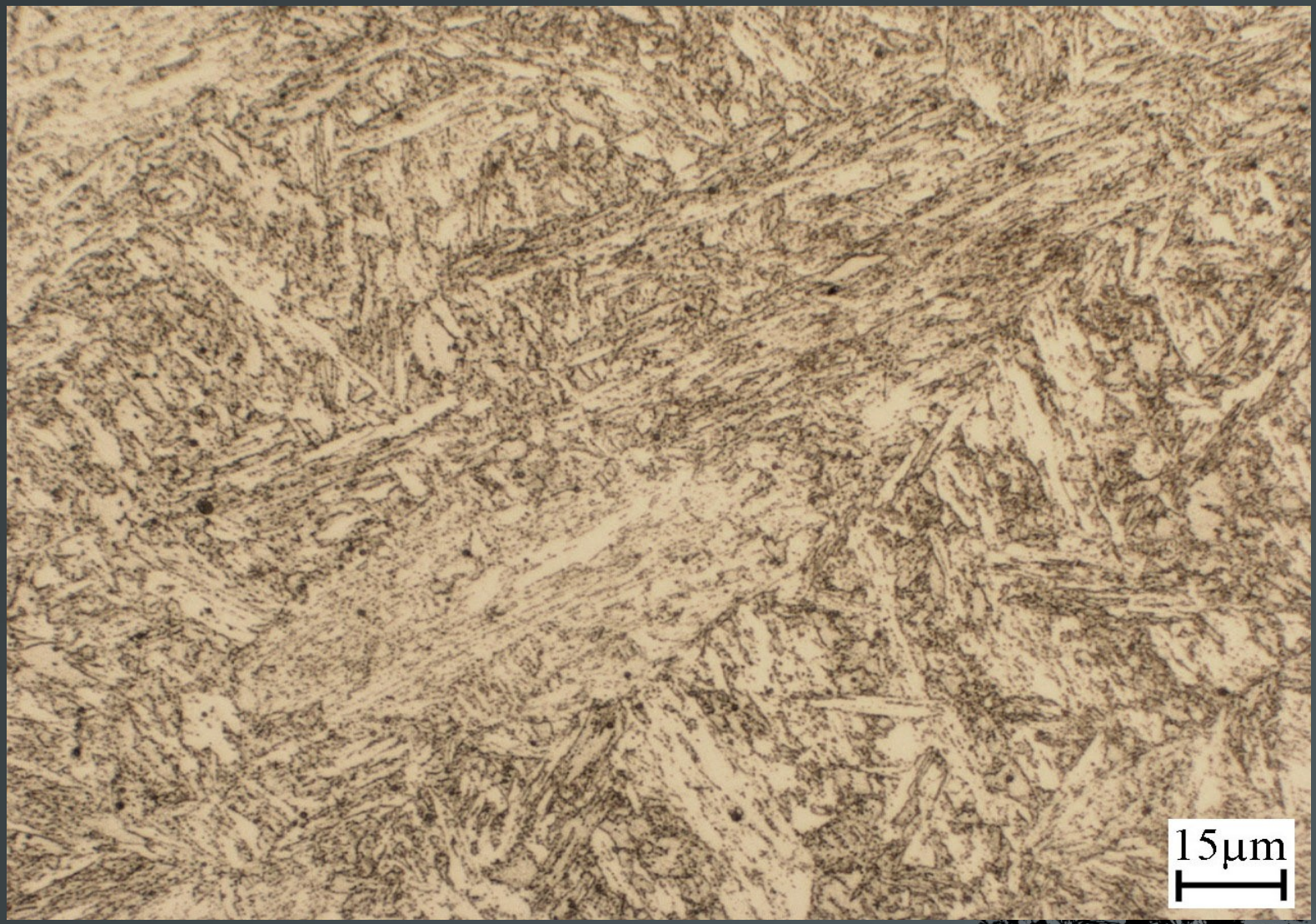


3. Types of Stainless Steel

3.3 Martensitic Stainless Steels

- 12% to 18% Cr, less than 2.5% Ni, 0.2% to 1.2% C
- contain martensite (fully martensitic above 0.4% C)
- proper heat treatment necessary
- martensite: hardest phase in steels, forced C solution, tetrahedral distorted structure
- hardenable, but not as good as tool steels

3. Types of Stainless Steel



3. Types of Stainless Steel

3.4 Duplex Stainless Steels

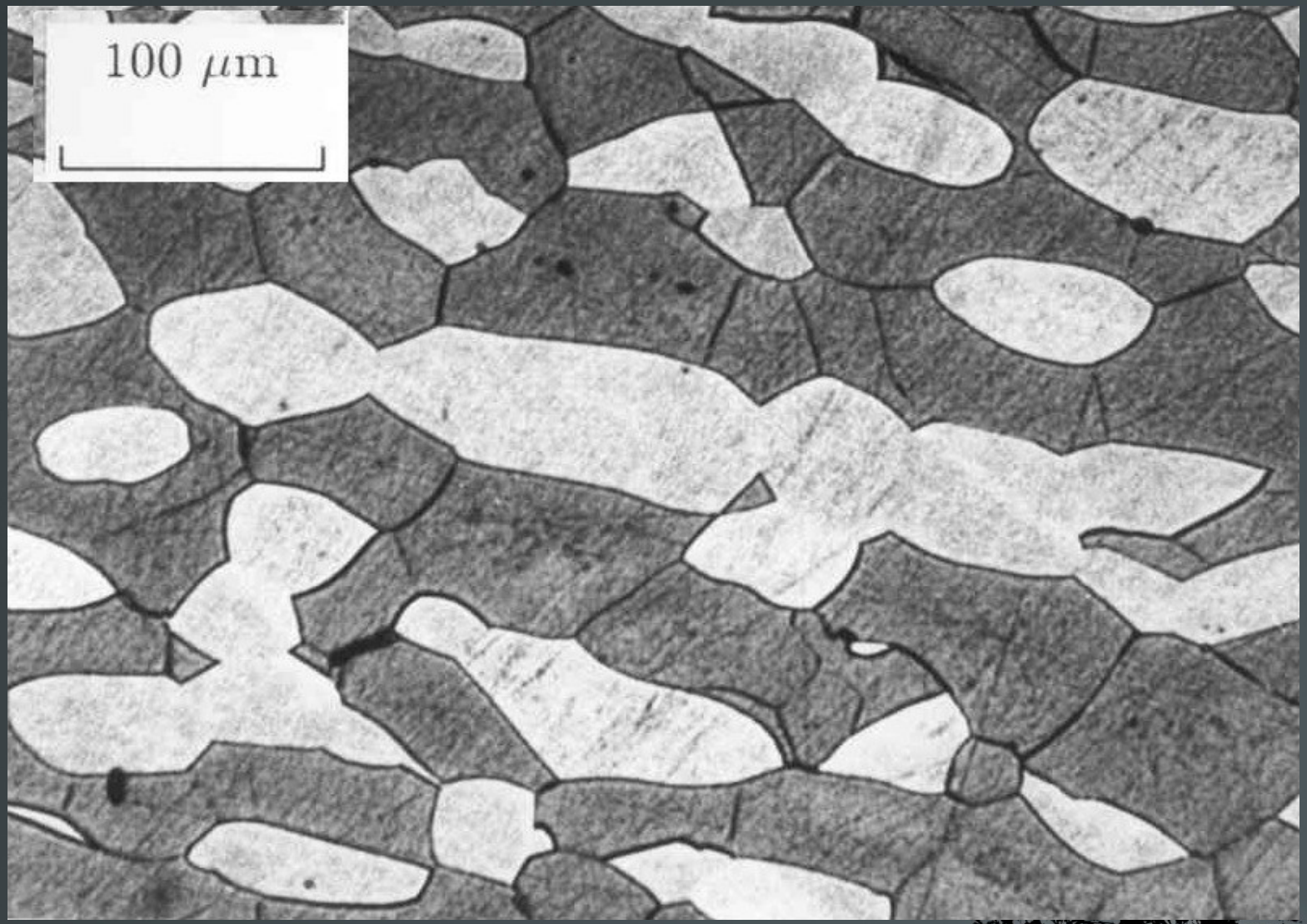
- 22% to 27% Cr and 4% to 8% Ni
- 50% austenite, 50% ferrite
- refined grain size

→ higher tensile strength and toughness

- excellent pitting resistance
- not hardenable

special grades: Superduplex, TRIP-Steel, ...

3. Types of Stainless Steel



4. Applications & Limits

What can Stainless Steels be used for?

4. Applications & Limits

4. Applications & Limits

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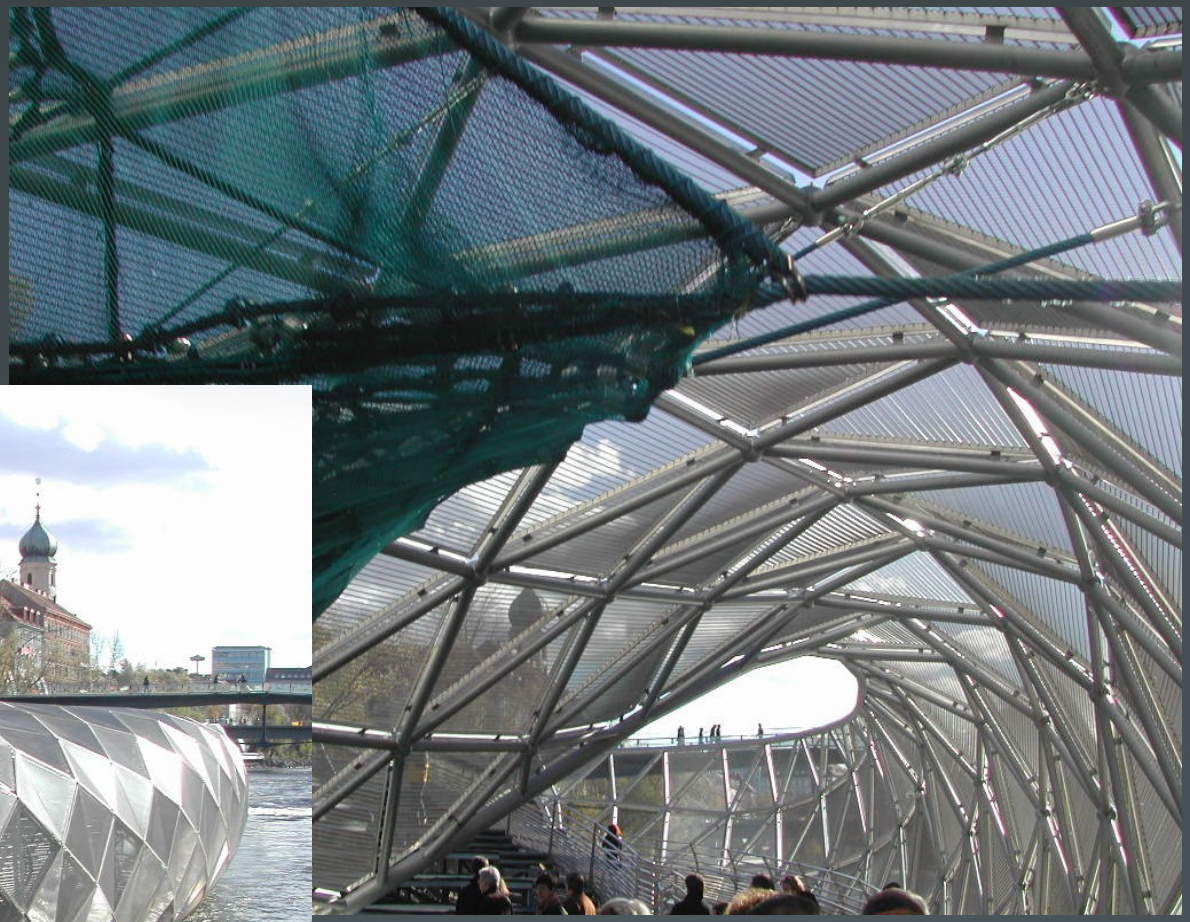

4. Applications & Limits

Stainless Steels

4. Applications & Limits

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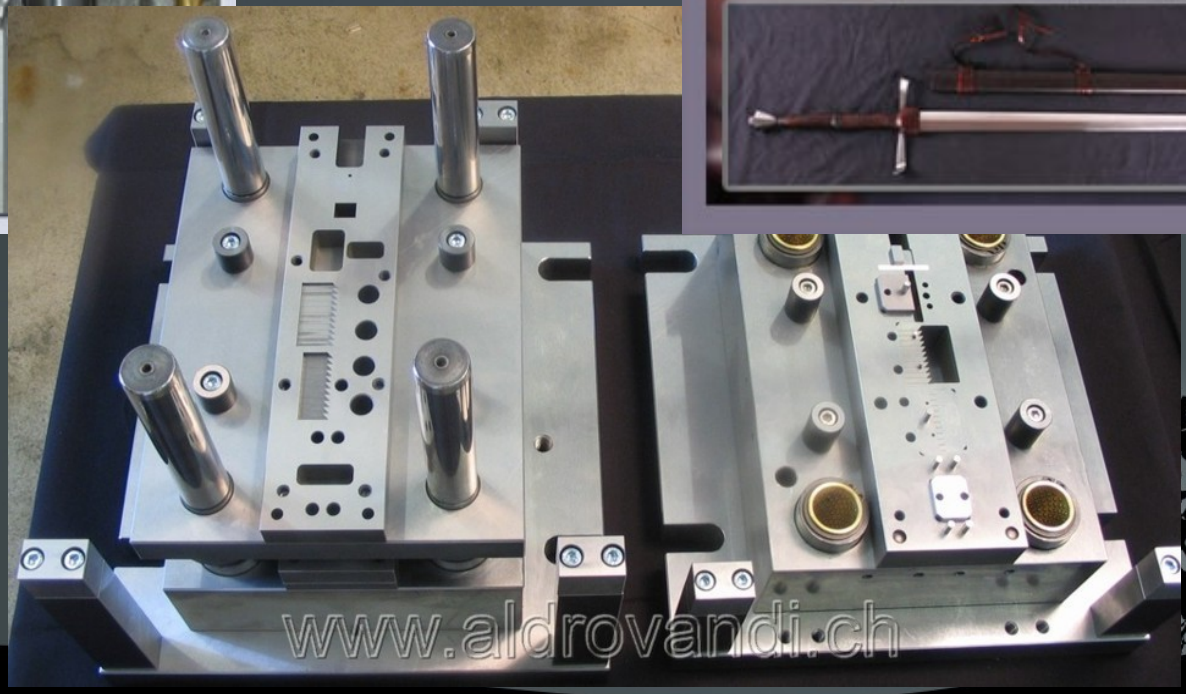
4. Applications & Limits

Other Applications

- surgical instruments
- chemical industry
- transportation
- cryogenic engineering
- aircraft
- superconductor housing
- jewelry
- ...

Stainless Steels

Would you use Stainless Steel for these purposes?

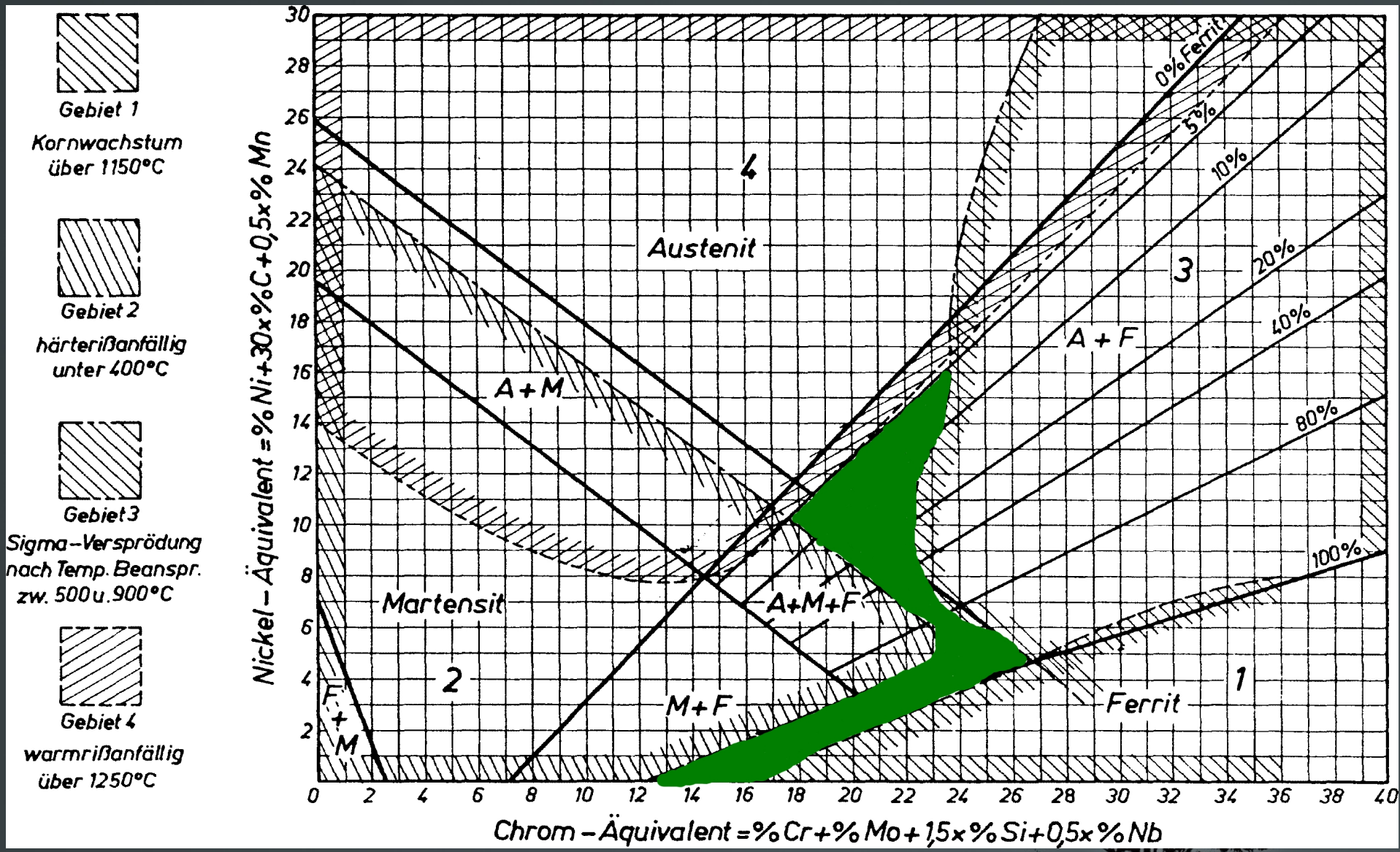


4. Applications & Limits

Main Limits

- hardenability
- YOUNG's modulus
- cost → alloying elements & processing
- weldability

4. Applications & Limits



5. Summary

What you should keep in mind:

- corrosion resistance is not absolute
- 12% Cr are needed for a passive film
- various types of corrosion
- there are four main groups of stainless steels
- each has special properties
- many applications, but not unlimited

6. Sources

6.1 Main Source of this Presentation

Sourmail, Bhadeshia: Stainless Steels
http://www.msm.cam.ac.uk/phase-trans/2005/stainless_steels/stainless.html

Nov 5th 2008, 6.47 p.m.

6. Sources

6.2 Additional Information

http://www.stainless-steel-world.net
http://www.worldstainless.org
http://www.ssina.com
http://steeluniversity.org
http://www.stahl-online.de