Supporting presentation for lecturers of Architecture/Civil Engineering

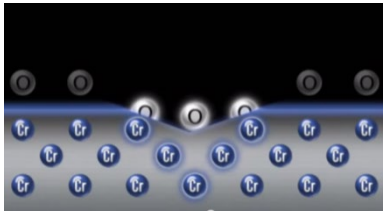
Chapter 04

What are the stainless steels?

Videos

100 Years of Stainless Steel
https://youtu.be/E-GcuxtWcnc

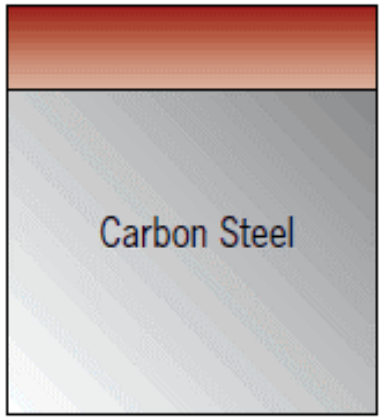
Alloyed for Lasting Value
https://youtu.be/l4Z1UVWm3DE



Self-repairing for Lasting Value
https://youtu.be/ngnT6dYo-M0

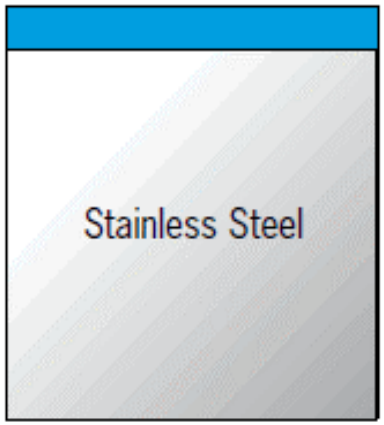
Stainless steels are Iron-base alloys containing at least 10.5% chromium

Surface Oxide (rust)
> 20µm thick



< 11% Chromium

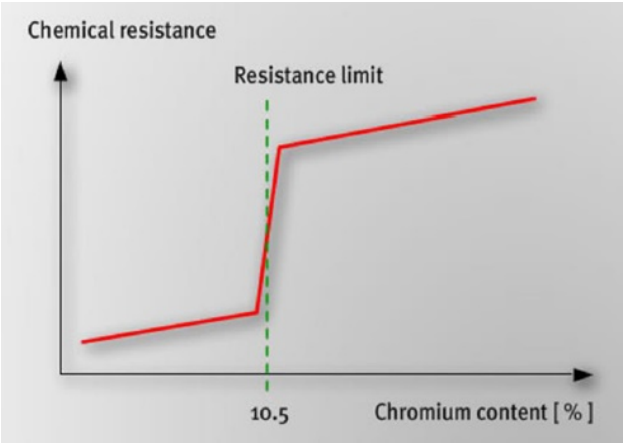
Surface Passive film
~ 2nm thick



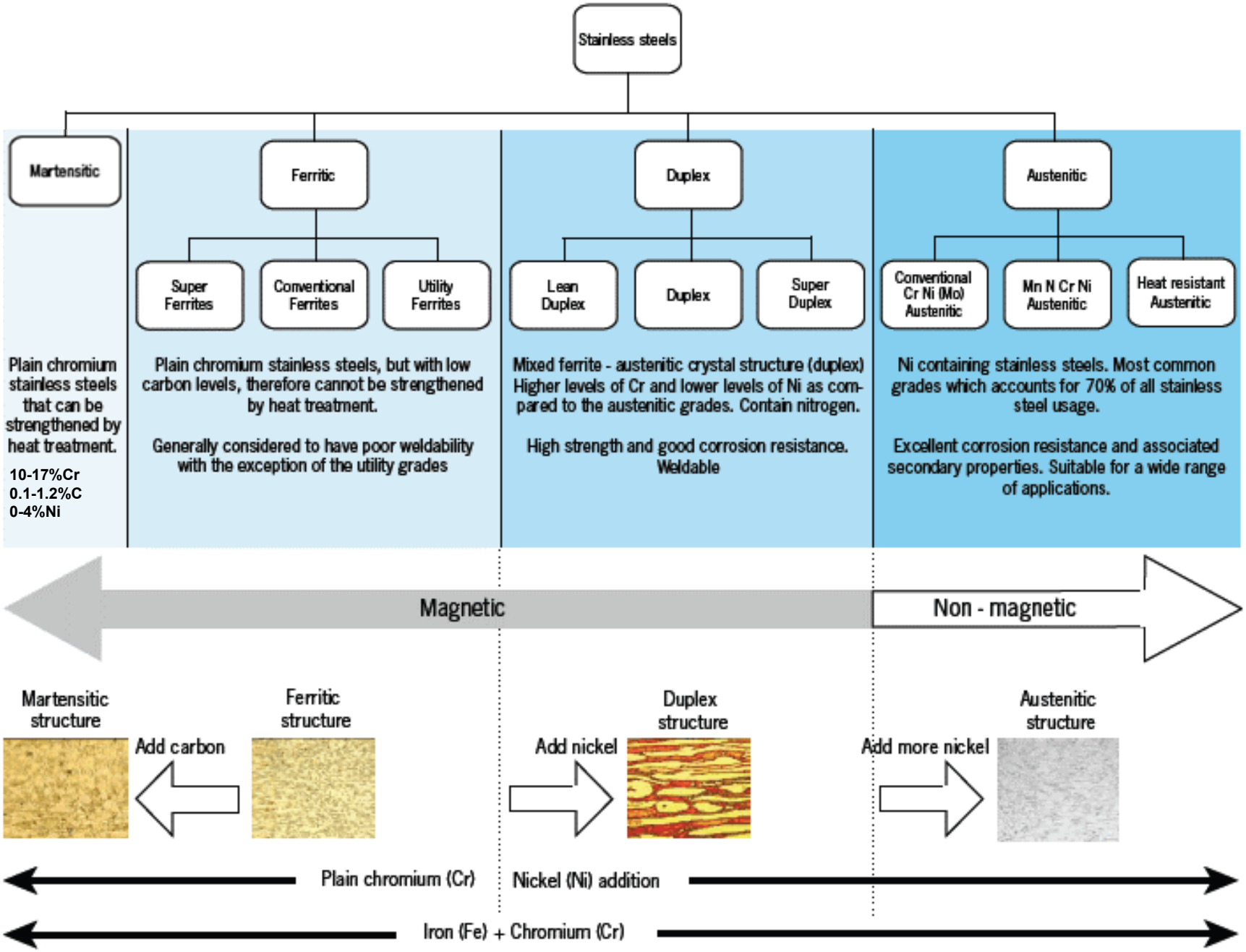
>11% Chromium

corrosion resistance

The passive film forms in a few minutes



Increasing Cr content increases the effectiveness of the passive film… but there are other important factors that influence the corrosion resistance
(see Chapter 5)


Stainless steels
Martensitic
Ferritic
Duplex
Austenitic
Super Ferrites
Conventional Ferrites
Utility Ferrites
Lean Duplex
Duplex
Super Duplex
Conventional Cr Ni (Mo) Austenitic
Mn N Cr Ni Austenitic
Heat resistant Austenitic
Plain chromium stainless steels that can be strengthened by heat treatment.
10-17%Cr
0.1-1.2%C
0-4%Ni
Plain chromium stainless steels, but with low carbon levels, therefore cannot be strengthened by heat treatment.
Generally considered to have poor weldability with the exception of the utility grades
Mixed ferrite - austenitic crystal structure (duplex) Higher levels of Cr and lower levels of Ni as compared to the austenitic grades. Contain nitrogen.
High strength and good corrosion resistance. Weldable
Ni containing stainless steels. Most common grades which accounts for 70% of all stainless steel usage.
Excellent corrosion resistance and associated secondary properties. Suitable for a wide range of applications.
Magnetic
Non - magnetic
Martensitic structure
Add carbon
Ferritic structure
Add nickel
Duplex structure
Add more nickel
Austenitic structure
Plain chromium (Cr)
Nickel (Ni) addition
Iron (Fe) + Chromium (Cr)

Cr-Ni Grades (Austenitics)[4]

Sub-groups:					
▪ Cr-Ni	Typically EN 1.4301/AISI 304	Cr: 18	Ni: 9		Fe: Balance
▪ Cr-Ni-Mo	Typically EN 1.4401/AISI 316	Cr: 18	Ni 10	Mo: 2.5	Fe: Balance

Common Properties:

- Very good corrosion resistance, increases with alloy content
- ... but can be susceptible to SCC in hot chloride environment (e.g. swimming pools)

- High ductility and impact resistance at all (including very low) temperatures
- Strength can be increased by cold working (but not by heat treatment)
- Very good fire resistance

- Very good cold and hot forming properties (ductility, elongation)
- Easy to weld (TIG, MIG)

The best known and still the most used today

Colour code: ▪ Corrosion resistance ▪ Mechanical properties ▪ Fabrication

Cr-Mn Grades (Austenitics with Manganese)[5]

Typical grade:						
▪ Cr-Mn-Ni-N	Typically EN 1.4372/AISI 201	Cr: 17	Mn: 7	Ni: 4	N:0.15	Fe: Balance

Common Properties:

- Lesser corrosion resistance
- ... but far more susceptible to SCC and to pitting, particularly at low Ni and Cr levels
- Higher strength
- Poor cold forming properties due to high work-hardening
- Poor machinability
- More difficult to weld
- Cost less than Cr-Ni Austenitics ... but more than Cr ferritics

Used mostly in India and China

Colour code: ▪ Corrosion resistance ▪ Mechanical properties ▪ Fabrication

Cr Grades (Ferritics)[6]

Sub-groups:					
▪ Cr	Typically EN 1.4016/AISI 430	Cr: 17			Fe: Balance
▪ Cr-Mo	Typically EN1.4521/AISI 444	Cr: 18	Mo: 2	Ti+Ni: 0.4	Fe: Balance

Common Properties:

- Insensitive to Stress Corrosion Cracking

- Good ductility (lower than austenitic grades, though)
- Not suitable for use at very low temperatures
- Strength can be somewhat increased by cold working (but not by heat treatment)

- Very good cold forming properties: (less springback, lower tool wear but lower elongation requires a different deep drawing process compared to austenitics)
- Stabilized grades (i.e. with Nb and/or Ti) are easy to weld (TIG, MIG)

Offer an optimum performance/cost for many applications and are increasingly used

Colour code: ▪ Corrosion resistance ▪ Mechanical properties ▪ Fabrication

Cr Grades (Martensitics)[7]

Sub-groups:						
▪ C-Cr	Typically EN1.4021/AISI 420	Cr: 13	C:0.2			Fe: Balance
▪ C-Cr-Ni	Typically EN1.4057/AISI431	Cr: 16	Ni: 2	C: 0.2		Fe: Balance
▪ Precipitation Hardening	Typically EN1.4542/AISI630	Cr: 17	Ni: 4	Cu:4		Fe: Balance

Common Properties:

- Fair to good corrosion resistance, increases with alloy content
- High strength obtained by heat treatment (not by cold work). Limited elongation.
- Not suitable for use at very low temperatures
- Not suitable for forming, often processed by machining
- Can be welded (TIG, MIG), but require usually post-weld heat treatment

Are used as engineering steels with corrosion resistance

Colour code: ▪ Corrosion resistance ▪ Mechanical properties ▪ Fabrication

Duplex (Austenitic-Ferritic)[8]

Sub-groups:						
▪ Cr-Ni	Typically EN1.4362	Cr: 23	Ni: 4		Fe: Balance
▪ Cr-Ni-Mo	Typically EN1.4462	Cr: 22	Ni: 5	Mo: 3	Fe: Balance

Common Properties:

- Excellent corrosion resistance, increases with alloy content
- Insensitive to Stress Corrosion Cracking

- High strength, good ductility
- Strength can be increased by cold working (but not by heat treatment)

- Good cold and hot forming properties (ductility, elongation)
- Weldable (TIG, MIG)

Offer the best combination of corrosion resistance and mechanical properties

Colour code: ▪ Corrosion resistance ▪ Mechanical properties ▪ Fabrication

Physical properties[9, 10]

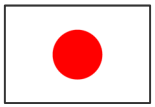
Materials	Modulus of Elasticity Gpa	Thermal Expansion Coefficient 10^{-6}°K-1	Thermal Conductivity W m^{-1}°K^{-1}	Ferro-Magnetism	Density Kg/dm³
Cr-Ni Austenitics	210	18	15	No	7.8
Cr-Mn Austenitics	210	17	15	No	7.8
Cr Ferritics	220	11	23	Yes	7.7
Cr-Ni (Mo)-N Duplex	210	14	15	Intermediate	7.8
Cr-C Martensitics	215	11	30	Yes	7.7
Carbon Steel	210	12	18	Yes	7.8
Copper	135	17	380	No	8.3
Aluminum	70	22	230	No	2.7
Glass	65	9	1,7	No	2.5
Concrete	48	10	1	No	2.5

Standards on Stainless Steels

Main World Standards:

ISO | EN | ASTM/AISI | UNS | JIS



Notes:

Most countries refer to the above standards, which are widely accepted.
A lot of the grades are very similar in all of the above standards.

List of the American Standards: ref 11
List of European Standards: ref 12

Correspondance tables are available: refs 13 - 15

Main grades in Architecture Building and Construction: EN 10088-4 (for sheet/plate/strip)[16, 17]

Grade	ASTM UNS	C Wt%	Cr Wt%	Ni Wt%	Mo Wt%	Other Wt%	Typical use [3,4]
4003	S40977	0,02	11,5	0,5	-	-	heated and unheated interiors
4016	430	0,04	16,5	-	-	-	decorative interior cladding
4509 4510	S43932 439	0,02 0,02	18 17	- -	- -	Nb Ti Ti	inland roofing and rainwater goods - often Tin-coated for patina
4521	444	0,02	17,8	-	2,1	Ti	domestic plumbing market
4301 4307 4306	304 304L 304L	0,04 0,02 0,02	18,1 18,1 18,2	8,1 8,1 10,1	- - -	- - -	building interiors and exteriors in normal industrial atmospheres away from the coast
4401 4404 4571	316 316L 316Ti	0,04 0,02 0,04	17,2 17,2 16,8	10,1 10,1 10,9	2,1 2,1 2,1	- - Ti	permanently wet applications, locations in a coastal atmosphere, polluted industrial atmospheres or near roads where de-icing salts can be an issue
4529 4547	N08926 S31254	0,01 0,01	20,5 20,0	24,8 18,0	6,5 6,1	N, Cu N, Cu	road tunnels and indoor swimming pools

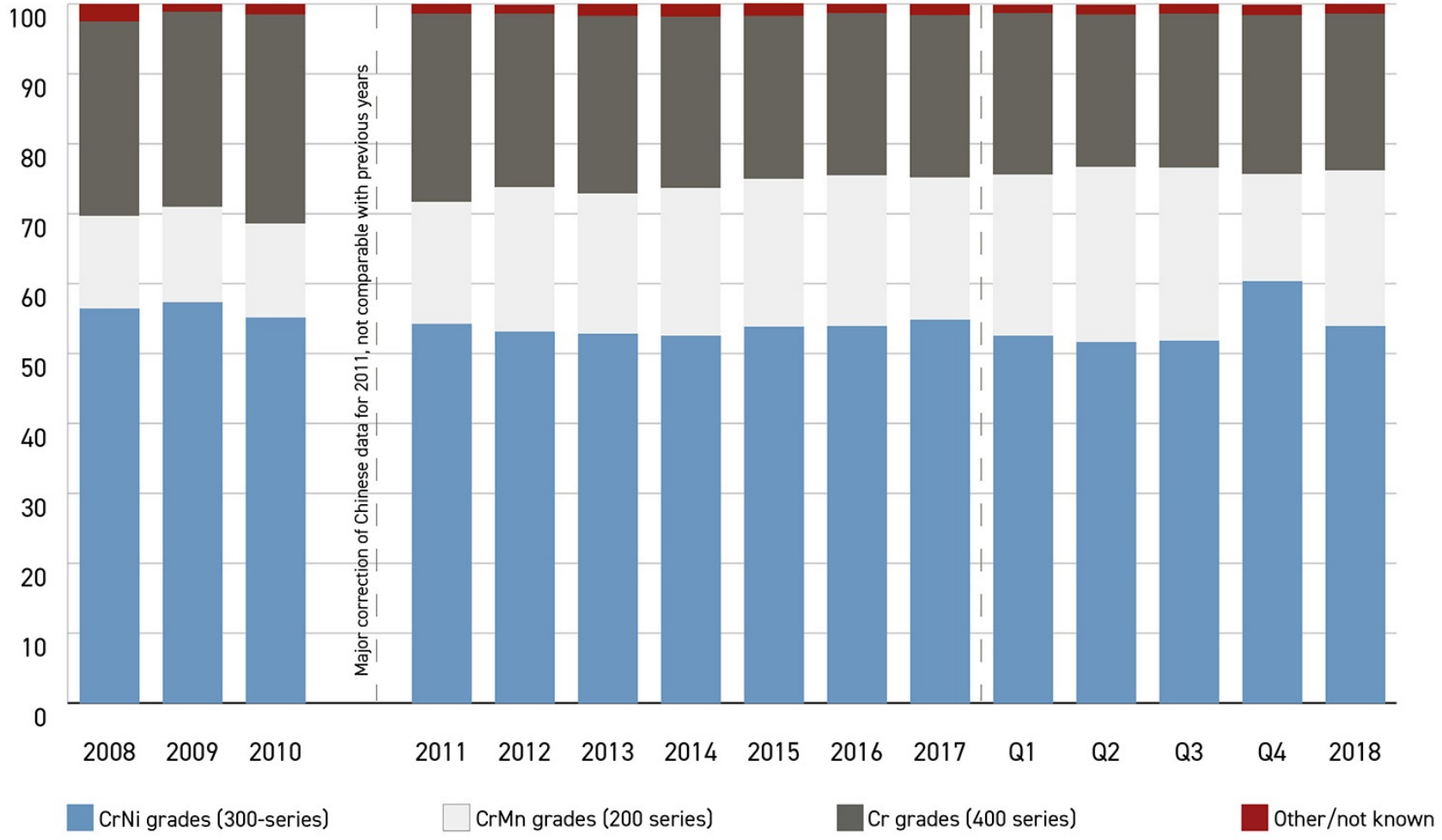
ABC = Architecture, Building and Construction

Main grades in Architecture Building and Construction: EN 10088-5(for bars/wires/sections)[18]

Grade	ASTM UNS	C Wt%	Cr Wt%	Ni Wt%	Mo Wt%	Other Wt%	Typical use [6]
4003	S40977	0,02	11,5	0,5	-	-	
4016	430	0,04	16,5	-	-	-	Slate hooks
4542	630	0,04	16,0	4,0		Cu,Nb	Tie bars
4301 4307 4311 4567	304 304L 304N 304Cu	0,04 0,02 0,02 0,02	18,1 18,1 18,1 17,1	8,1 8,1 8,6 8,6	- - - -	- - N Cu	 Rebar A2 fasteners
4401 4404 4429	316 316L « 316LN »	0,05 0,02 0,02	16,6 16,6 16,6	10,1 10,1 11,1	2,1 2,1 2,6	- - N	Building interiors and exteriors in normal industrial atmospheres away from the coast, Rebar
4529 4547	« 926 » S31254	0,01 0,01	20,5 20,0	24,8 18,0	6,5 6,1	N, Cu N, Cu	Road tunnels and indoor swimming pools
4362	S32304	0,02	22,5	3,6	0,3	N, Cu	Rebar and mechanical components
4462	S32205	0,02	21,5	4,6	2,8	N	Rebar and mechanical components

Breakdown of the stainless steel production worldwide by family

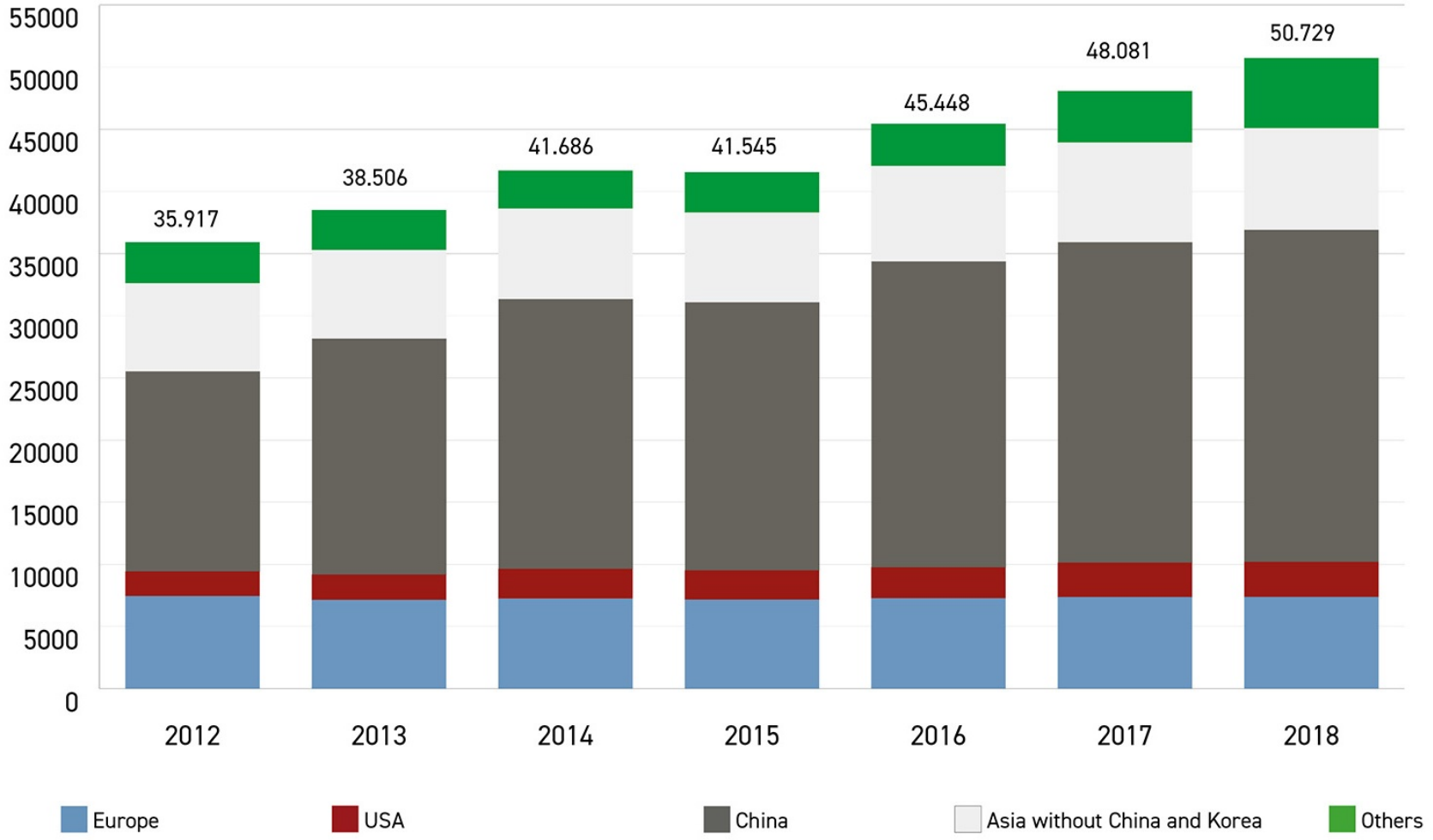
Breakdown of the world production by family[19]



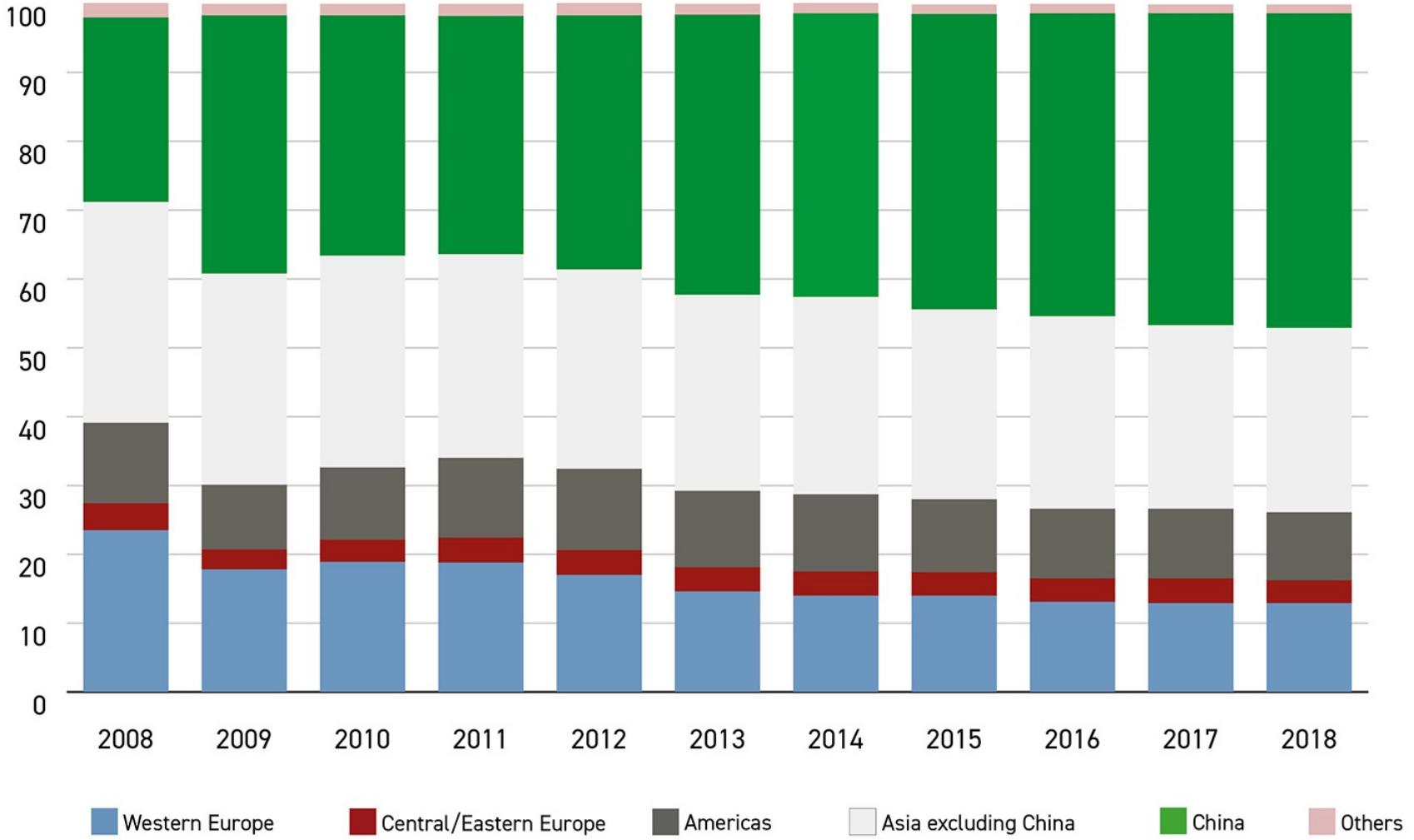
High Ni prices favour the replacement of popular CrNi grades by Cr-Mn or Cr Grades
Duplex grades marginal today, are expected to grow in the future

World stainless meltshop production (slab/ingot equivalent)

UPDATED 2019!



Apparent stainless use by region



References (1/2)

1. http://www.worldstainless.org/Files/issf/non-image-files/PDF/TheStainlessSteelFamily.pdf
2. D. Peckner Handbook of Stainless Steels Hardcover – June, 1977 ISBN-13: 978-0070491472 ISBN-10: 007049147X
3. http://www.imoa.info/download_files/stainless-steel/Austenitics.pdf
4. New « 200 series steels »: An opportunity or a threat to the image of stainless steel? https://www.worldstainless.org/Files/issf/non-image-files/PDF/ISSFNew200seriessteelsAnopportunityorathreat_EN.pdf
5. The ferritic solution: http://www.worldstainless.org/Files/issf/non-image-files/PDF/ISSF_The_Ferritic_Solution_English.pdf
6. http://www.outokumpu.com/en/stainless-steel/about-stainless-steel/stainless-steel-types/pages/default.aspx
7. Martensitic stainless steels https://www.worldstainless.org/Files/issf/non-image-files/PDF/ISSF_Martensitic_Stainless_Steels.pdf
8. Duplex stainless steels: https://www.imoa.info/molybdenum-uses/molybdenum-grade-stainless-steels/architecture/structural-duplex-stainless.php?d=1
9. https://www.nickelinstitute.org/~/Media/Files/TechnicalLiterature/CapabilitiesandLimitationsofArchitecturalMetalsandMetalsforCorrosionResistanceI_14057a_.pdf
10. https://www.worldstainless.org/Files/issf/non-image-files/PDF/Euro_Inox/Tables_TechnicalProperties_EN.pdf
11. http://www.imoa.info/download_files/stainless-steel/2014-8-Specification-and-Guideline-list.pdf
12. http://www.bssa.org.uk/topics.php?article=370&featured=1
13. https://www.worldstainless.org/about-stainless/what-is-stainless-steel/standards/

References (2/2)

14. Chemical composition of stainless steel flat products for general purposes to EN 10088-2: http://www.bssa.org.uk/topics.php?article=44
15. Chemical composition of stainless steel long products for general purposes to EN 10088-3: http://www.bssa.org.uk/topics.php?article=46
16. EN 10088-4:2009 Stainless steels. Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes www.worldstainless.org/Files/issf/non-image-files/PDF/Euro_Inox/EN10088-4_EN.pdf
17. Stainless steel flat products for building – the grades in EN 10088-4 explained: https://www.worldstainless.org/files/issf/non-image-files/PDF/Euro_Inox/EN10088-4_EN.pdf
18. EN 10088-5: 2009 Stainless steels. Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes.
19. ISSF publication « Stainless Steel in Figures »: https://www.worldstainless.org/Files/issf/non-image-files/PDF/ISSF_Stainless_Steel_in_Figures_2019_English_public_version.pdf

Thank you!

Test your knowledge of stainless steel here:

https://www.surveymonkey.com/r/3BVK2X6