



The Scenario of High Performance Steels

DONG Han

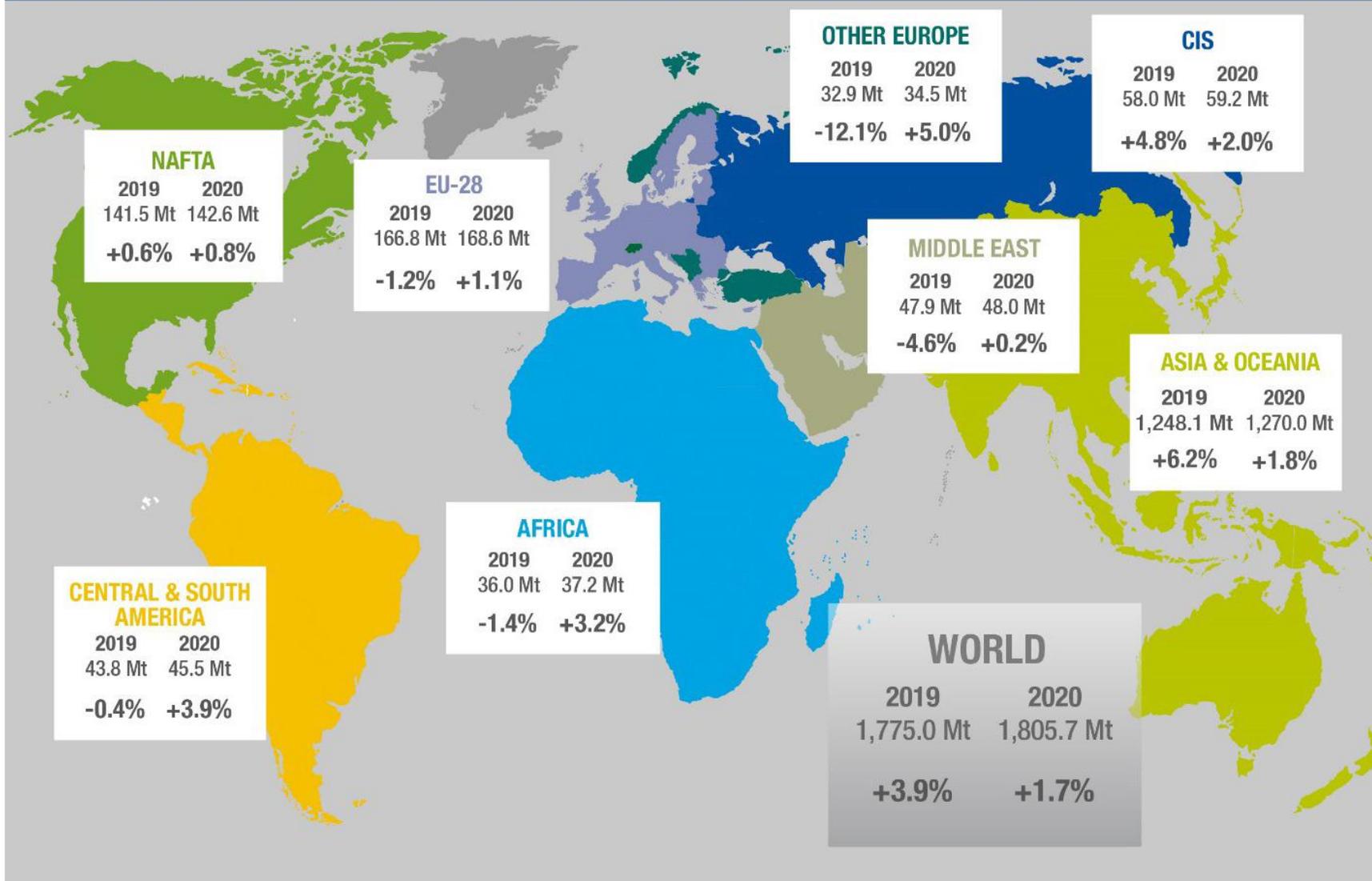
Chinese Society for Specialty Steels

Shanghai University, Shanghai, China

Central Iron & Steel Research Institute, Beijing, China

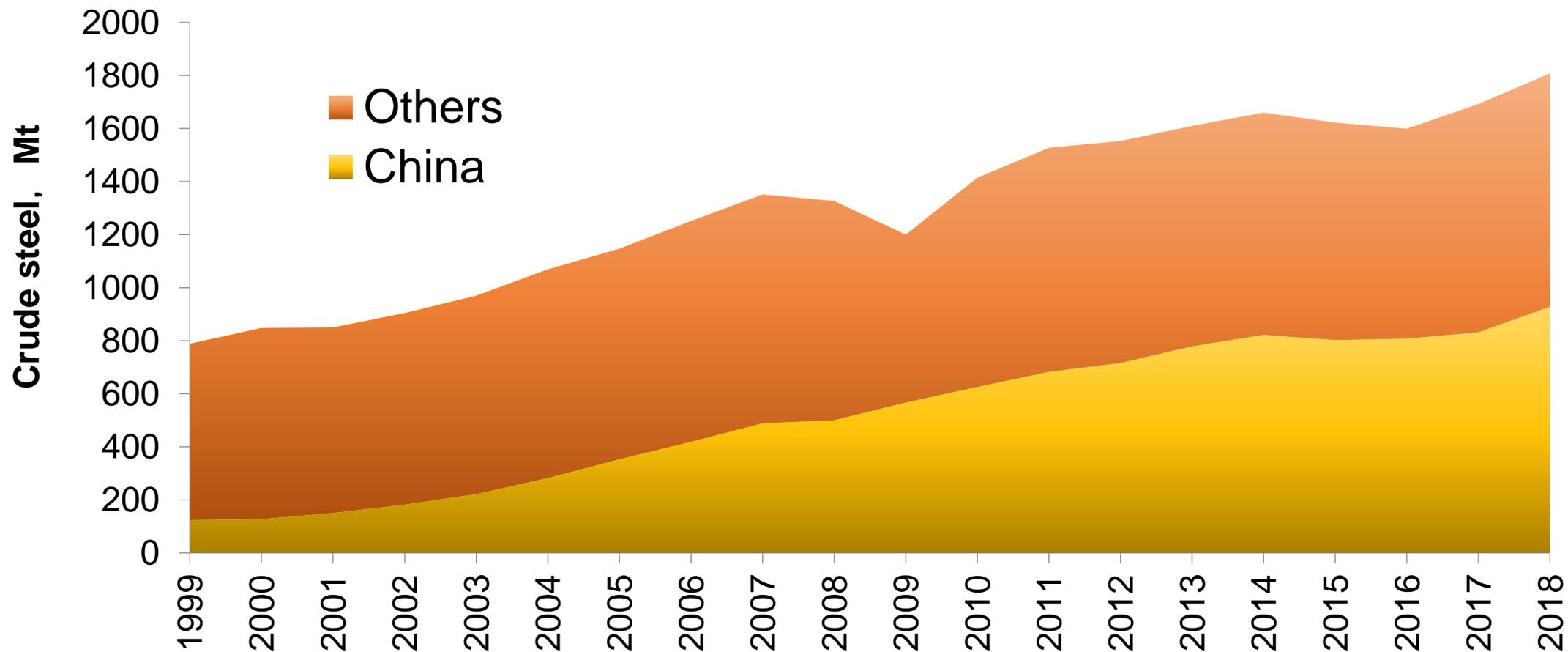
STEEL DEMAND, FINISHED STEEL

Mt =million tonnes
y-o-y growth rate is expressed in %

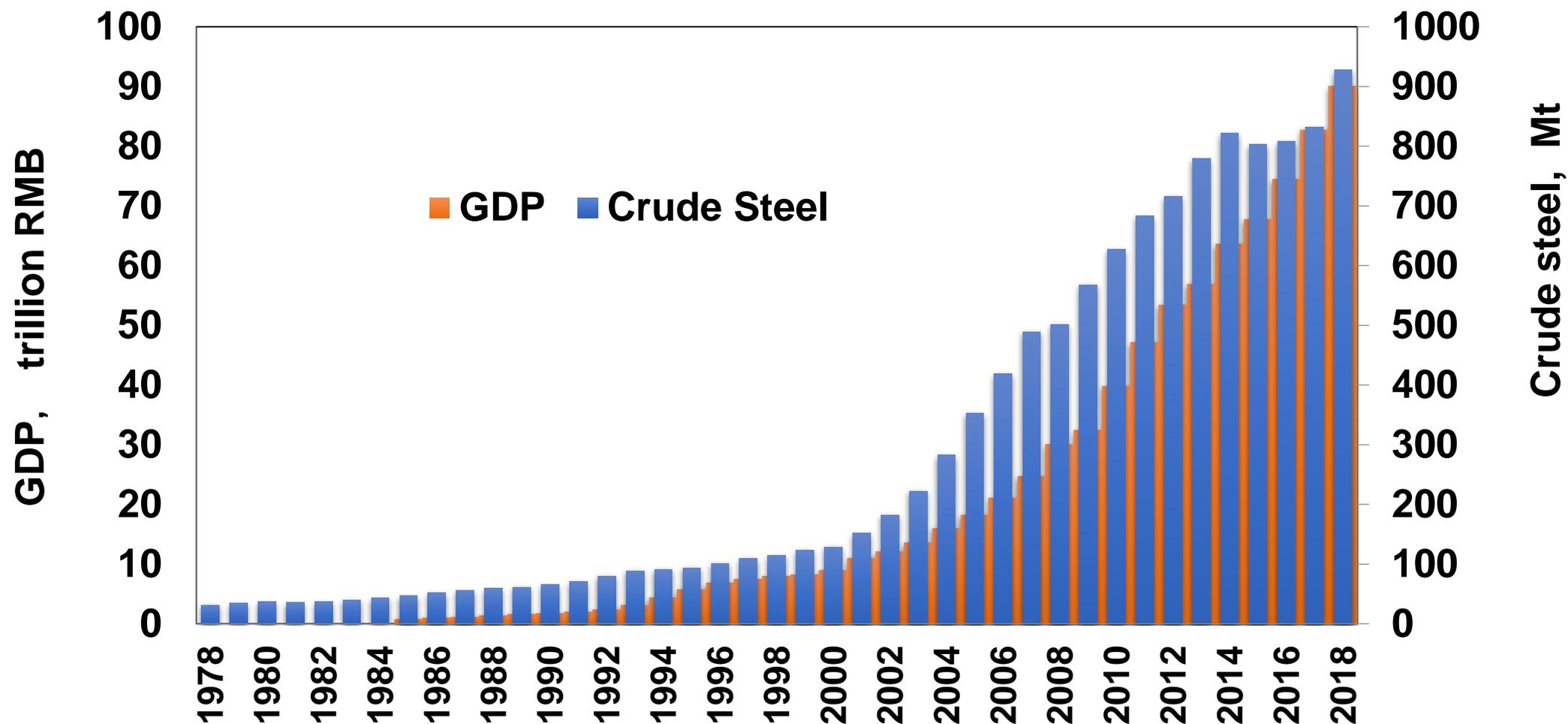


In 2018, pig iron 771Mt,
crude steel 928Mt, steel
product 1105Mt, State
Statistics Bureau, China

China: produced half of total steel



GDP growth and steel output



The feature of steel

**Abundant iron
ore reserve**

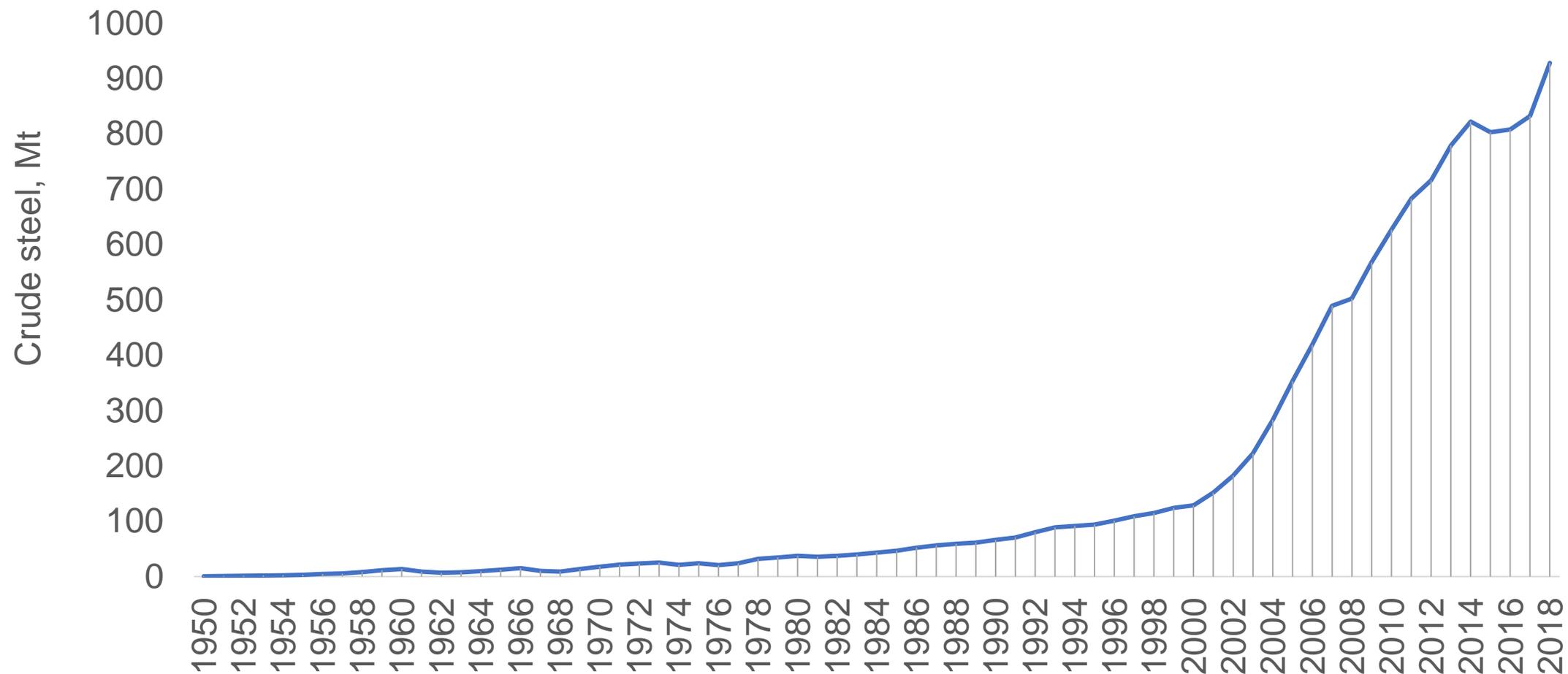
**Multi functions
100-4000MPa**

**Low cost
Mineral water**

**Easy fabrication
Cutting &
welding**

Easy recycling

Crude steel output since 1950 in China



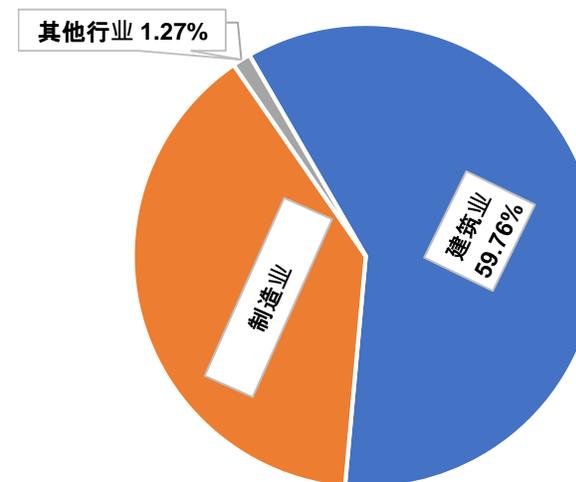
Milestones

- In 1950, 610 thousand tons
- In 1959, great leap forward, trying to overtake UK & USA, but only 11 million tons
- In 1978, reform and opening-up, 31.78 million tons
- In 1996, exceed 100 million tons
- In 2003, exceed 200 million tons
- In 2018, exceed 900 million tons, about 1500 times of steel output in 1950

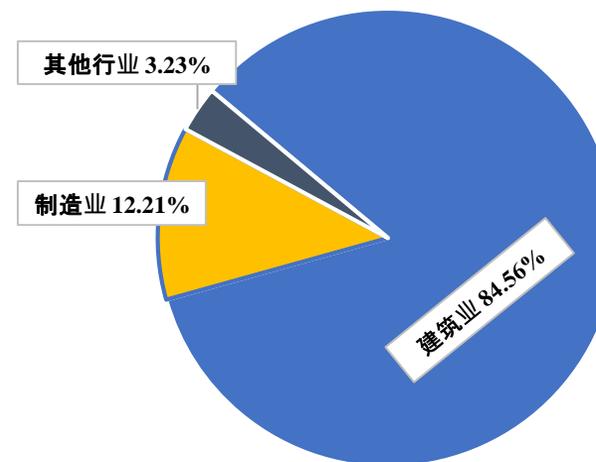
Steel consumptions in 2019

2019年1-11月下游行业钢材消费量测算表				
行业	消费量	占比	同比增减	同比增幅
一、建筑业	47272.19万吨	100%	+4193	▲+9.73%
1.房屋建筑	33451.77	70.76%	+2731	▲+8.89%
1.1房地产开发	7498.41	15.86%	+599	▲+8.69%
2.铁路建设	2954.23	6.25%	+47	▲+1.60%
3.道路建设	2745.44	5.81%	+222	▲+8.80%
4.机场建设	181.90	0.38%	-32	▼-15.00%
5.矿山建设	3356.98	7.10%	+678	▲+25.30%
6.其他建筑业	4581.87	9.69%	+549	▲+13.60%
二、制造业	30824.44万吨	100%	+606	▲+2.00%
1.机械（不含汽车）	17775.63	57.67%	+943	▲+5.60%
1.1金属冶炼设备	44.59	0.14%	-12	▼-20.60%
1.2水泥专用设备	27.18	0.09%	+0	▲+1.70%
2.汽车	4876.37	15.82%	-518	▼-9.60%
3.船舶	987.28	3.20%	+95	▲+10.70%
4.家电	1324.76	4.30%	+82	▲+6.61%
4.1电冰箱	260.35	0.84%	+10	▲+4.00%
4.2冷柜冷冻箱	59.86	0.19%	+10	▲+20.00%
4.3空调	598.68	1.94%	+33	▲+5.80%
4.4洗衣机	140.91	0.46%	+13	▲+10.10%
5.金属制品	984.31	3.19%	-420	▼-29.91%
5.1金属集装箱	357.79	1.16%	-207	▼-36.60%
5.2工业锅炉	134.37	0.44%	-3	▼-2.50%
6.电力	303.51	0.98%	-67	▼-18.00%
7.其他制造业	4572.58	14.83%	+490	▲+12.00%
三、其他行业	1003.57万吨	100%	+160	▲+19.00%
钢材消费量合计	79100.20		+4959	▲+6.69%
折合粗钢消费量	82396.04		+5166	▲+6.69%
折合钢表消费量	85511.14		+6308	▲+7.96%

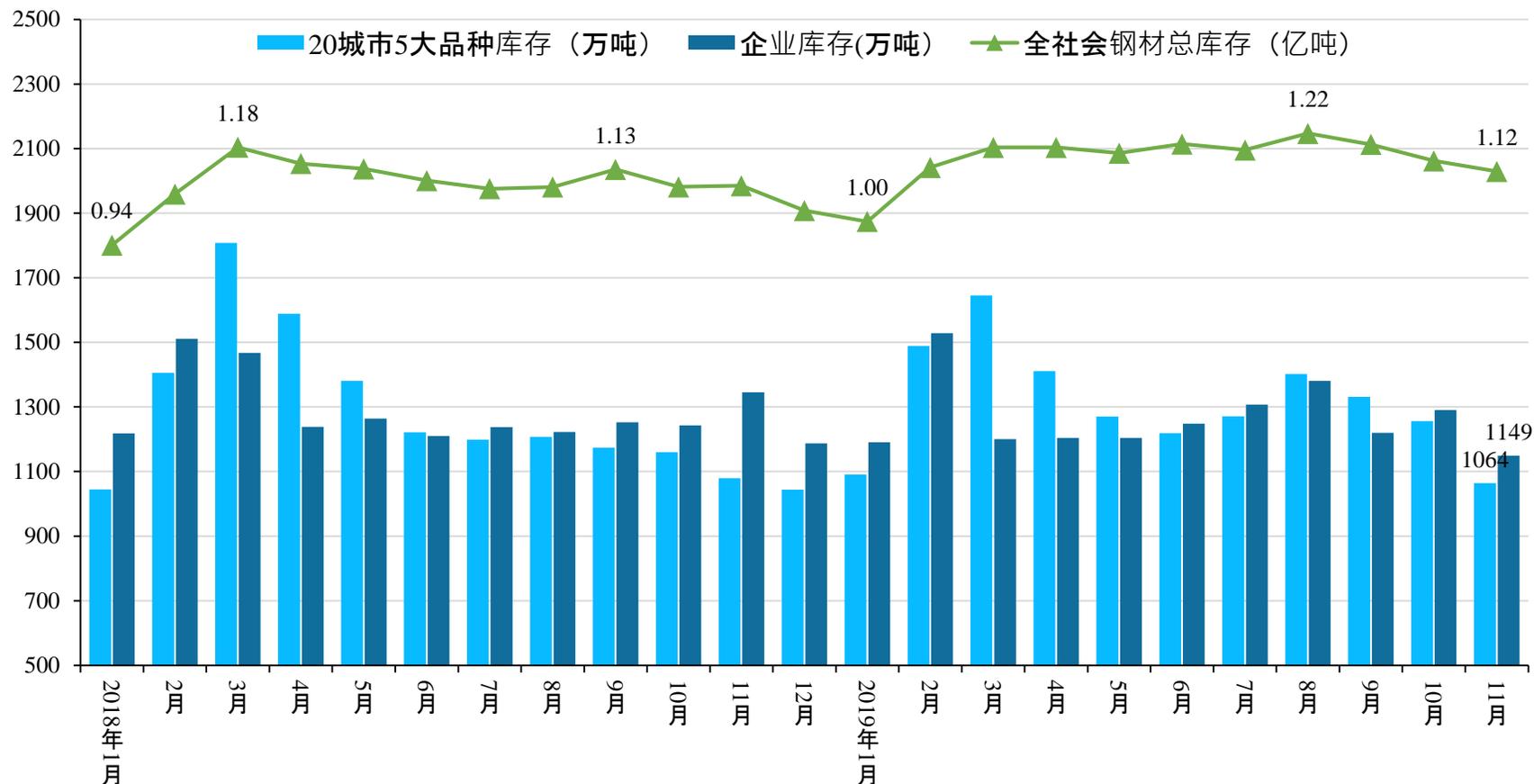
钢材消费量占比



钢材消费量增量占比

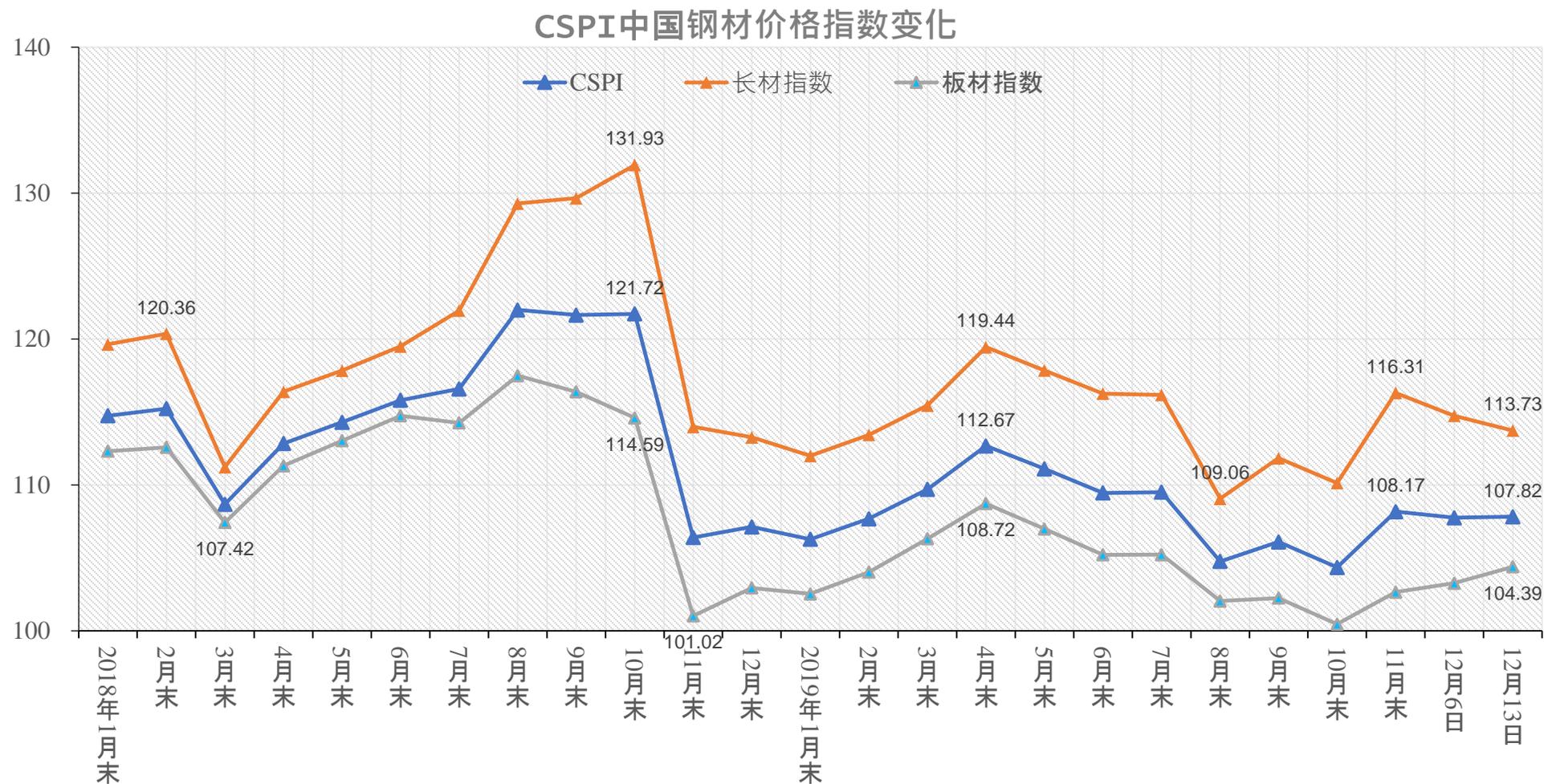


各月钢材库存情况



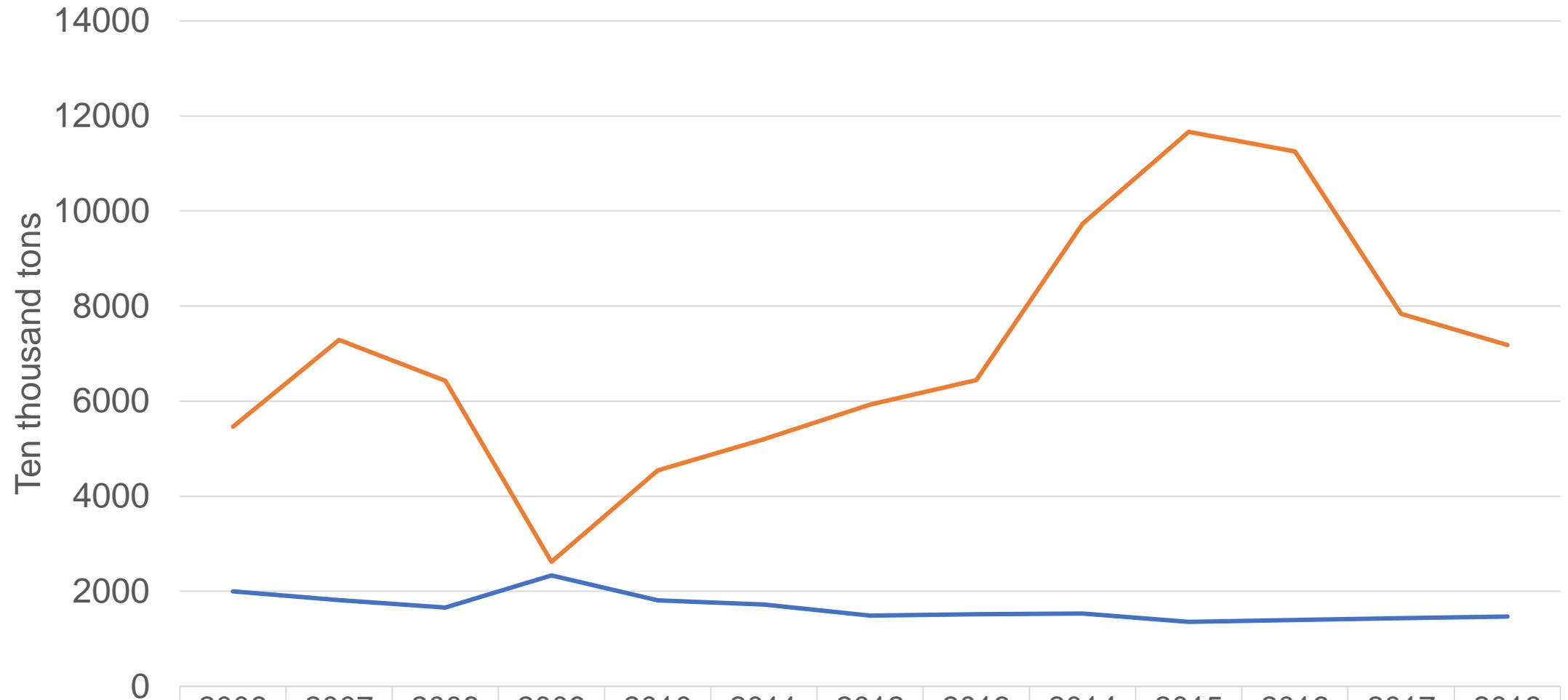
11月份，全社会钢材总库存11234万吨，环比减少334万吨、下降2.28%，同比增加353万吨、增长3.24%。其中，20个重点城市5个钢材品种库存1064万吨，环比减少192万吨，下降15.3%，同比减少15万吨、下降1.4%；会员企业库存1149万吨，环比减少142万吨、下降11.0%，同比减少196万吨、下降14.6%。**12月13日数据显示，20个重点城市5个钢材品种的库存继续大幅下降，至879.90万吨。**

Steel price index



11月末，CSPI钢材价格指数为108.17点，环比上升3.83点，升幅为3.67%；同比上升1.78点，升幅为1.67%。其中长材指数为116.31点，环比上升6.18点，升幅为5.61%，板材指数为102.65点，环比上升2.20点，升幅为2.19%；长材价格升幅比板材高3.42个百分点。进入12月后，钢材价格小幅回落，截至12月13日，钢材价格指数为107.82点，比11月末下跌0.35点，跌幅0.32%，其中长材下跌2.58点、板材上涨1.74点。

Import and export



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
— import	2000	1813	1661	2335	1812	1721	1489	1516	1532	1357	1399	1434	1469
— export	5464	7287	6430	2621	4542	5201	5929	6442	9732	11665	11254	7838	7182

螺纹期货上市10周年，钢铁业产融结合步入新时代

我的钢铁网，2019-03-27 19:37



- 10年前的3月27日，螺纹指数开盘报3566元/吨，10年后的3月27日，螺纹指数收盘报3566元/吨，十年轮回弹指一挥间
- 从上市首日以3561元/吨报收，到2011年2月11日创出5230元/吨的历史新高，此后受到行业整体产能过剩等因素的影响，价格持续下行，最低跌至2015年12月1日的1618元/吨的历史低位
- 2016年以来，钢铁业供给侧结构性改革让整个钢铁行业焕发出新的勃勃生机。螺纹钢主力合约价格随之一路上行，并于2018年8月22日创出近年来的新高4418元/吨
- Myspic螺纹钢绝对价格指数与螺纹主力期货合约在过去10年的走势基本上保持一致

The evolution of steel industry

- In 1875, Britain accounted for 47% of world production of pig iron and almost 40% of steel. 40% of British output was exported to the U.S., which was rapidly building its rail and industrial infrastructure.
- Two decades later in 1896, however, the British share of world production had plunged to 29% for pig iron and 22.5% for steel, and little was sent to the U.S.
- The U.S. was now the world leader and Germany was catching up to Britain. Britain had lost its American market, and was losing its role elsewhere; indeed American products were now underselling British steel in Britain. (the first half of 20th century)

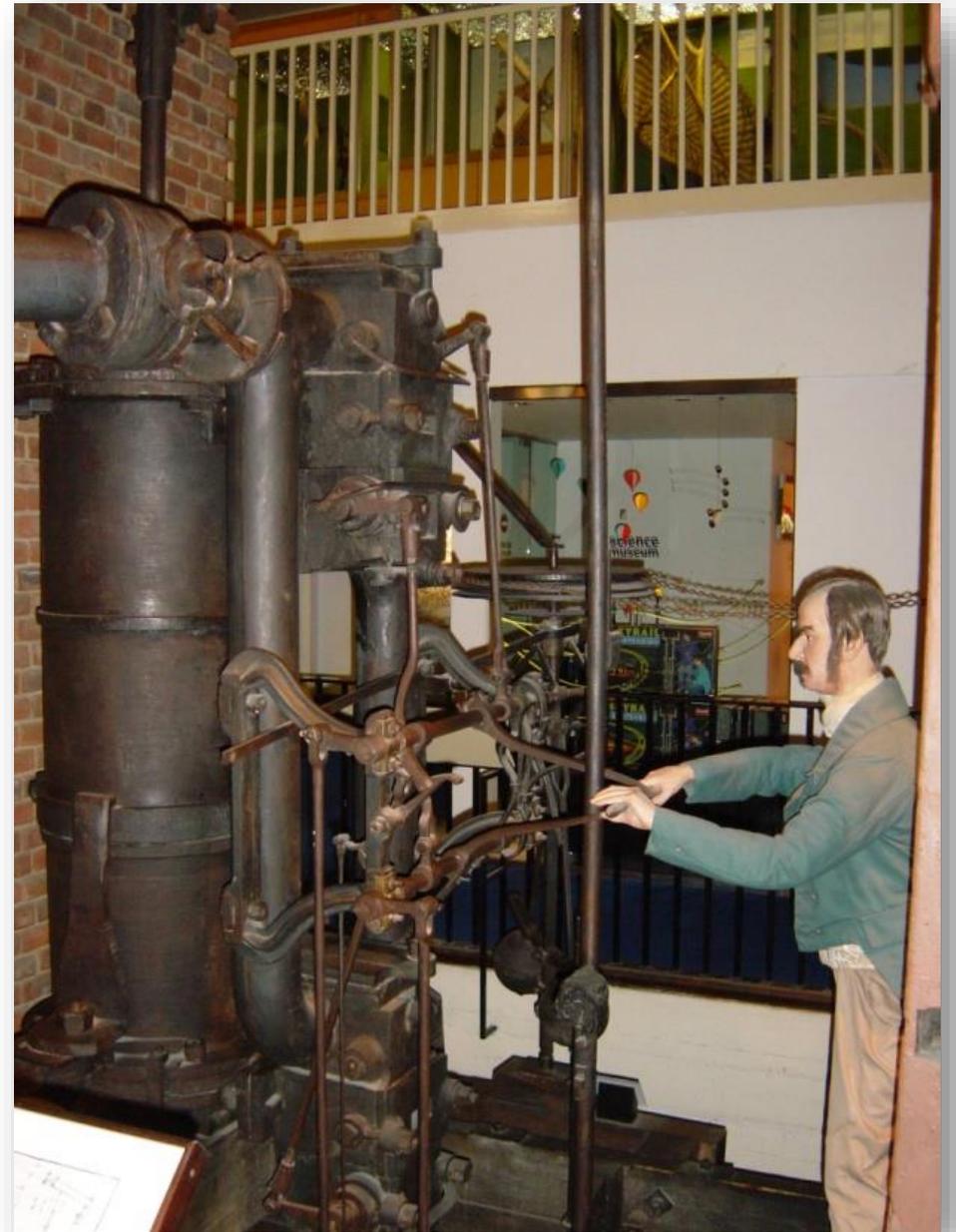
Ironworks in Blaenavon, Wales, UK





In 1856, Bessemer in England declared the technology to produce mild steel. Then, mild steel have been used instead of wrought iron to increase strength level from 100MPa to 200MPa.

Steam power enabled mass production of iron and steel



Radical changes to steel processing

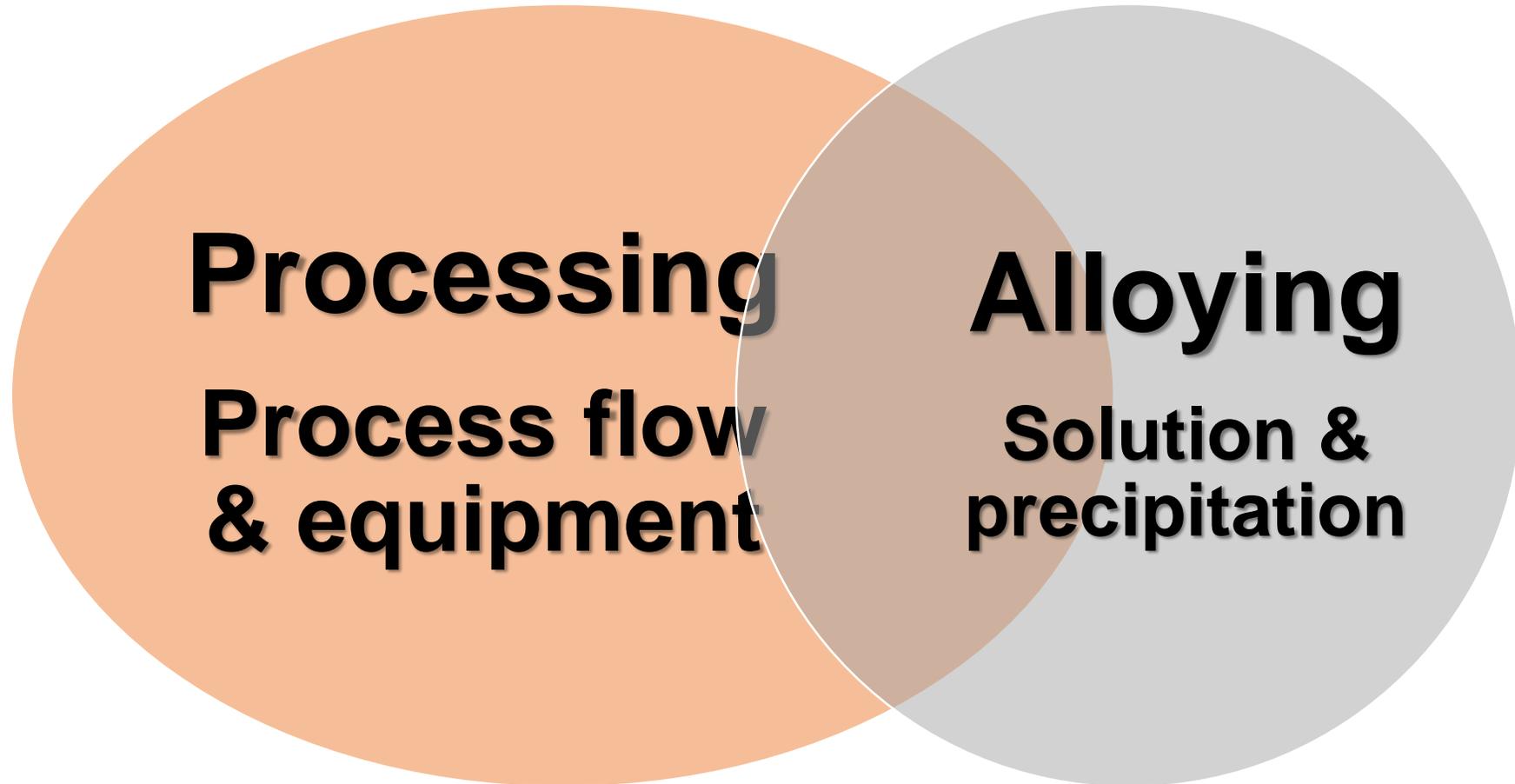


汉冶铁画像石 山东滕州



Blade and vest armor
in Han Dynasty 2000
years ago

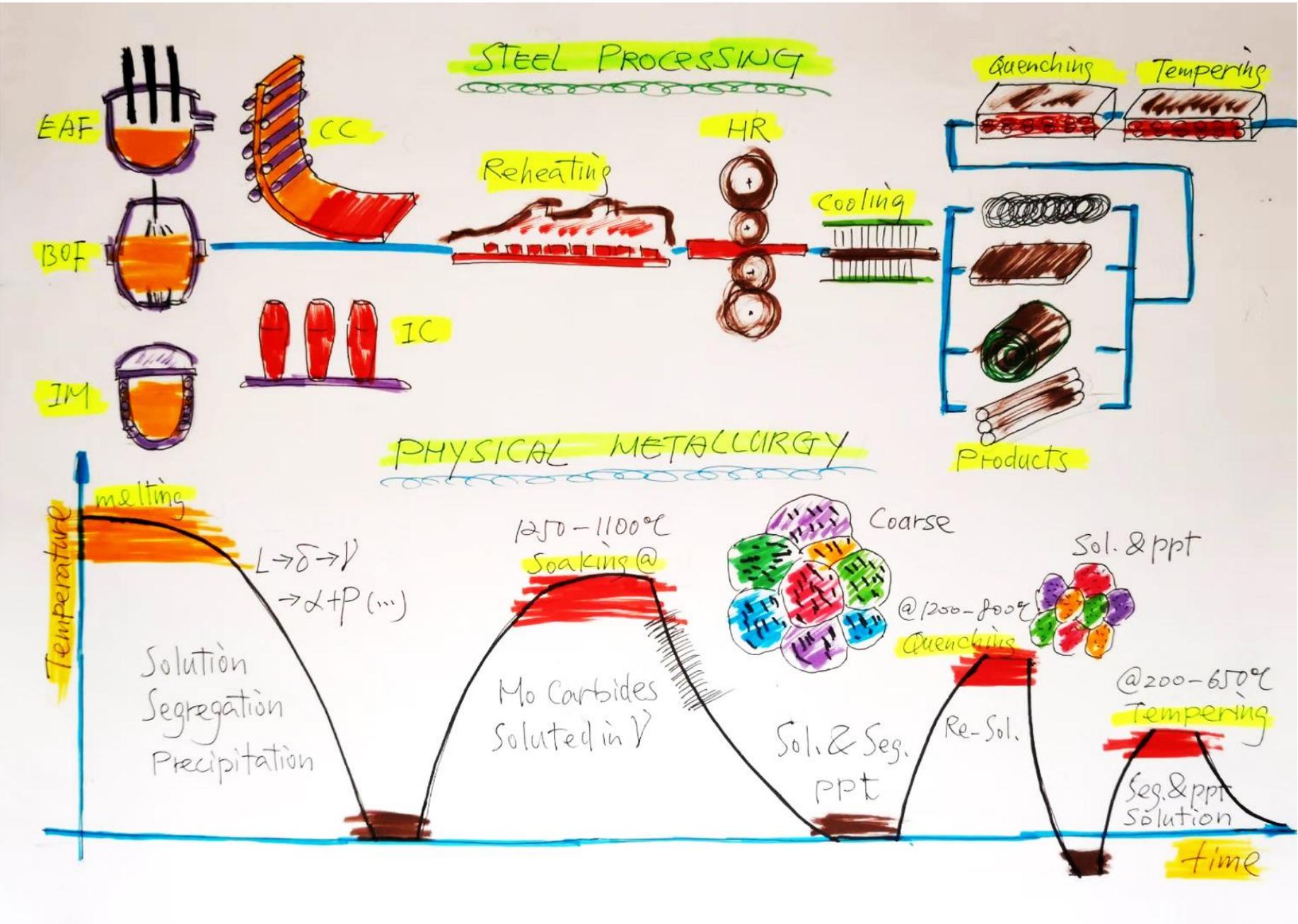
Two variables on steel products



Four main transformations during processing



Physical metallurgy during the processing



Advanced steel, 2004

国家发改委, 先进钢铁材料国家工程研究中心

高性能、低成本、高精度、易加工、绿色化

High quality SS, 2007年

国家科技部, 十二五支撑计划重点项目, 高品质特殊钢技术开发

新品种与高质量

HP steel, 2009

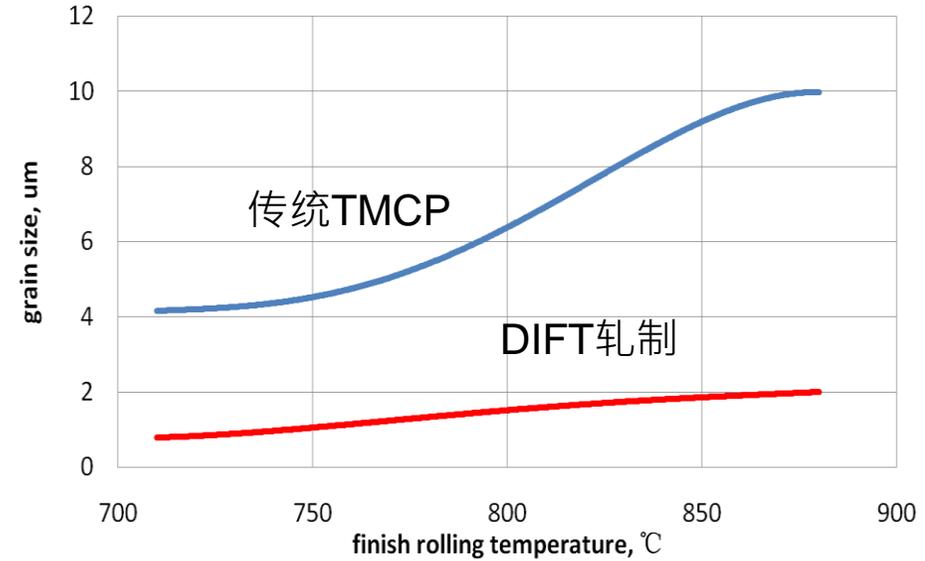
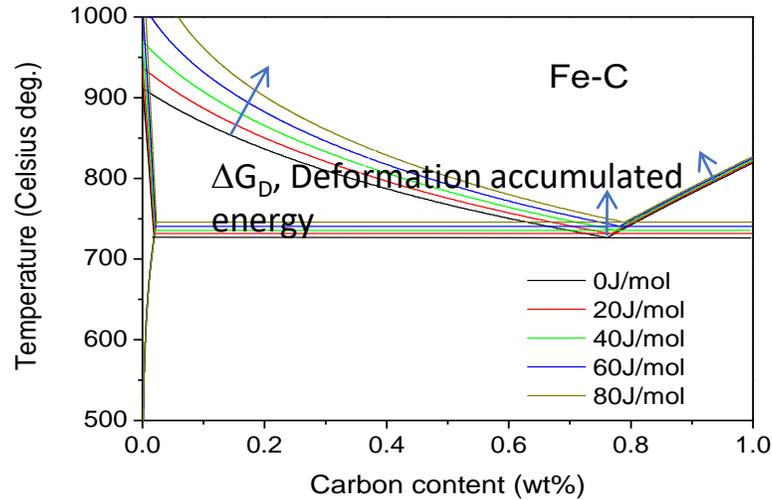
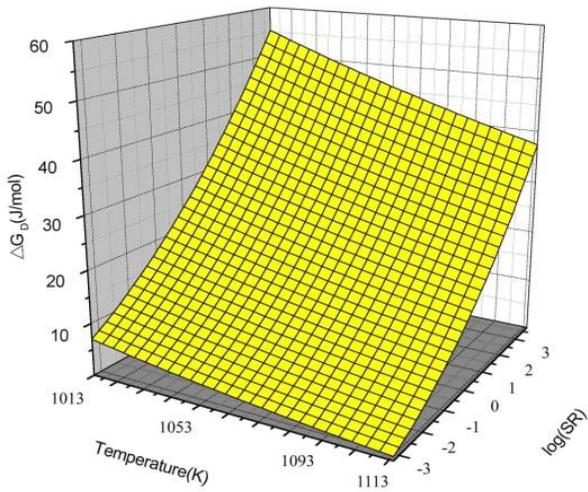
国家科技部, 973项目, 高性能钢的组织调控与技术基础研究, M3

高塑性与高韧性@高强度

高持久强度@高温

Deformation Induced Transformation: strengthening and softening

Since 1999, 973 Project, CISRI, first prize of national S&T Progress Award in 2004



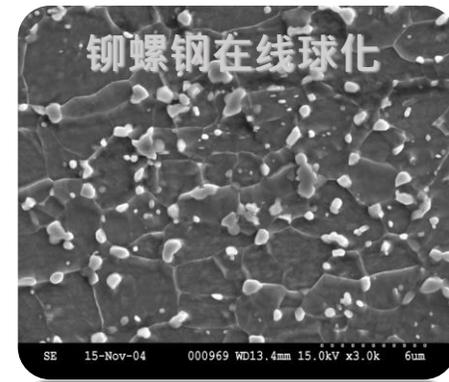
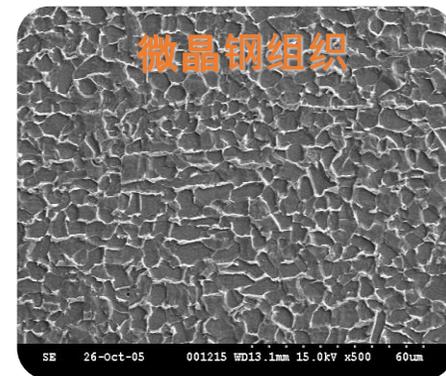
- Average deformation stored energy as a function of temperature and strain rate (strain=0.6) in a microalloyed low carbon steel

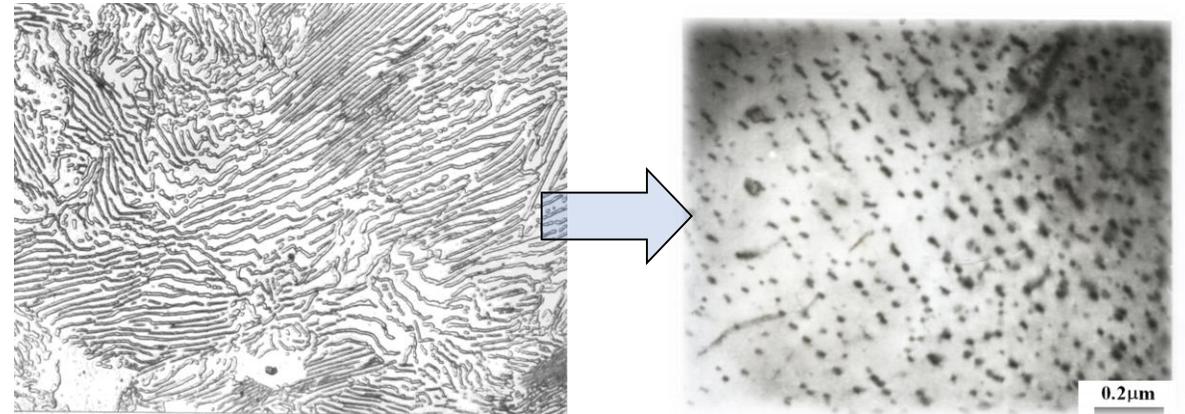
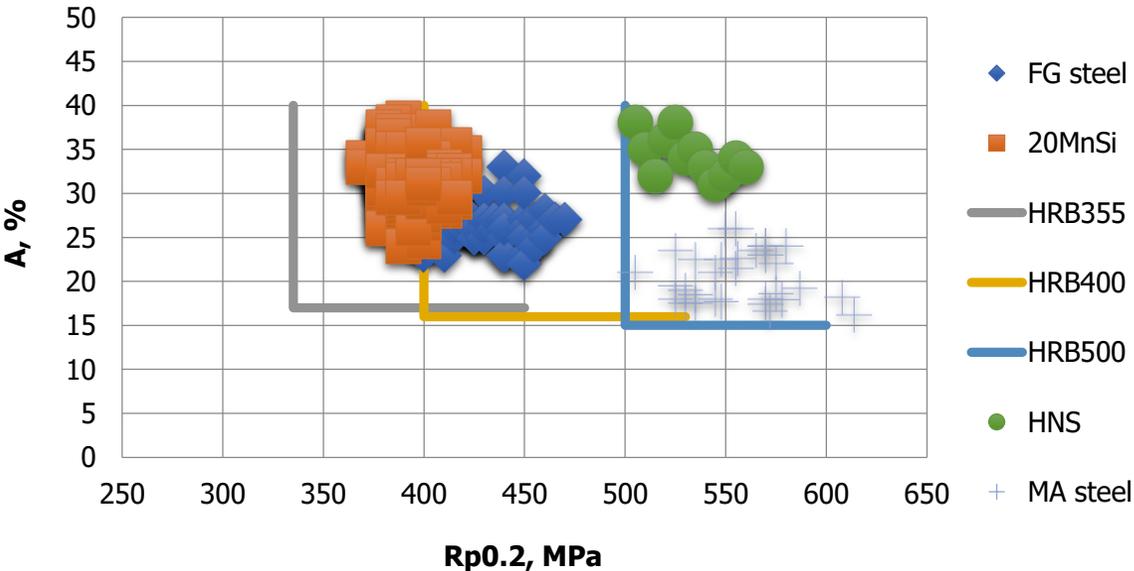
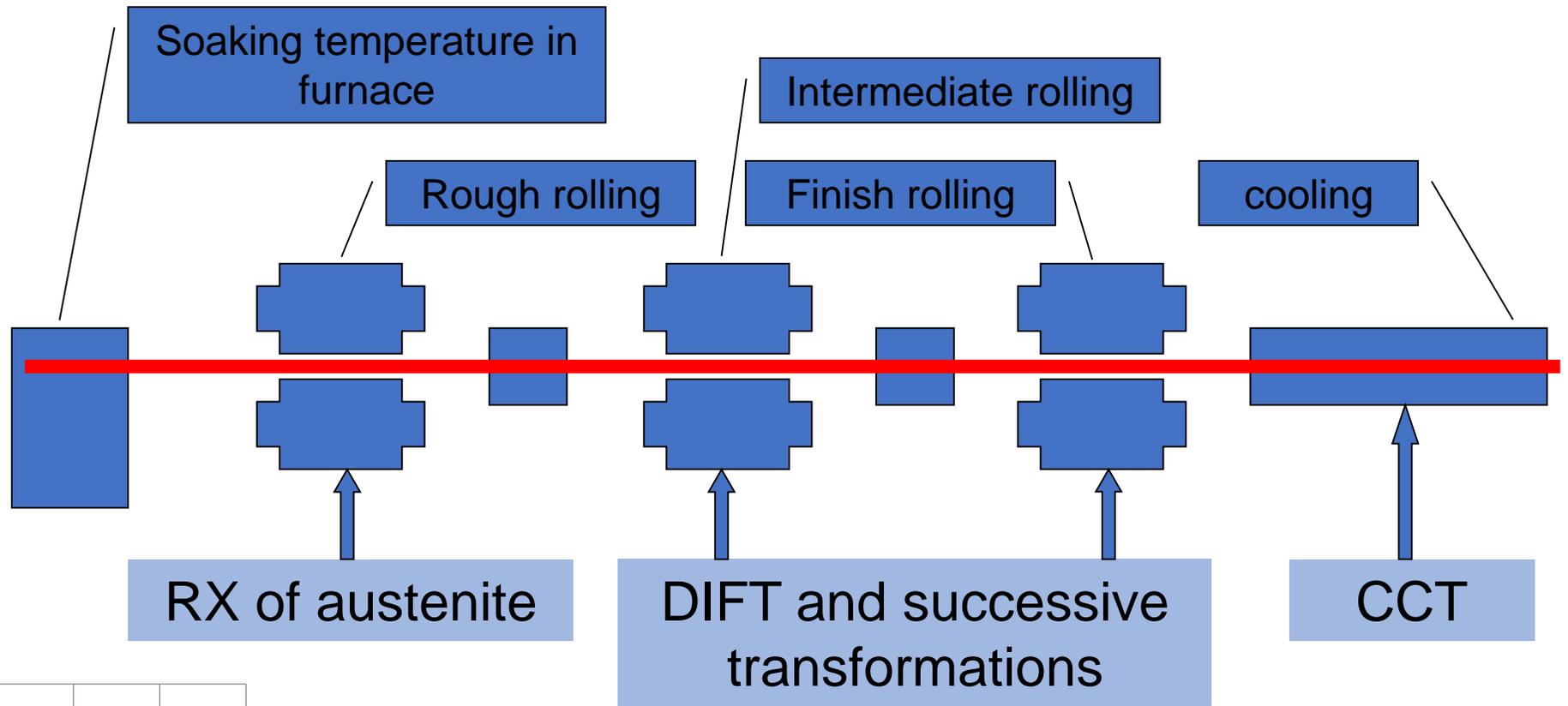
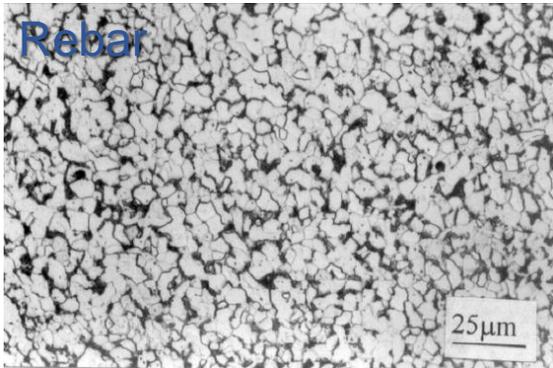
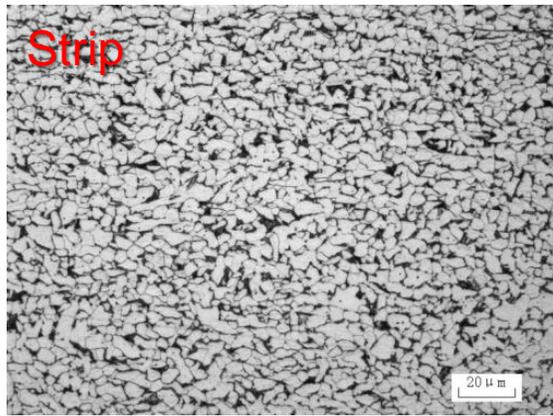
Hardening

- high strength PLC steel
- High strength microalloyed steel
- Non heat treating steel

Softening

- Spheroidization for bolt steel
- Spheroidization for bearing steel
- Patenting for pearlitic steel

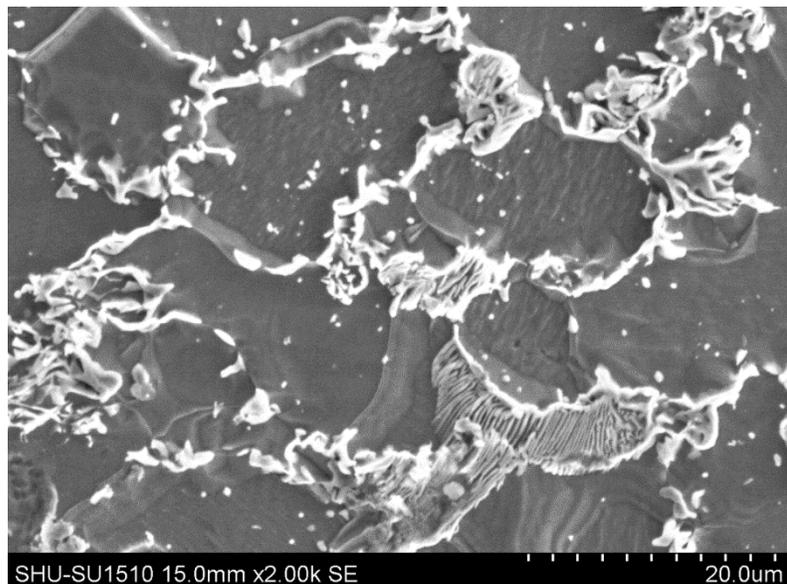
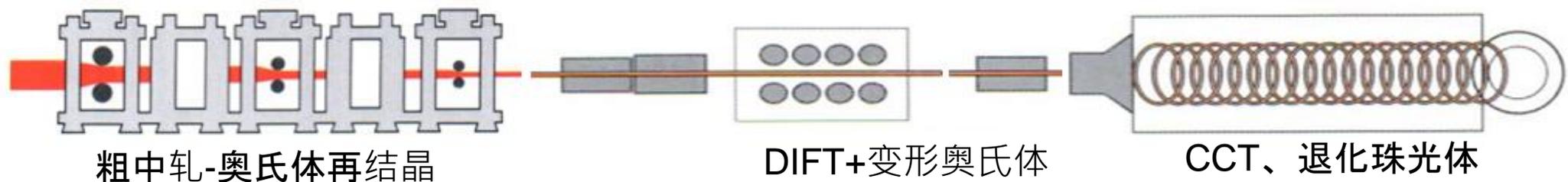




SWRCH35K bolt steel on-line annealing

技术目标：抗拉强度 $R_m \leq 570\text{MPa}$ 、面缩率 $Z \geq 57\%$ 、洛氏硬度 $HRB \leq 78$ ；1/3冷顶锻合格

目标组织：变形诱导铁素体（DIFT）+球状渗碳体+退化珠光体（Degenerated pearlite）



SHU-SU1510 15.0mm x2.00k SE

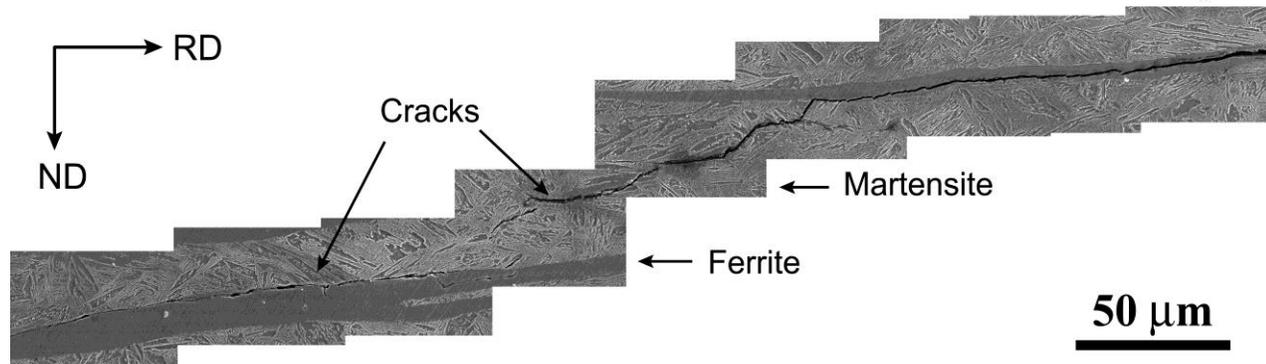
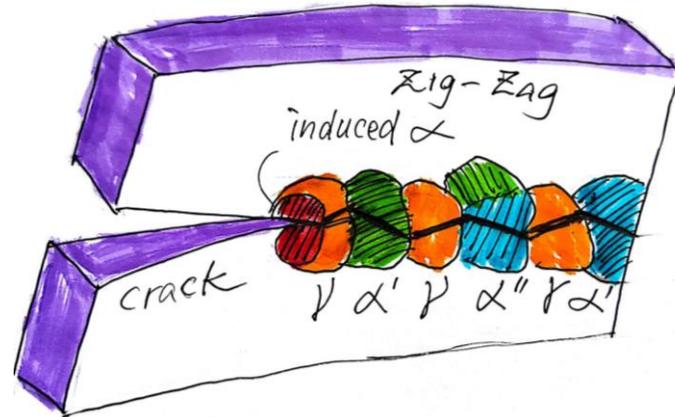
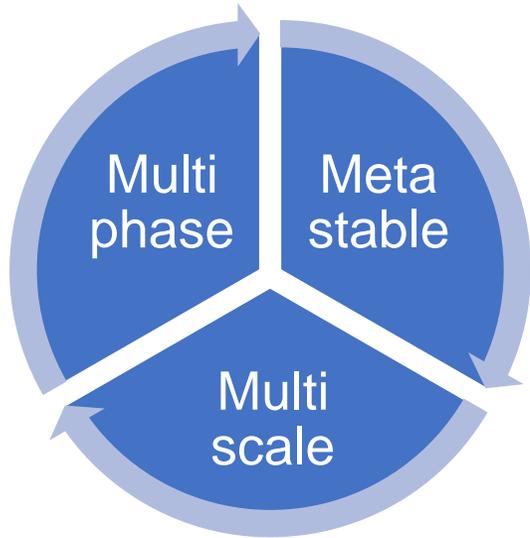
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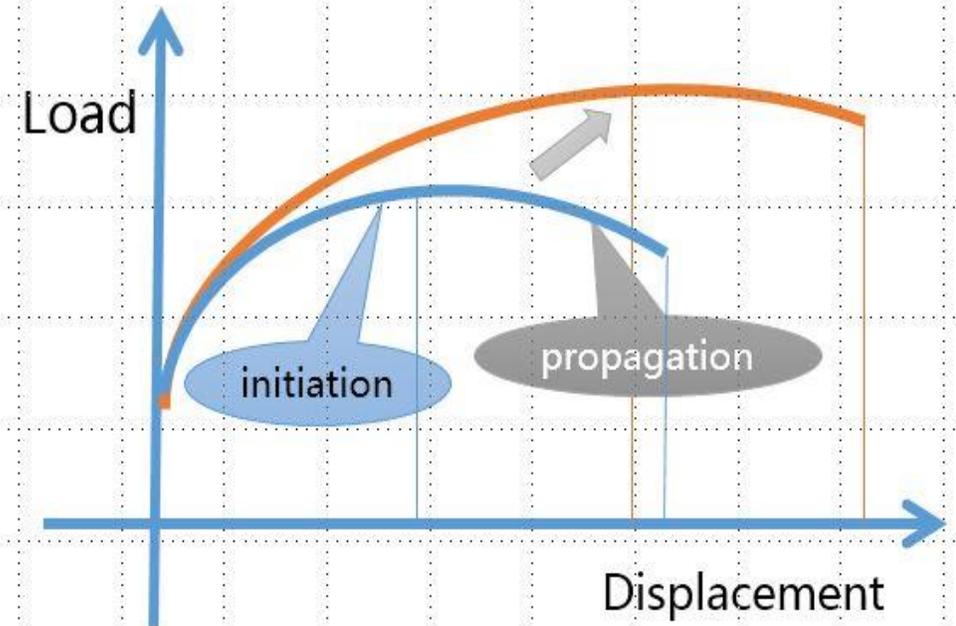
$R_m = 519\text{MPa}$, $Z = 59\%$, $HRB = 75$, 1/3冷顶锻合格

M³ structure control: high ductility and high toughness

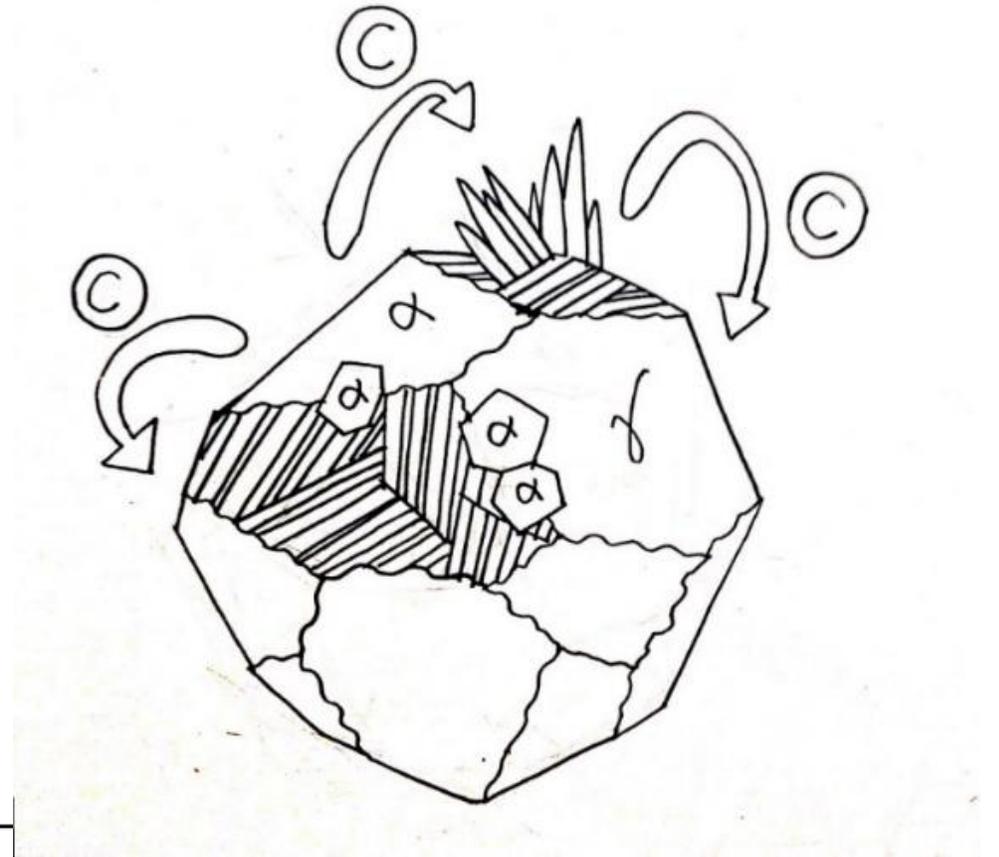
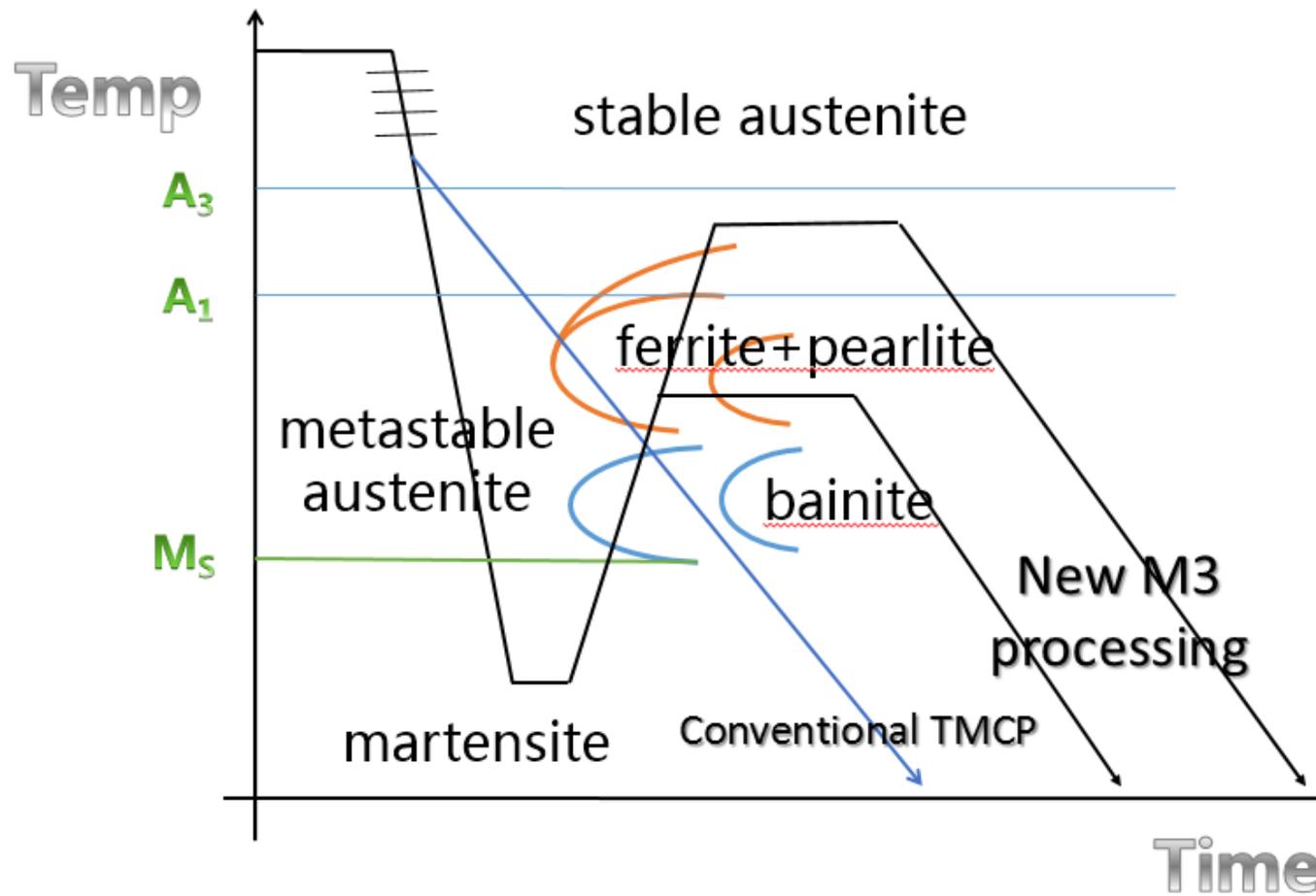
Since 2009, 973 Project, CISRI, 2nd prize of national technology invention award in 2018



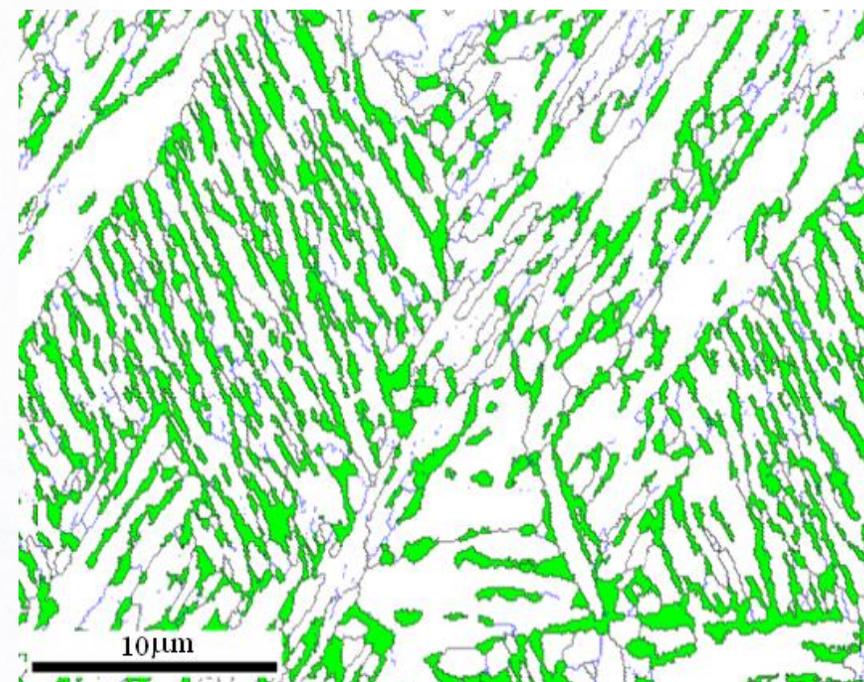
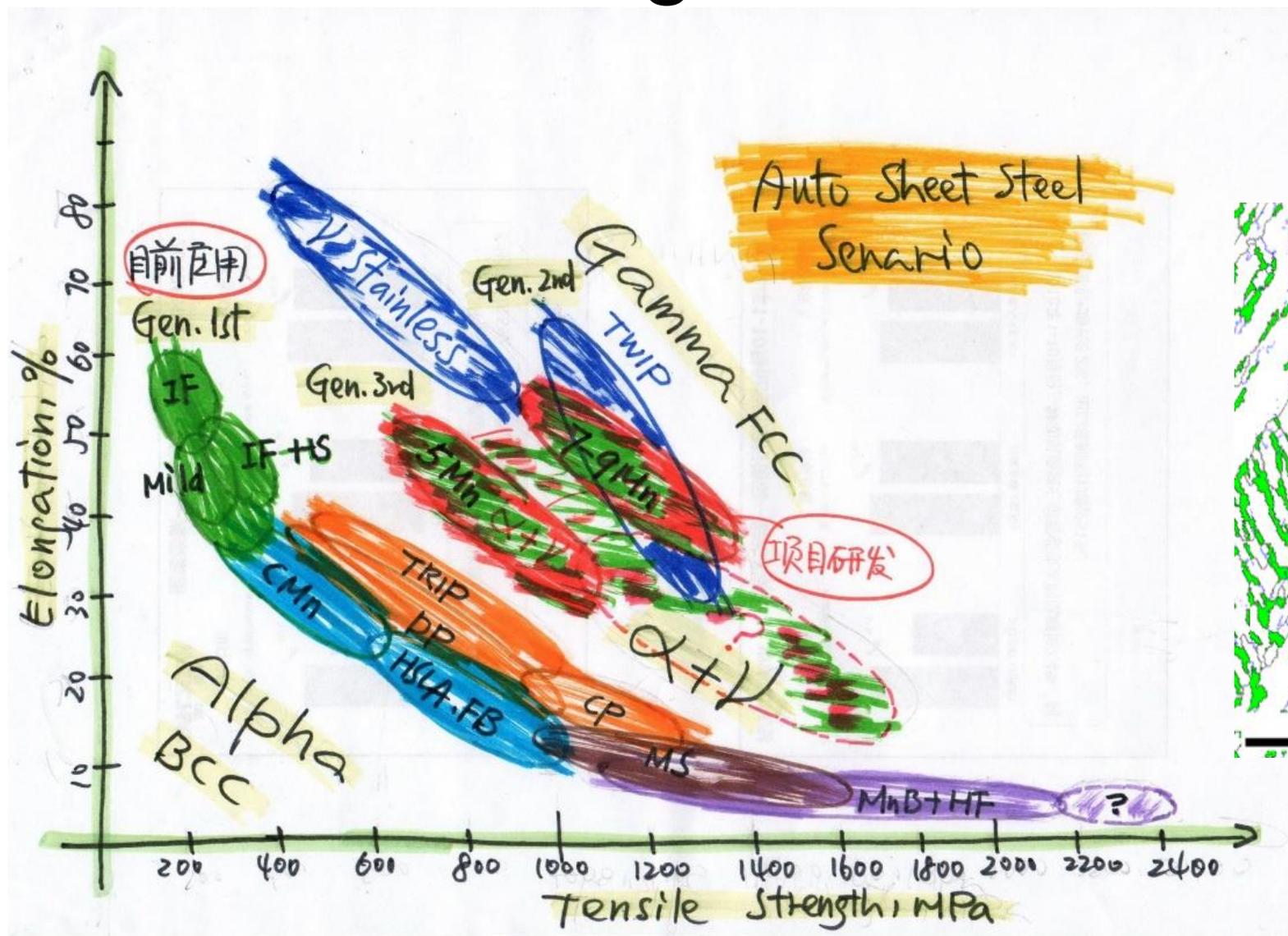
Strength, ductility, toughness upon crack initiation and propagation



Processing and microstructure



Medium manganese steel





Available online at www.sciencedirect.com

ScienceDirect

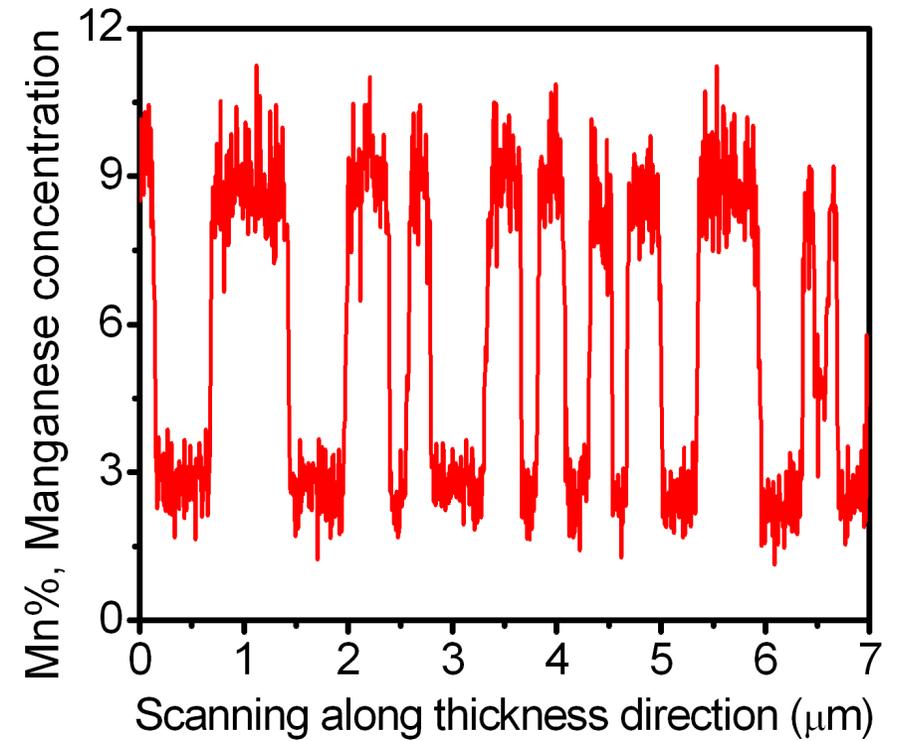
Acta Materialia 59 (2011) 4002–4014



www.elsevier.com/locate/actamat

Experimental and numerical analysis on formation of stable austenite during the intercritical annealing of 5Mn steel

Haiwen Luo*, Jie Shi, Chang Wang, Wenquan Cao, Xinjun Sun, Han Dong

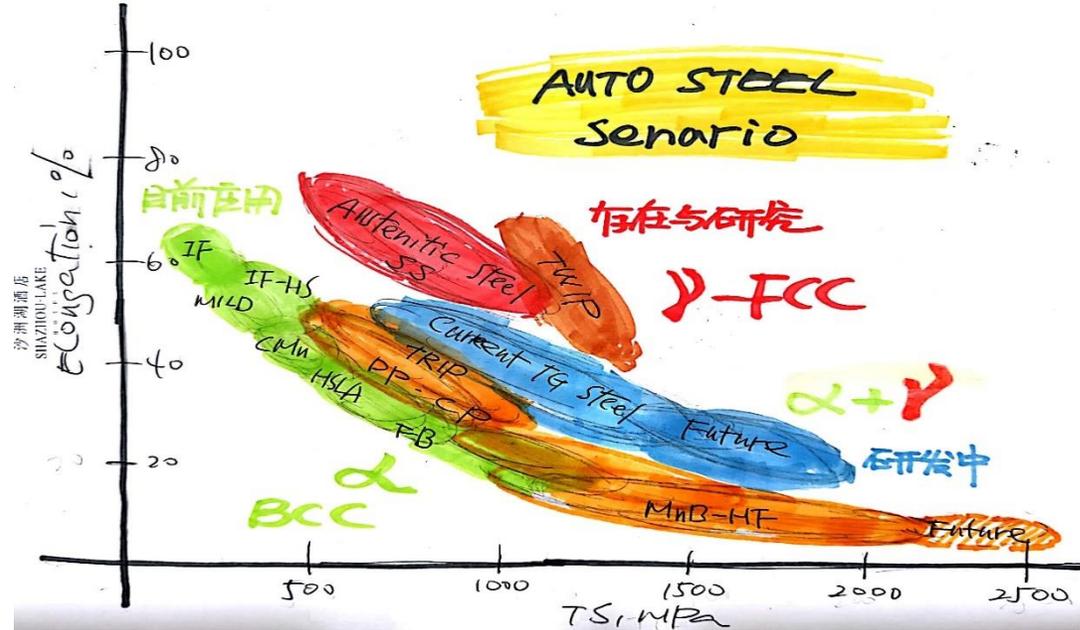


The third generation AHSS

国家973项目《高性能钢的组织调控理论与技术基础研究》2010CB630800

国家科技支撑计划《高强塑积热轧汽车钢板技术开发》2013BAE07B05

国家重点研发计划《高性能超高强汽车用原型钢的技术基础研究》2017YFB0304401



Hot rolled coil



Cold rolled coil



Warm stamping



Cross beam



Car body

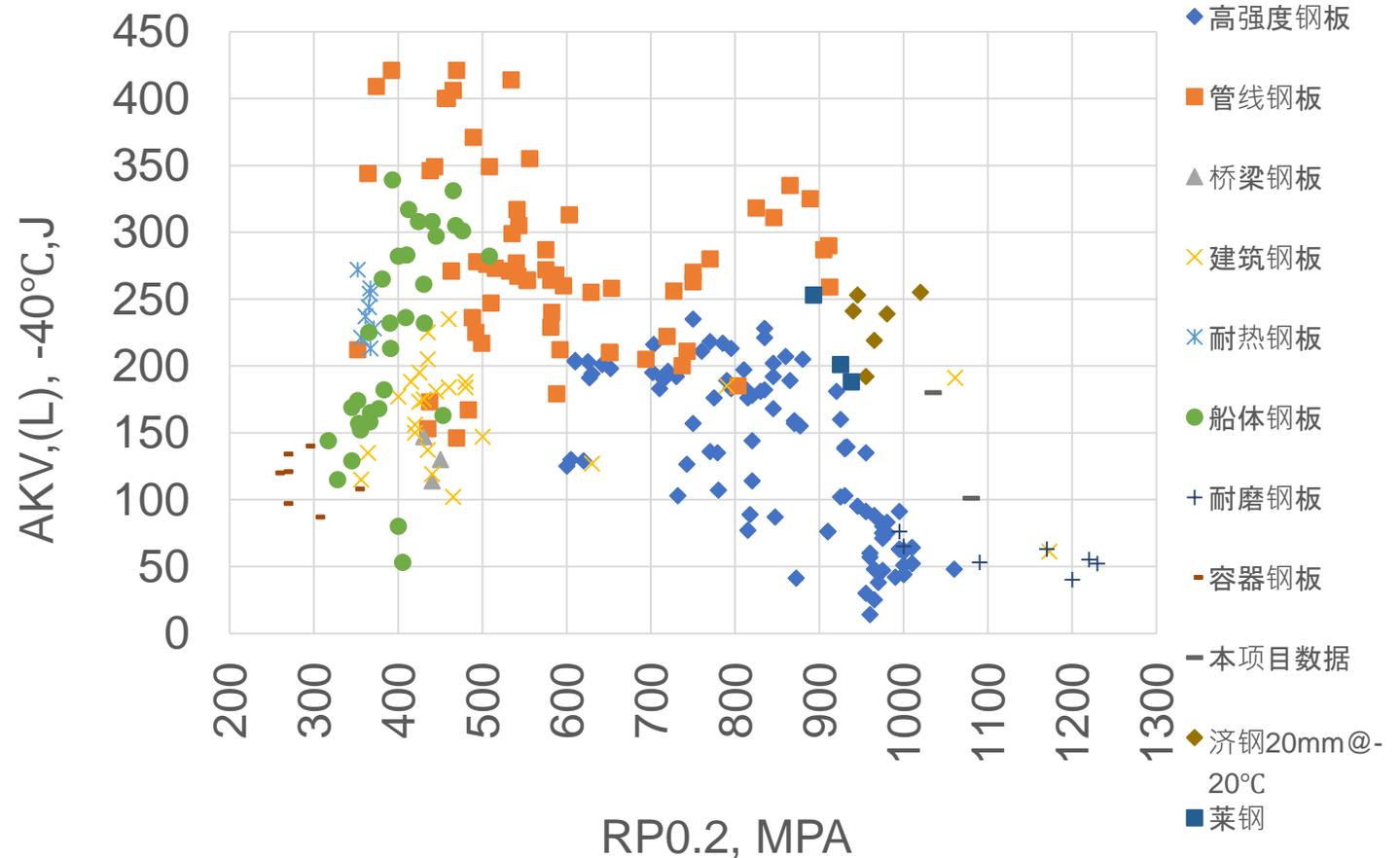
Shanjing pipe line X80



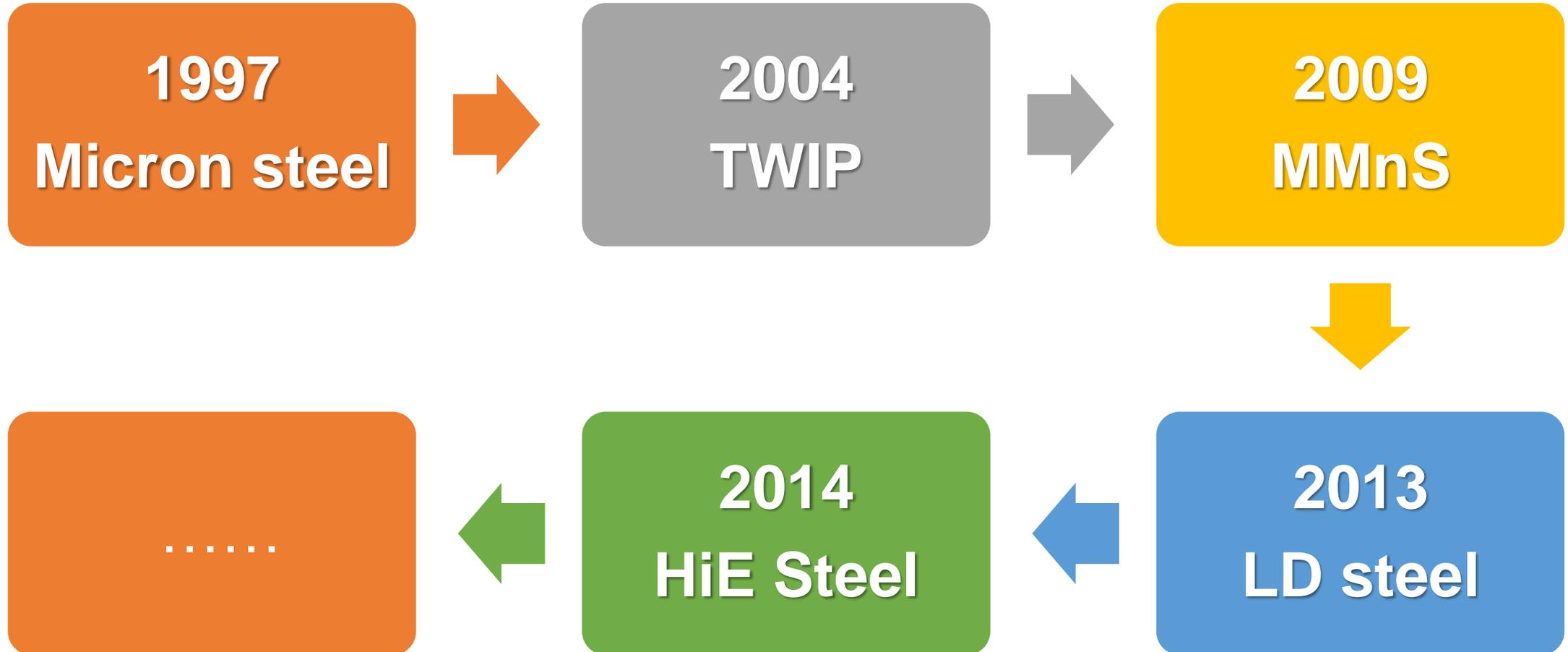
Hutong Bridge Q500qE



HSLA Steel toughness and ductility



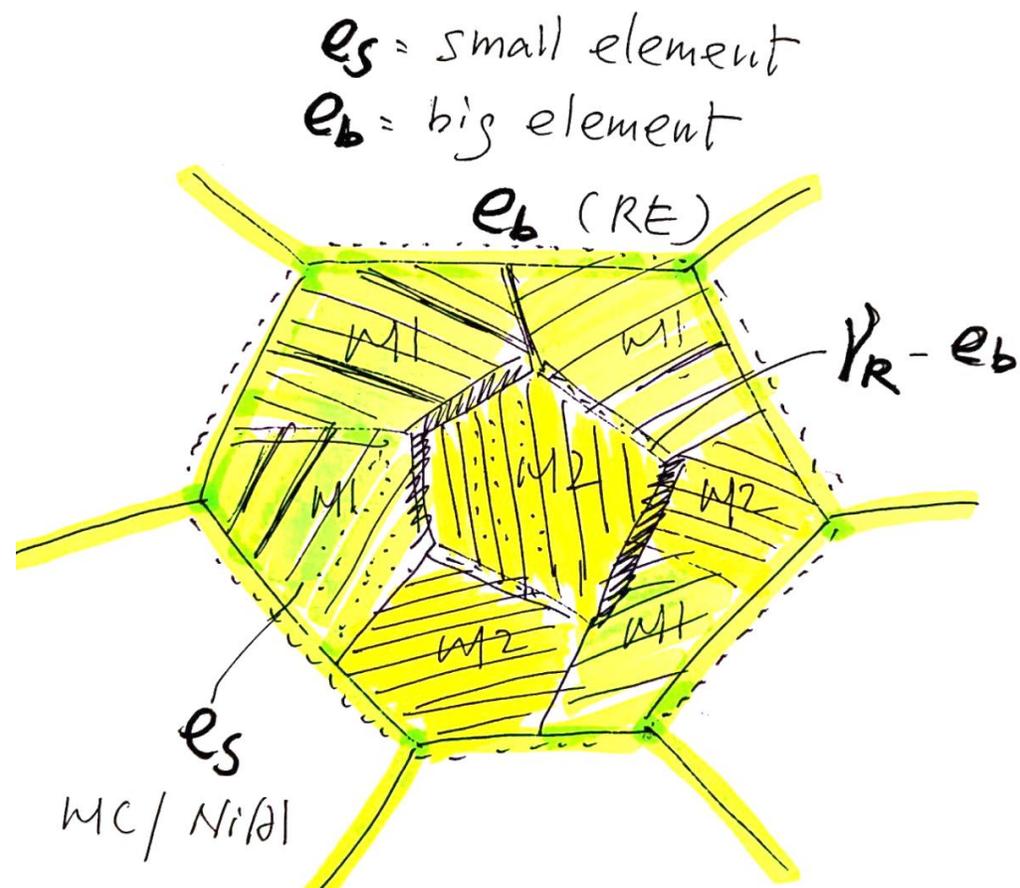
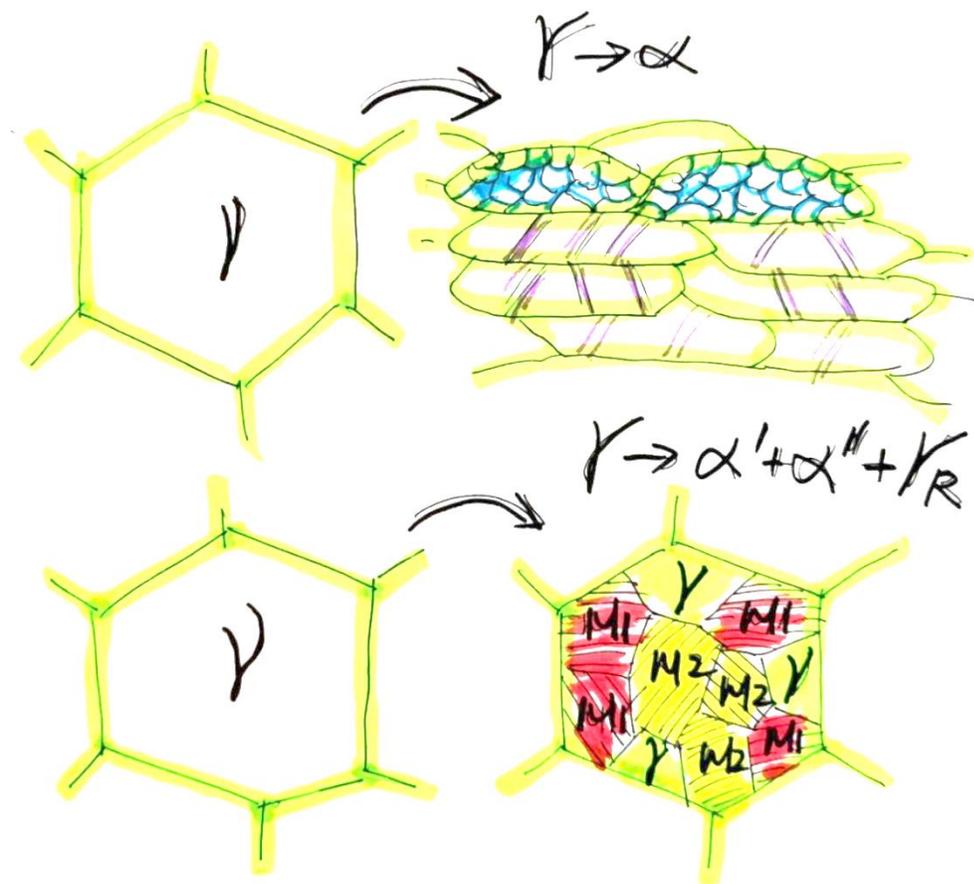
Cutting-edge steels



Ferrous materials: easy to be rusted

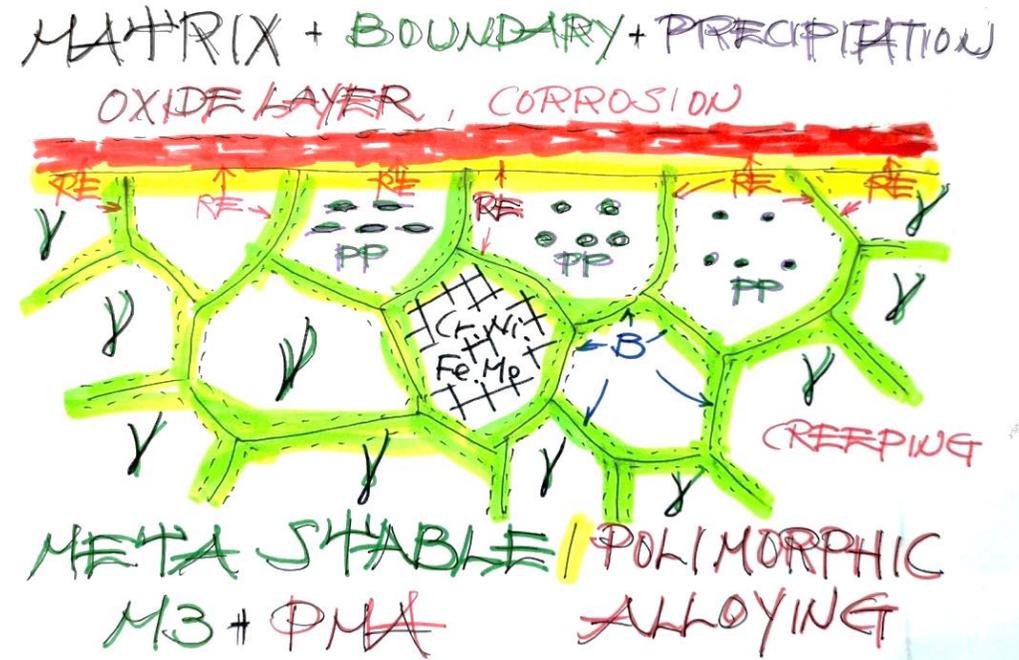
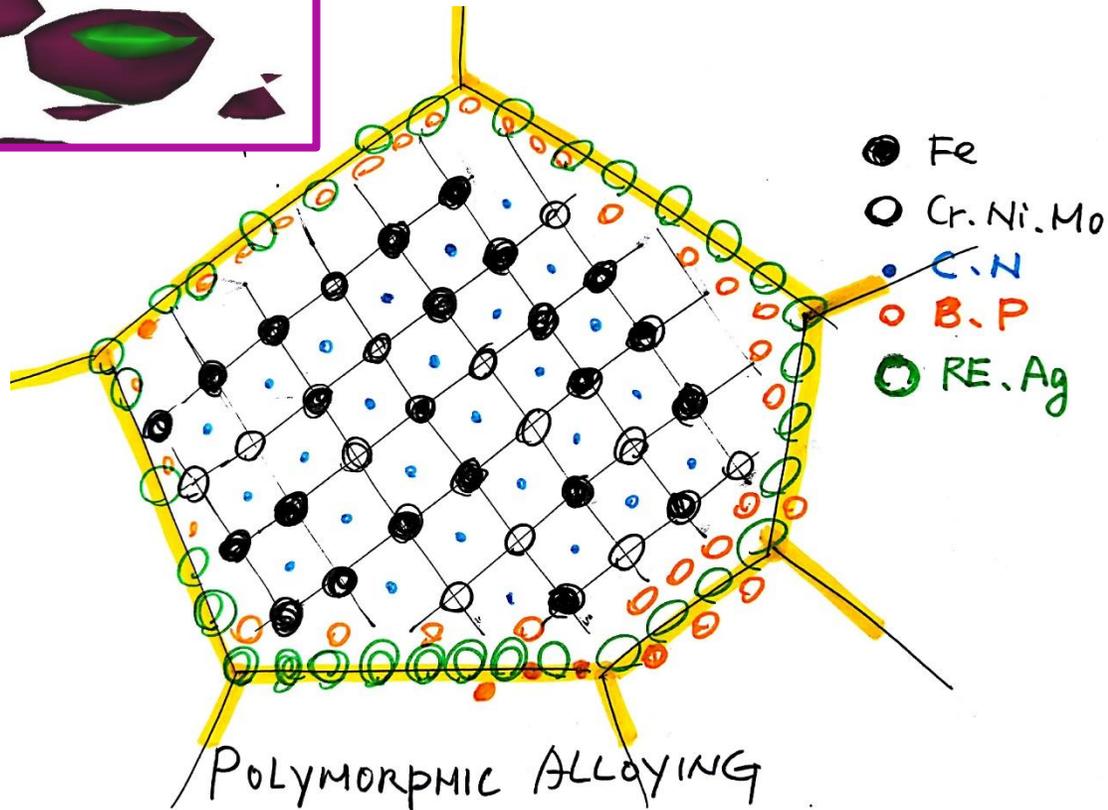
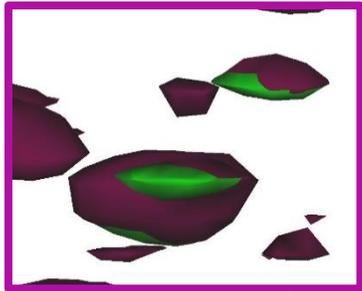


DIT to M3, and then to PMA



Polymorphic Alloying: to improve performance

Since 2019, SHU, CISRI, JITRI



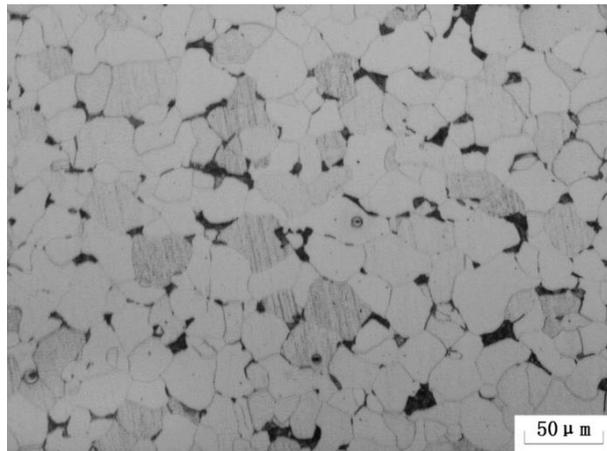
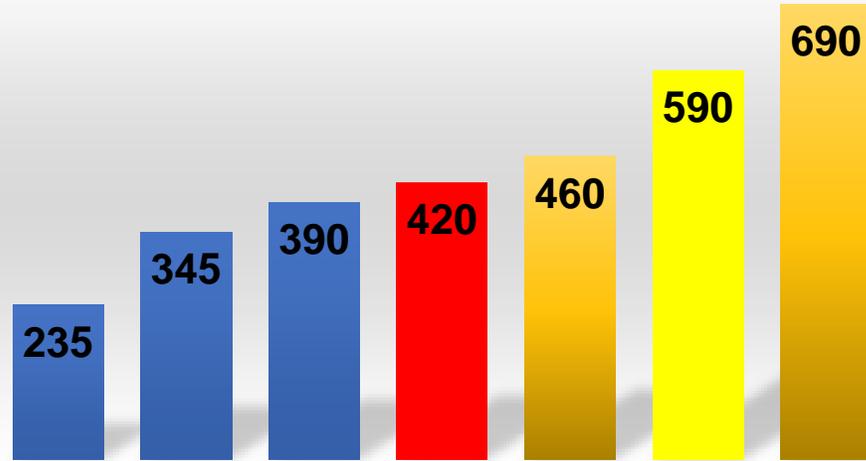
Widely used Q235 steel & Q355 steel: corrosion?

Q235B、Q235BRE、Q355B、Q355BRE



Polymorphic Alloying: 09CuPCrNi+RE

屈服强度, MPa



Corrosion resistance steels

梁柱材料: Q390FEW, 耐火、抗震、耐候
 $YS \geq 390\text{MPa}$ 、 $TS \geq 490\text{MPa}$ 、 $RY \leq 0.80$ 、
 $A(5.65\sqrt{S_0}) \geq 22\%$
10.9S级优良抗延迟断裂性能螺栓



Novel Q235BRE and Q355BRE steels for JITRI laboratory





Timeline

2005

2015

2025

Gear

$\sigma_{-1} \sim 600\text{MPa}$
@1200MPa

$\sigma_{-1} \sim 800\text{MPa}$
@1200MPa

$\sigma_{-1} \sim 1000\text{MPa}$
@1400MPa

Bolt

14.9 @
 $K_{ISCC} \sim 30\text{MPam}^{1/2}$

16.9 @
 $K_{ISCC} \sim 30\text{MPam}^{1/2}$

18.9 @
 $K_{ISCC} \sim 30\text{MPam}^{1/2}$

Spring

$\sigma_{-1} \sim 0.4\sigma_b$
@1800MPa

$\sigma_{-1} \sim 0.5\sigma_b$
@2000MPa

$\sigma_{-1} \sim 0.5\sigma_b$
@2200MPa

Bearing

L10 $\sim 10^6$
[O] $\sim 10\text{ppm}$

L10 $\sim 10^7$
[O] $\sim 8\text{ppm}$

L10 $\sim 10^8$
[O] $\sim 4\text{ppm}$



High strength bolt steel: 14.9

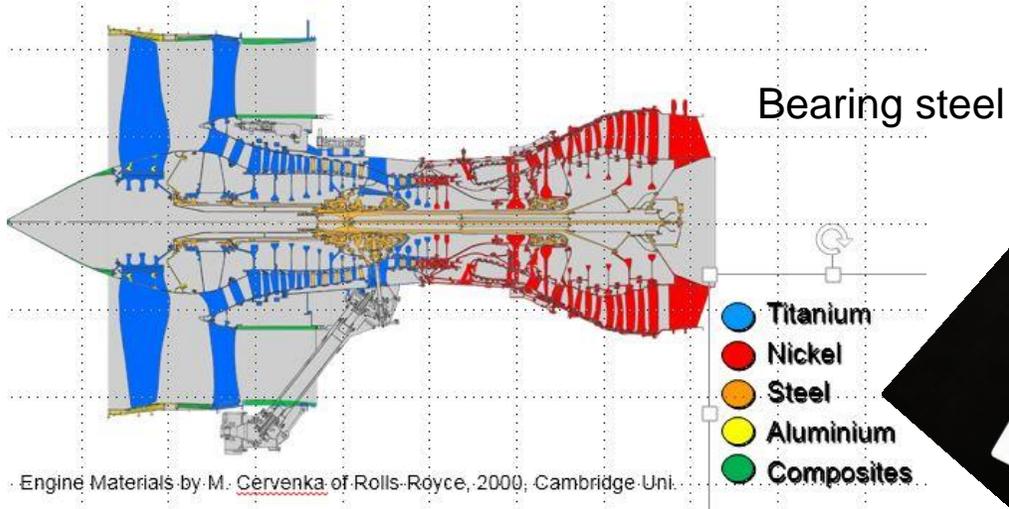


2000MPa leaf spring



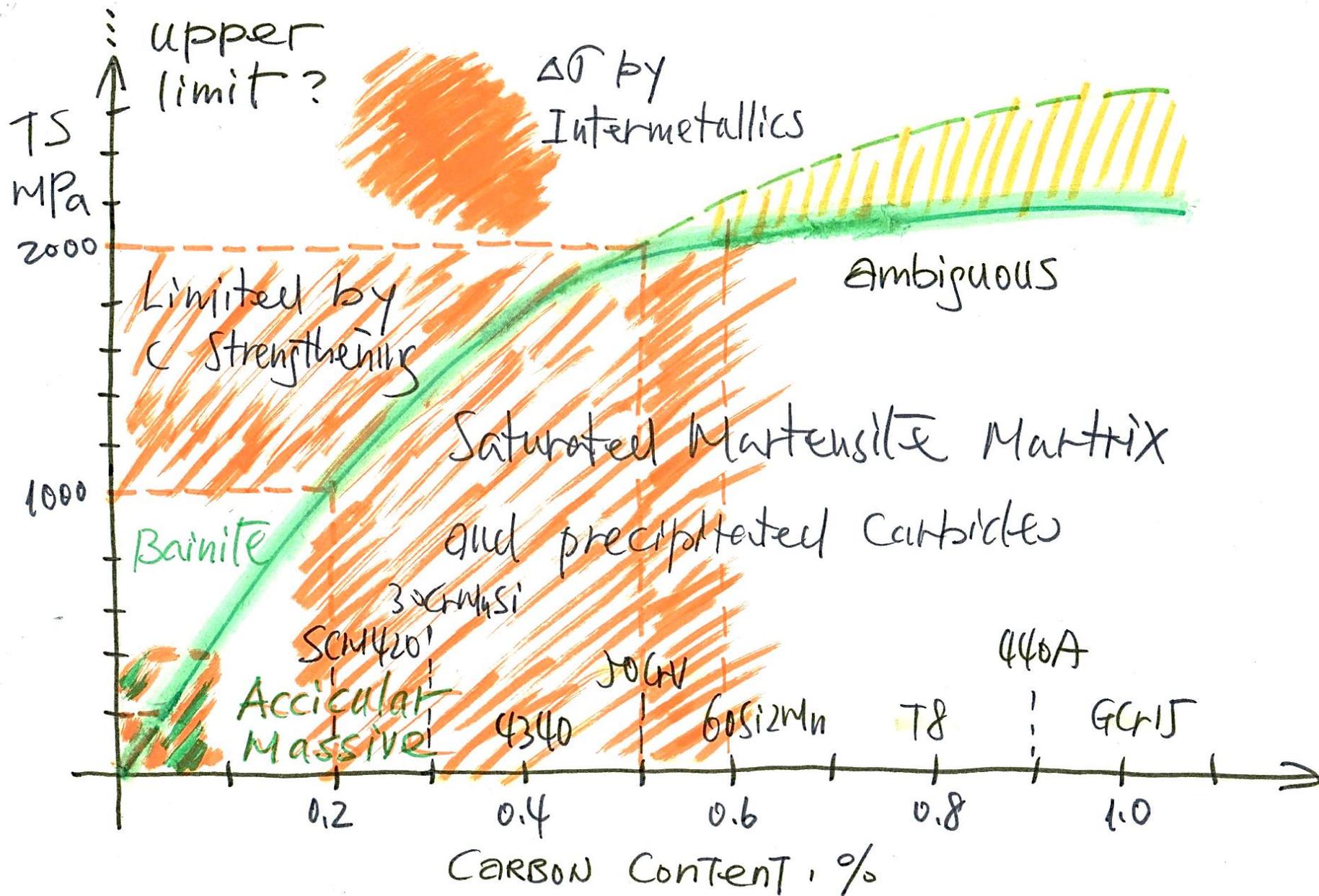
The best steel used for knives and bearings

6Cr16MoMA steel



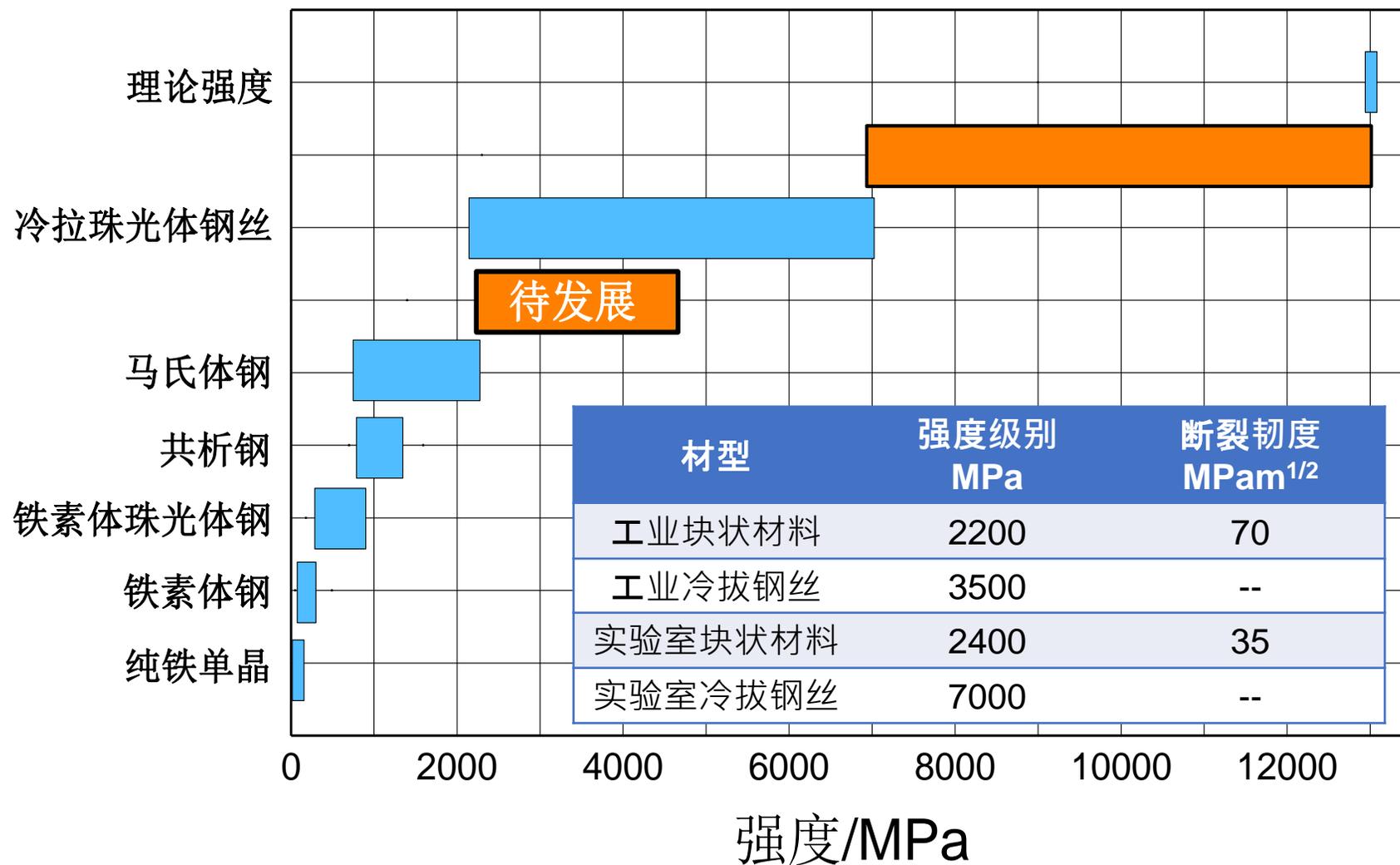
Kitchen knife made of 6Cr16MoMA steel



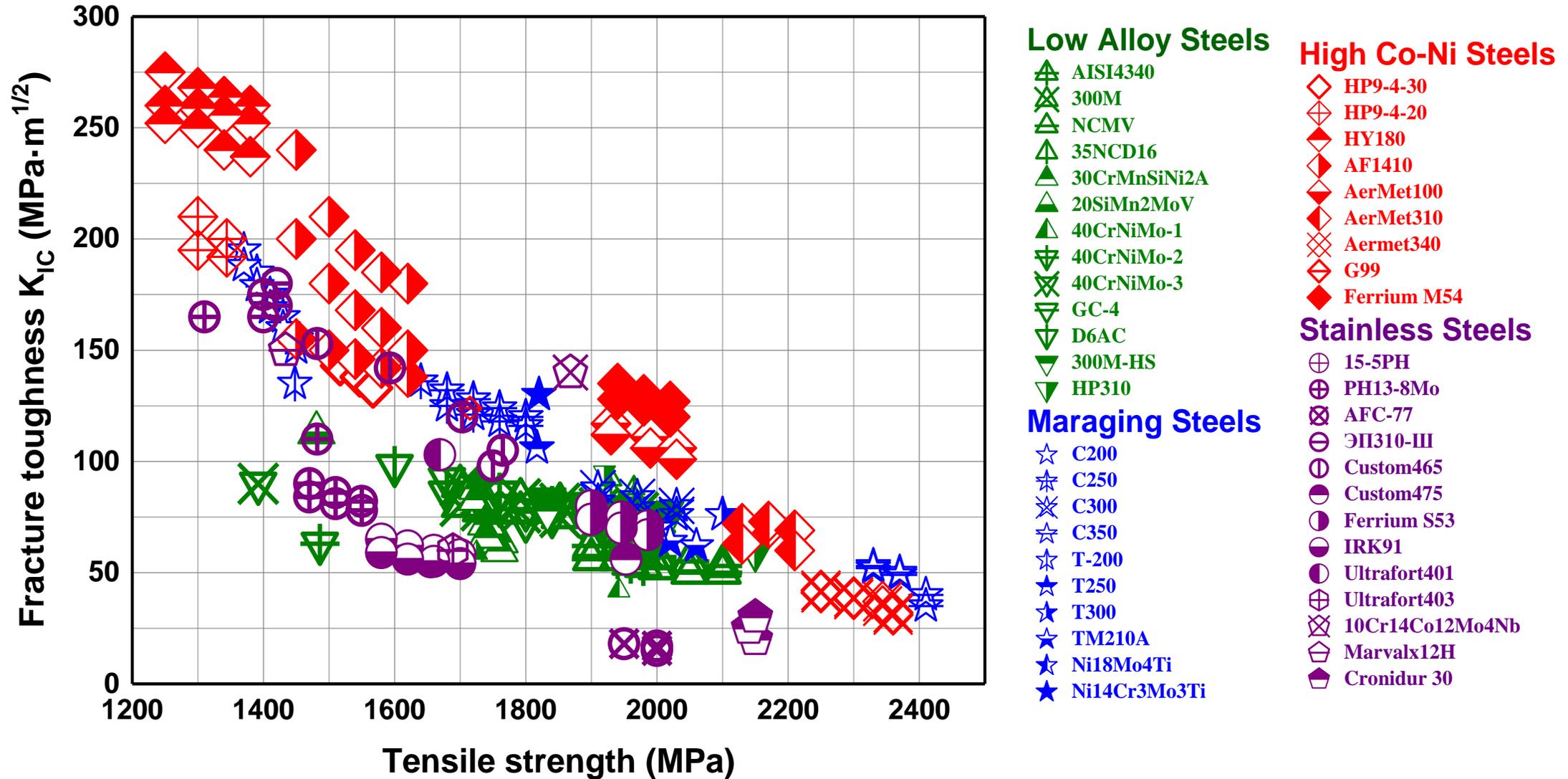


Interstitial carbon alloying and precipitation

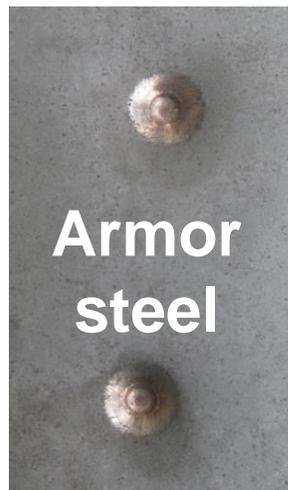
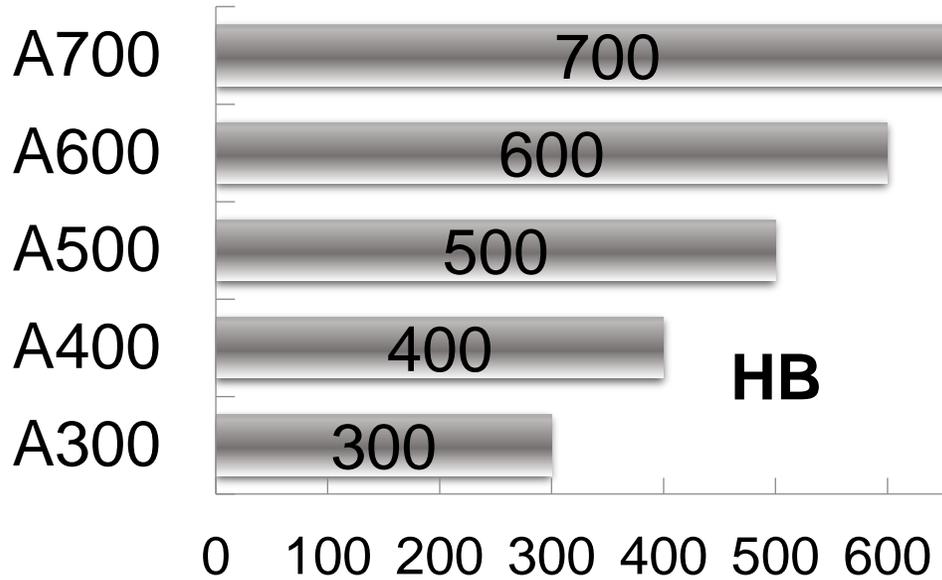
Strengthening to be even higher by defects



To study new ultrahigh strength steel



CrNiMoV alloying: substitutional and precipitation



Polymorphic alloying

30CrNiMo bullet proof and 09CuPCrNi corrosion resistant



Basic study (DIT、M³、PMA)

Micron steel, TG steel, Novel steel

Construction

50-60%

Cost &
Resources

Automobile

Advancing

Strength &
Ductility

Special steel

10%

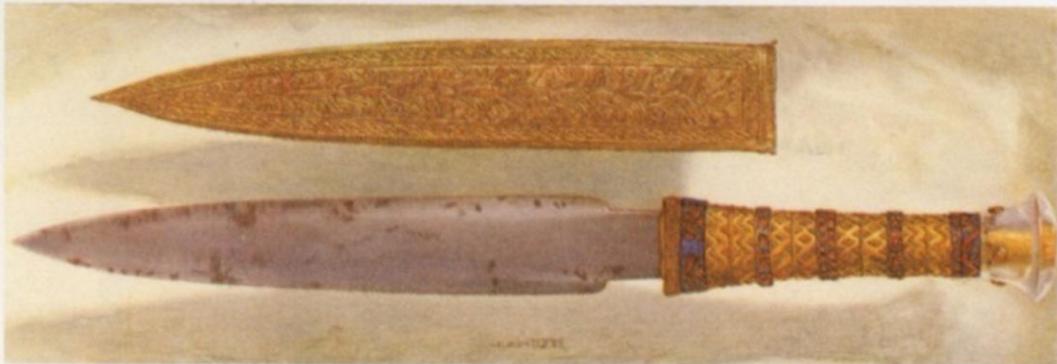
High quality

Iron meteorite: the gift from heaven to open up human civilization



Facts about iron in the early ages

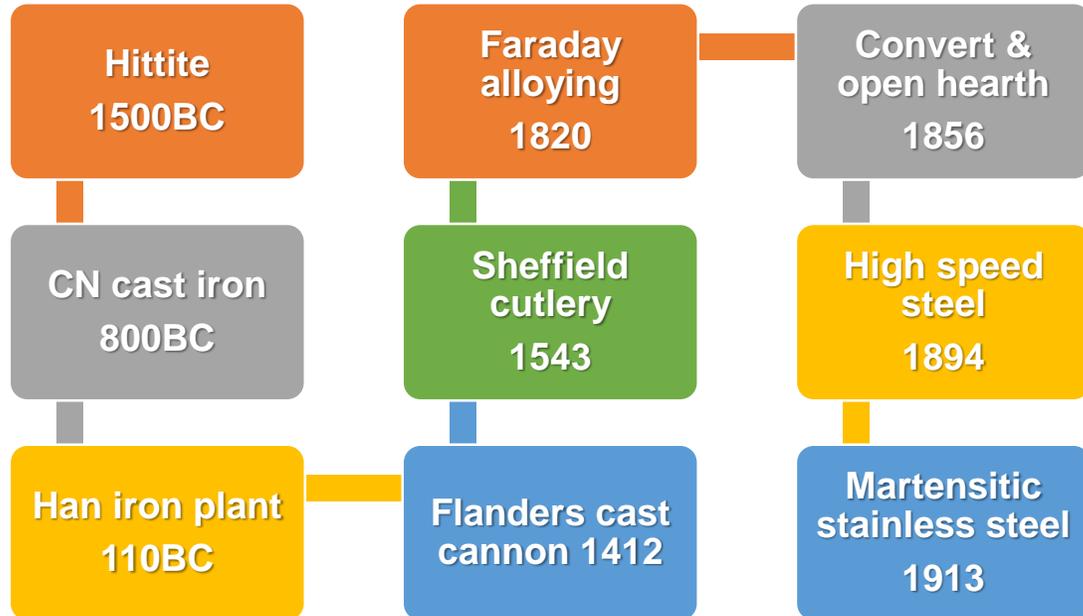
Tutankhamen's daggers, 1333 BC
FeNi alloy



early bronze age in Anatolia
3000-1950 BC



Man made iron, 3500 years history



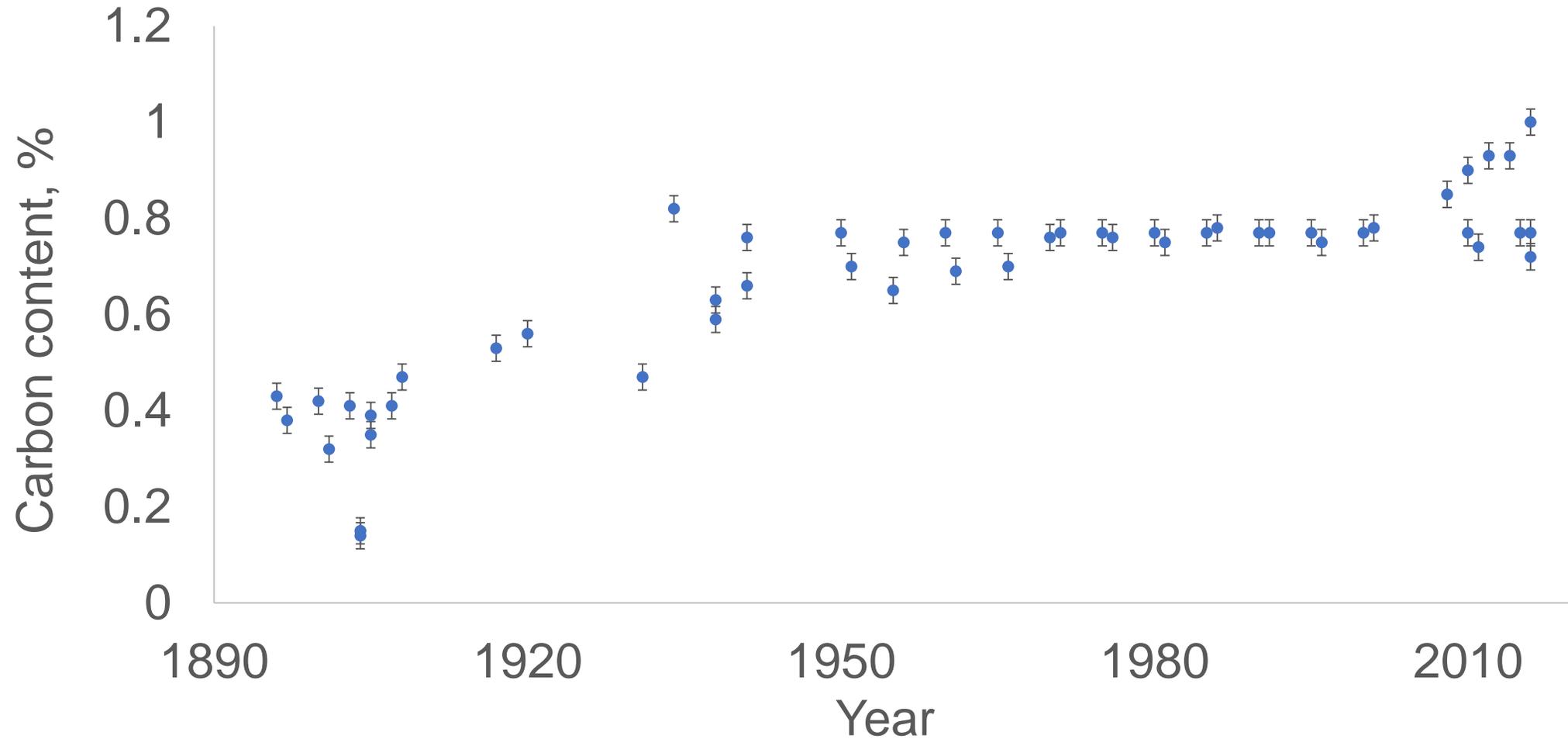
100m rails and bullet train (350km/h) five rail mills in China



Rails in China hundred year ago imported from Belgium

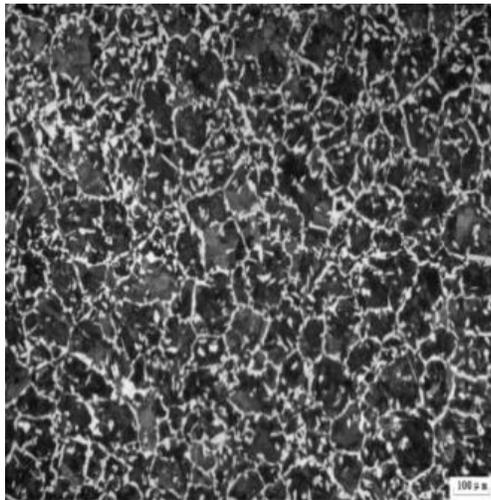


Carbon content evolution of rails over hundred years

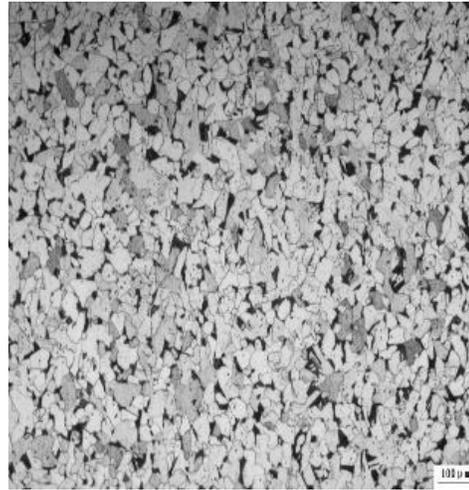


Microstructure evolution

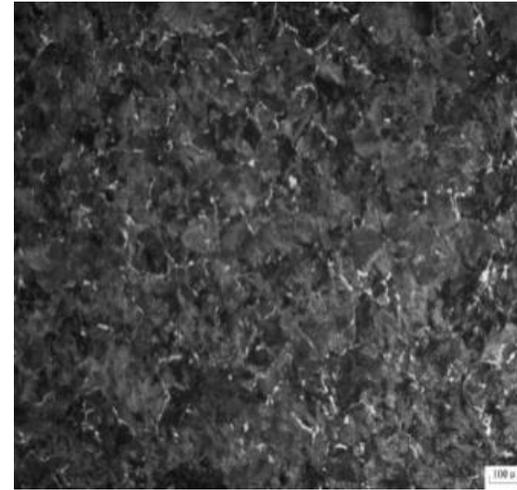
欧洲企业的中
碳钢



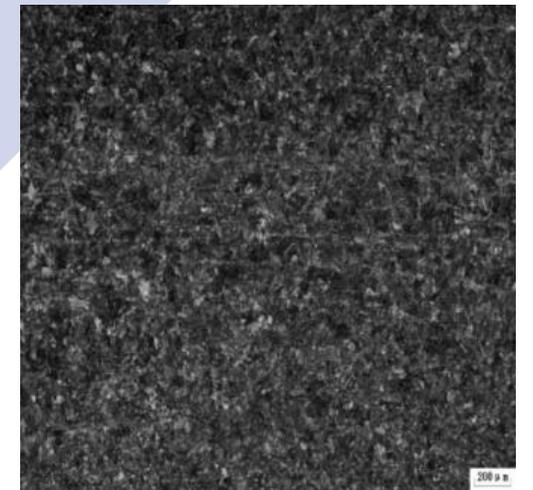
汉阳铁厂的低
碳钢



伪满昭和制钢
中高碳钢



现代各国高碳
共析钢



铁素体+珠光体 大量铁素体+珠光体 少量铁素体+珠光体 全珠光体

3500 years ago, man made iron was created and accompanies us until now. Today's steels are distinctively different with those of decades ago. What shall we do in the future?