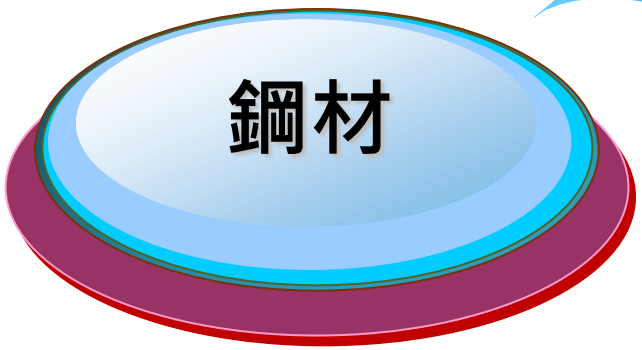
KUANG TAI

新一代船舶用銲接技術與銲接材料

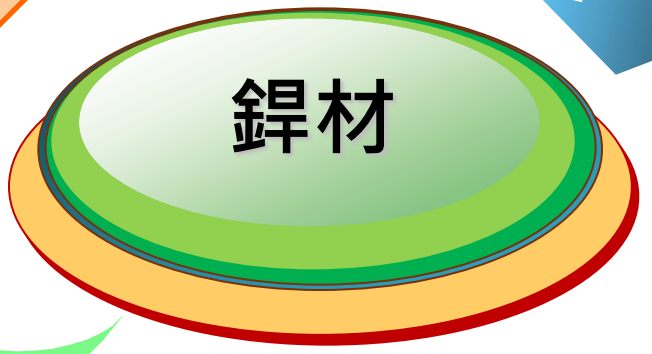
張家銘博士
廣泰金屬公司研發課長

鋼材與銲接材料的關係



- 做為銲接的母材
- 提供盤圓製作SMAW、GMAW及GTAW銲材
- 提供鋼帶製作FCAW銲材

冶金原理
材料特性



- 使鋼材經銲接後成為結構材料擴大應用範圍
- 覆面於鋼材進行表面改質

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銲接材料的分類

SMAW

GMAW/
FCAW

SAW

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船舶種類

HIGHER STRENGTH

CORROSION RESISTANT

DUPLEX

stainless steel

CHEMICAL TANKERS

USED WELDING PROCESSES

SMAW • GMAW • FCAW • SAW

HIGH STRENGTH

tempered steels

SUBMARINE VESSELS

USED WELDING PROCESSES

SMAW • GMAW • FCAW • SAW

-163°C methane

CRYOGENIC STEELS

LIQUID GAS CARRIERS

USED WELDING PROCESSES

SMAW • GTAW • GMAW • FCAW • SAW

Good impact toughness

LIGHT WEIGHT

corrosion resistant

ALUMINIUM BOATS

USED WELDING PROCESSES

GTAW • GMAW

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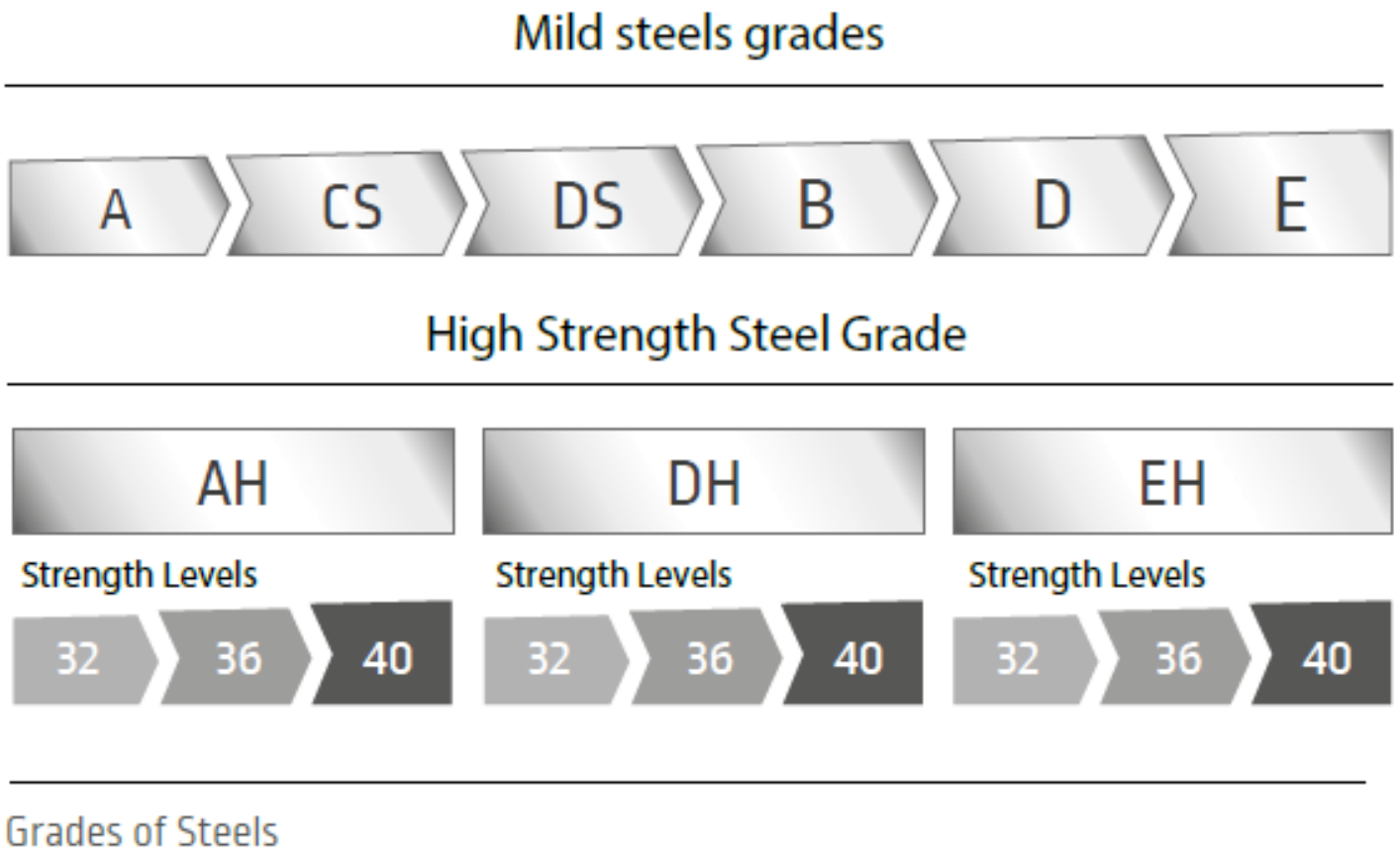
船舶用鋼



MILD STEEL CE	HIGH STRENGTH STEEL CE
C [%] + (Mn [%] / 6)	C + (Mn / 6) + (Cr + Mo + V) / 5 + (Ni + Cu) / 15

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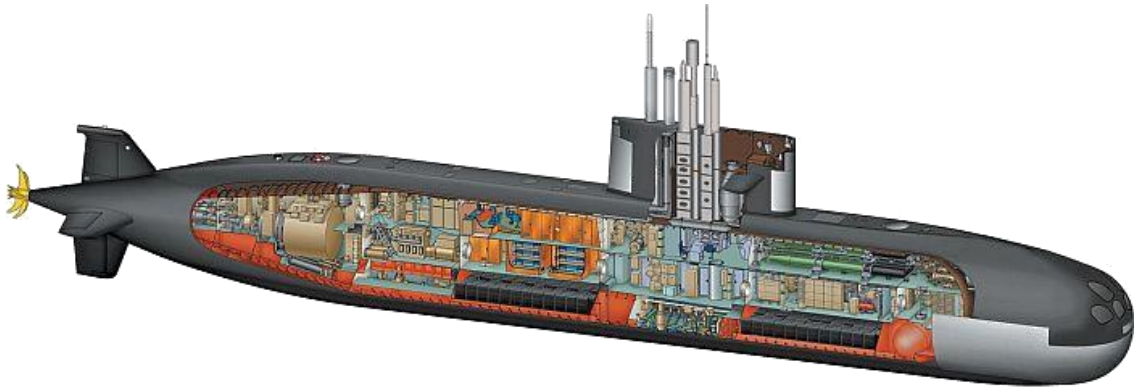
船艦種類

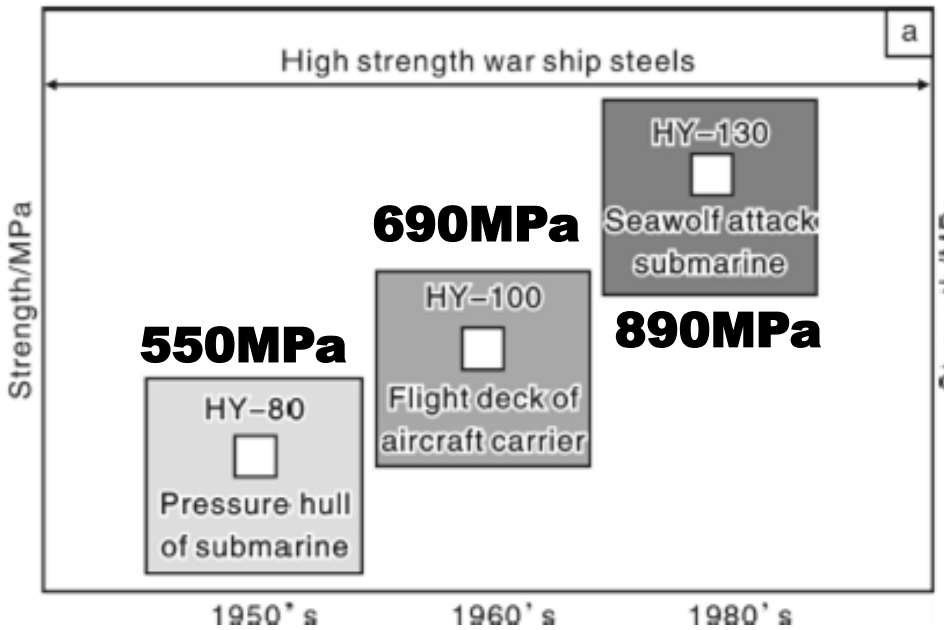
- 水面艦
- 航空母艦
- 潛艦

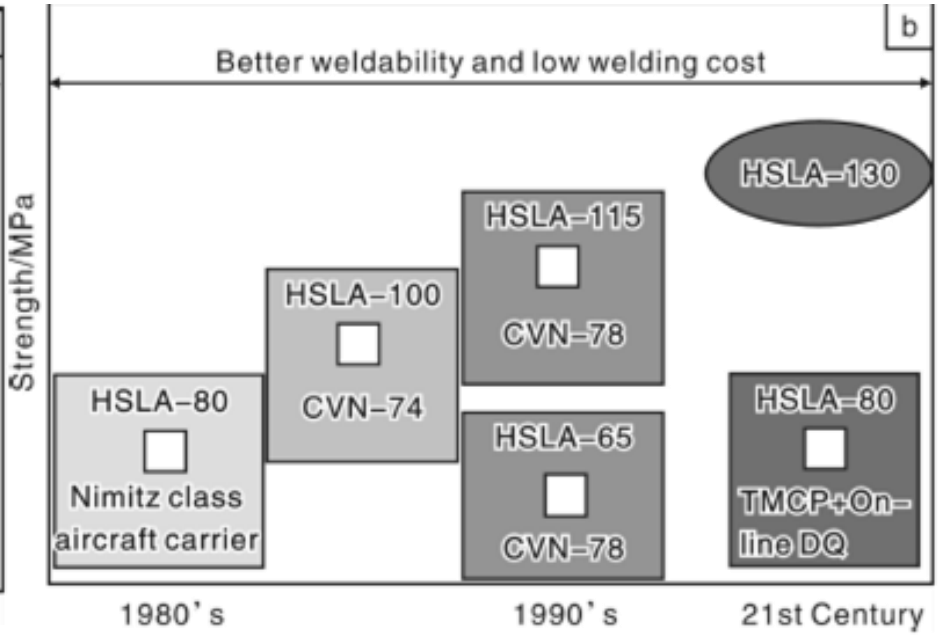
潛艦用低合金高強度高韌性鋼

- 美國
  - HY-80 & HSLA-80
  - HY-100 & HSLA-100
  - HY-130
- 日本
  - NS 46
  - NS 63
  - NS 80
  - NS 90
  - NS 110



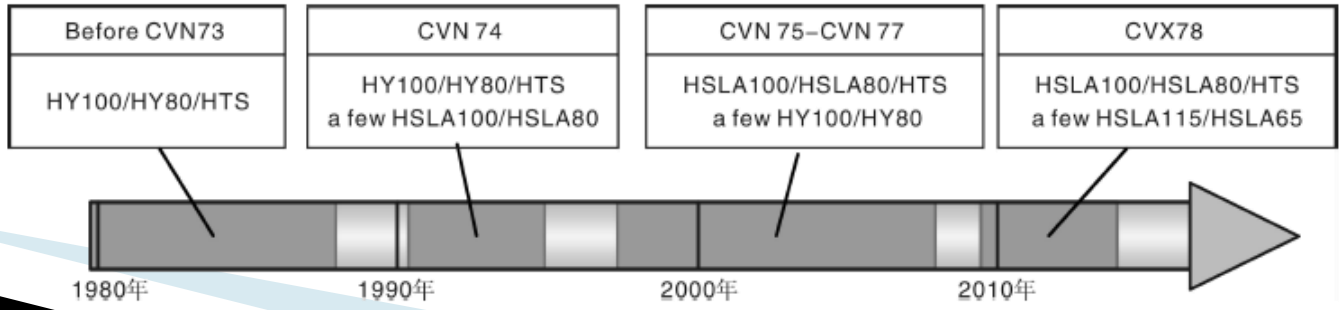
美國船艦用鋼發展





鎳鉻鉬系的淬火回火

銅析出硬化+DQ



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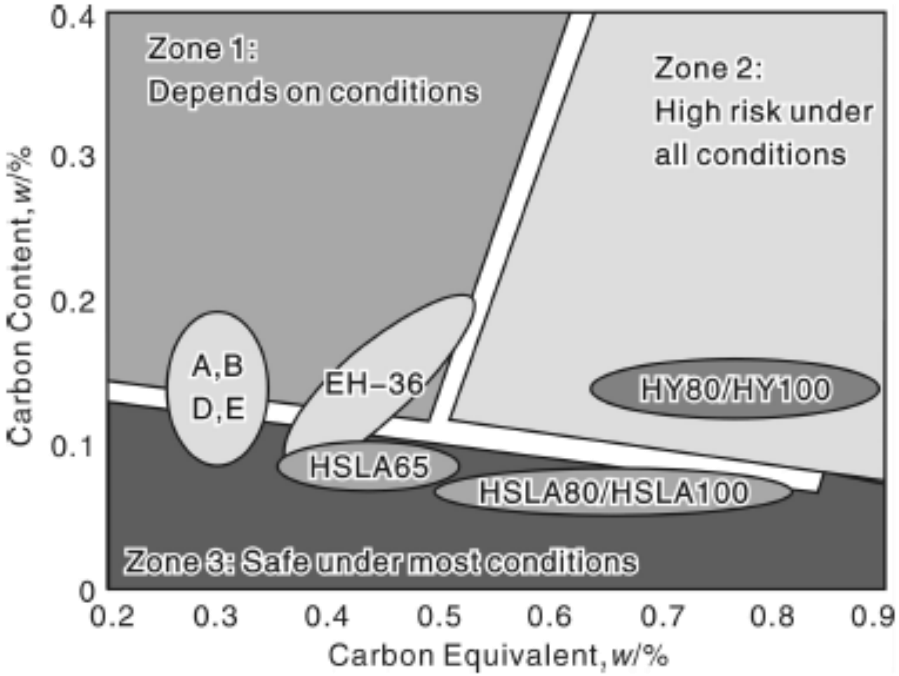
HY-80 VS HLSA-80

- Cost
  - Alloy (Ni 、Cr 、Mo) ↓
  - Save 2000~3000 USD/ ton

- Weldability
  - C_E ↓
  - Preheat temperature ↓
  - Interpass temperature ↓



HIGH STRENGTH STEEL CE

$C + (Mn/6) + (Cr + Mo + V)/5 + (Ni + Cu)/15$

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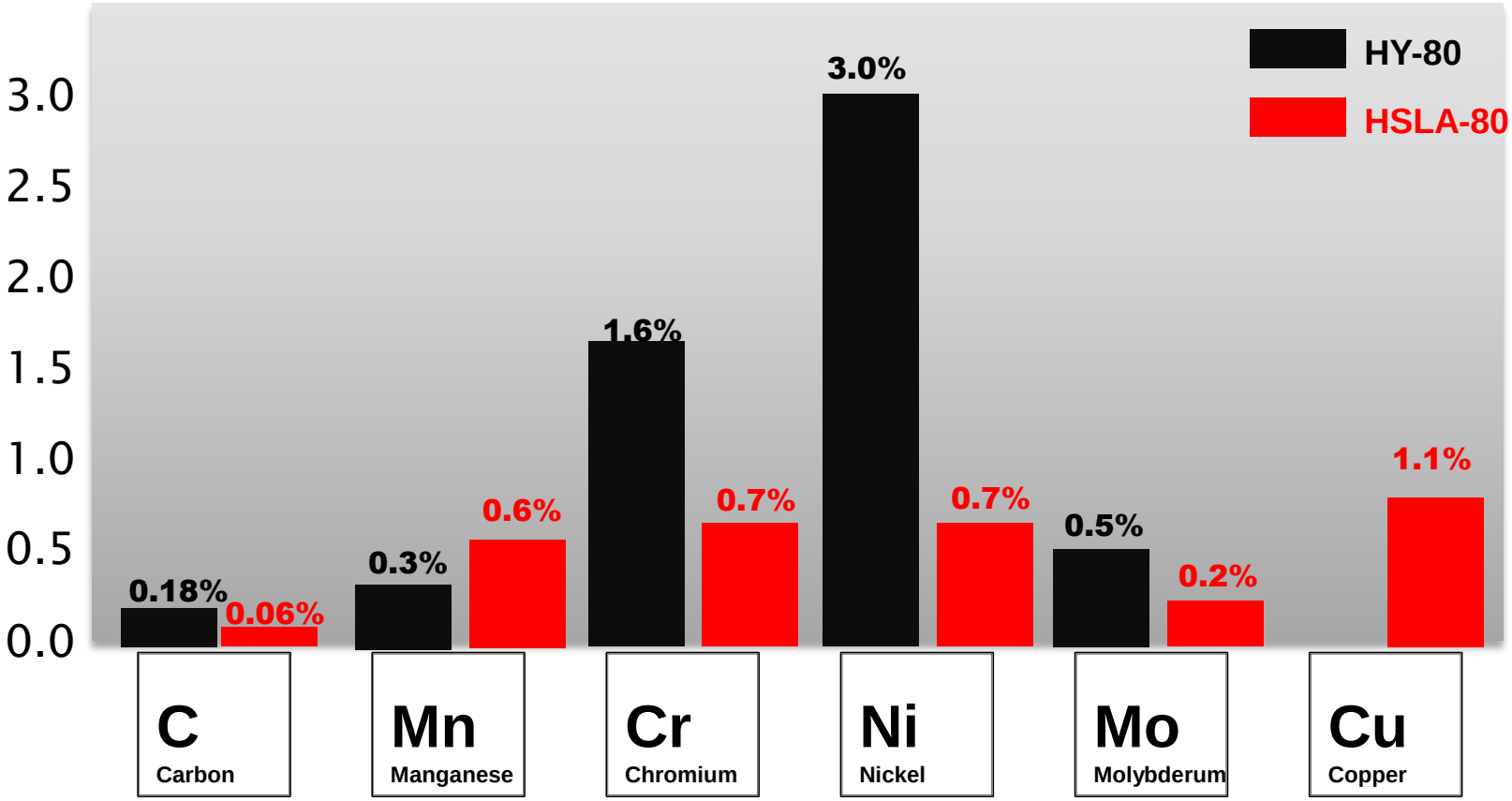
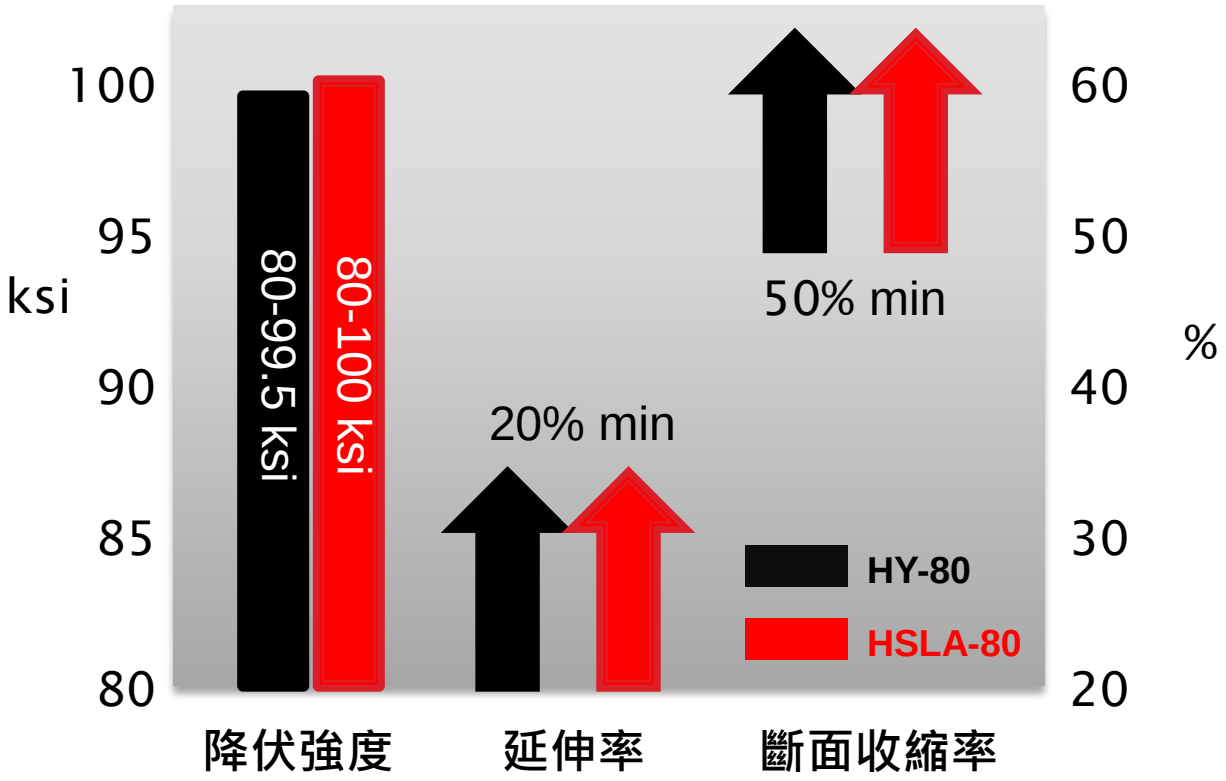
HY&HLSA-成份比較



SUBMARINE VESSELS

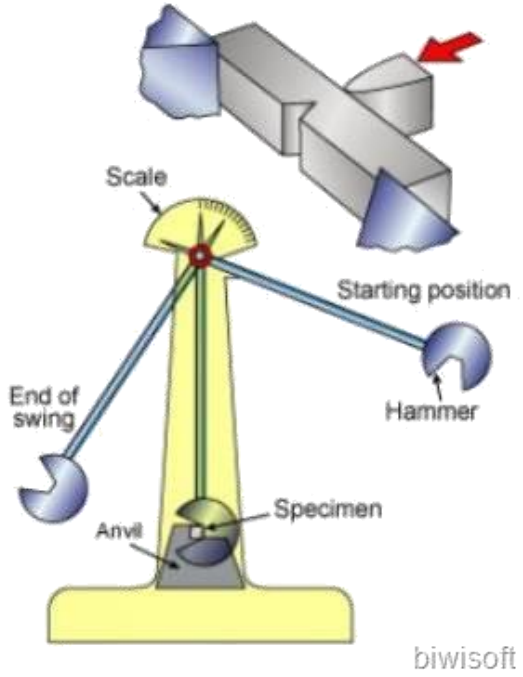
HY&HLSA-物性比較

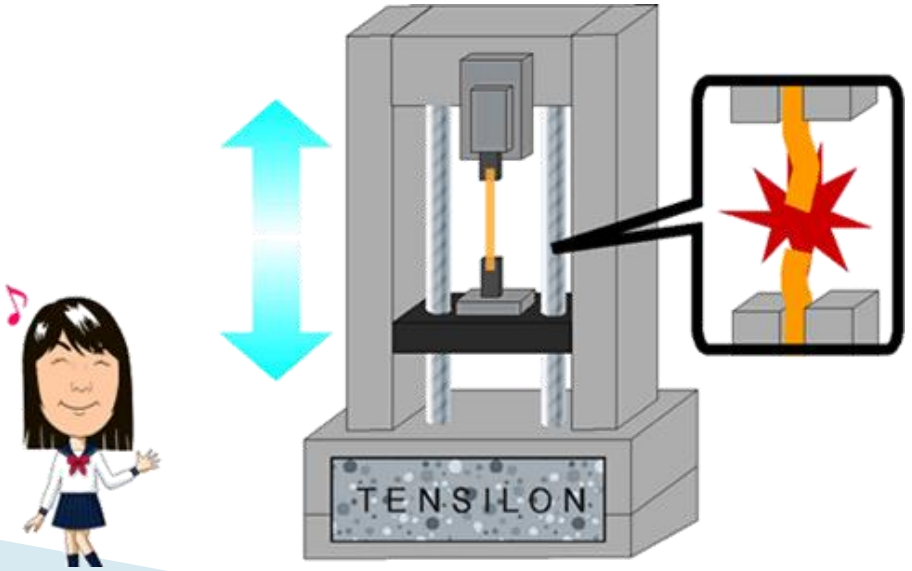


低溫衝擊值	-18°C	-84°C
HY-80	65J	47J
HSLA-80	-	65J

船艦用鋼要求

- **高強度**
  - 降伏強度: 550~1100MPa
- **高韌性**
  - 低溫韌性: 47J min
  - 韌脆轉換溫度





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船艦用鋼要求

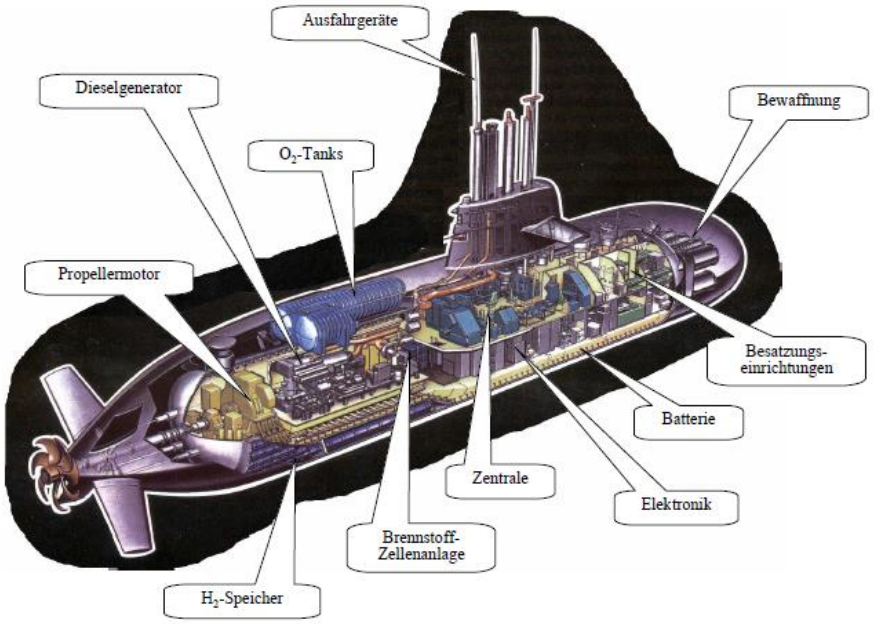
- 爆炸試驗

潛艦用銲材

Welding Consumable specification:

T9074-BC-GIB-010/0200

FILLER MATERIALS FOR CRITICAL APPLICATIONS:
REQUIREMENTS FOR FLUX-CORED WELDING ELECTRODES, BARE WELDING ELECTRODES AND FLUXES, AND COVERED WELDING ELECTRODES FOR LOW-ALLOY STEEL APPLICATIONS



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測試項目

Table III. Summary of weld metal tests required for qualification. 1/

Test	Schedule		Test procedures	Requirements
	A	B 2/, 6/		
Chemical analysis	X	---	AWS A5.29 and Main Body 4.8	Table I herein
Alloy identity	X	---	AWS A5.01	Main Body 3.8
Diffusible hydrogen 5/	X	---	AWS A4.3	A.3.1.3 and A.3.1.4 herein
Welded test assembly	X	X	AWS A5.29 and A.4.4.1 herein	AWS A5.29
Nondestructive testing	X	X	Main Body 4.5.1 and 4.5.2	Main Body 3.7.1 and 3.7.2
Visual and Dimensional Examination	X	X	Main Body 4.4.2	A.3.1.5
Tension	X	X	AWS B4.0	Table II herein
Transverse side bend	X	X	AWS B4.0	Table II herein
Charpy V-notch 3/	X	X	AWS B4.0	Table II herein
Dynamic tear 3/	X	X	AWS B4.0	Table II herein
Explosion test series 4/	---	X	A.4.4.2 herein	Table II herein

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SMAW-APPEDIX C

- *SMAW-Chemical Composition*

Element	MIL-10018-M1	MIL-10718-M	MIL-12018-M2
Carbon	0.06	0.07	0.07
Manganese	0.80 - 1.85	0.80 - 1.85	0.80 - 1.85
Silicon	0.65	0.60	0.65
Phosphorus	0.025	0.025	0.025
Sulfur	0.017	0.017	0.012
Chromium	0.40 4/	0.40 4/	0.65
Nickel	1.25 - 3.00	1.25 - 2.50	1.50 - 4.00
Molybdenum	0.50	0.25 - 0.50	0.90
Vanadium	0.05	0.05	0.05
Copper	2/	2/, 3/	2/, 3/
Boron	---	3/	3/

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FCAW-APPEDIX A

- *FCAW-Chemical Composition& Mechanical Properties*

MIL-type 1/	Chemical composition (wt. percent) 2/ 3/									
	Carbon	Manganese	Silicon	Phosphorus	Sulfur	Nickel	Chromium	Molybdenum	Vanadium	Copper
MIL-101TC MIL-101TM	0.07	0.50 to 1.50	0.60	0.015	0.015	1.30 to 3.75	0.20	0.50	0.05	0.06

MIL-type	101TC 101TM
Yield strength (1000 pounds per square inch) (ksi) 2/	82 to 110
Elongation in 2 inches min. (percent)	18
Transverse side bend	3/
Charpy V-notch. Energy ft-lb minimum average @ Temperature (degrees Fahrenheit) (F) 4/	35@(-60F) 60@(0F)
Dynamic tear. Energy ft-lb minimum average @ Temperature (degrees Fahrenheit) (F)	300@(-20F) 5/ 450 @(+30F) 6/
Explosion crack starter test	7/

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GMAW&SAW-APPEDIX B

- *GMAW & SAW-Chemical Composition*

Welding process	ALL	GMAW SAW	ALL	GMAW SAW
Type 2/	100S-1 100S-2	100S-1C 100S-2C	120S-1 120S-2	120S-1C 120S-2C
Chemical composition (weight percent) 1/				
Carbon	0.07 3/	0.07 3/	0.070 3/, 4/	0.070 3/, 4/
Manganese	1.25-1.8	1.25-2.5	0.90-2.35	1.4-3.8
Silicon	0.20-0.55	0.20-0.55	0.60	0.20-0.55
Phosphorus	0.012	0.012	0.012	0.012
Sulfur	0.008	0.010	0.008	0.010
Nickel	1.40-2.10	1.40-2.10	1.00-3.0	1.00-3.5
Molybdenum	0.25-0.55	0.25-0.55	0.30-1.00	0.30-1.10
Chromium	0.30 8/	0.30 8/	0.80	0.60
Vanadium	0.05	0.04	0.03	0.04
Aluminum	0.10	0.05	0.10	0.05
Titanium	0.10	0.10	0.10	0.10
Zirconium	0.10	0.10	0.10	0.10
Copper	5/, 6/, 7/	5/, 6/, 7/	5/, 6/, 7/	5/, 6/, 7/
Boron	7/	7/	7/	7/

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GMAW&SAW-APPEDIX B

- *GMAW & SAW-Mechanic Properties*

Type 2/	100S-1 100S-1F 100S-2 100S-2F	120S-1 120S-1F 120S-2 120S-2F
Yield Strength (1000 pounds per square inch) (ksi)	82 to 120 3/, 12/	102 to 123 3/, 4/, 12/
Elongation in 2 inches min. (percent)	16	15
Transverse side bend	5/	5/
Charpy V-notch. Energy ft-lb min. average @ Temperature (degrees Fahrenheit) (F)	35@(-60F) 6/ 60@(0F) 6/	45@(-60F) 6/, 7/ 60@(0F) 6/
Dynamic tear. Energy ft-lb minimum average @ Temperature (degrees Fahrenheit) (F)	300@(-20F) 8/, 9/ 450@(+30F) 9/, 10/	400@(-20F) 8/, 9/ 575@(+30F) 9/, 10/
Explosion test series	11/	11/

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SMAW-APPEDIX C

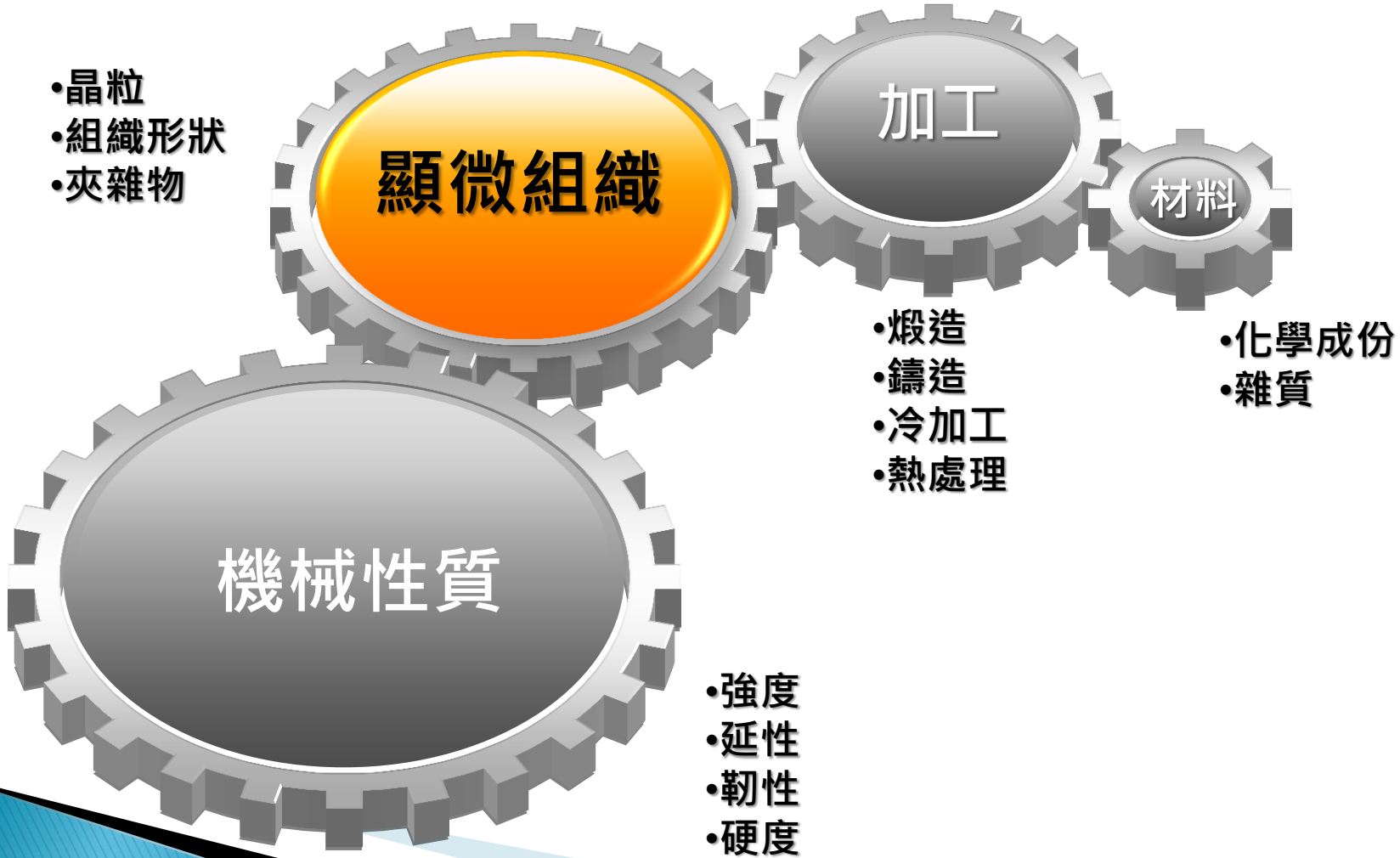
- *SMAW-Mechanical Properties*

Property	Condition	MIL-10018-M1	MIL-10718-M	MIL-12018-M2
Yield strength (ksi)	As-welded	82 - 110 2/	88 - 122 2/, 12/	102 - 123 2/, 3/
	Stress relieved	80	86	----
Ultimate tensile strength (ksi)		4/	4/	4/
Elongation in 2 inches (percent)	As-welded	20 5/	20 5/	18 5/
	Stress relieved	20	20	----
Transverse side bend		6/	6/	6/
Charpy V-notch 8/ Energy ft-lb average @ Temperature (F)	As-welded	35@(-60F) 60@(0F)	35@(-60F) 60@(0F)	45@(-60F) 8/ 60@(0F)
	Stress relieved	20@(-60F) 50@(0F)	20@(-60F) 50@(0F)	----
Dynamic tear, Energy ft-lb average @ Temperature (F) 9/, 10/	As-welded	300@(-20F) 450@(30F)	300@(-20F) 450@(30F)	400@(-20F) 575@(30F)
Explosion test series		11/	11/	11/

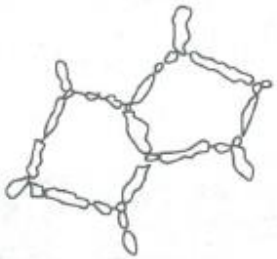
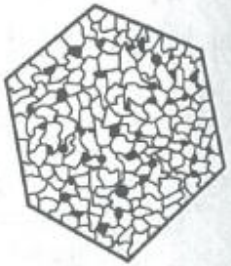
銲接材料設計

- 高強度
  - 合金設計　C、Mn、Si、Cr、Ni、Mo
- 高韌性
  - 合金化
  - Ti/B韌化
  - 控制有害元素:H、O、N
- 低擴散氫
  - 低水素原料
  - 除氫機制

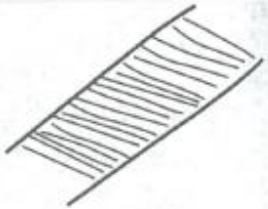
材料性質關聯



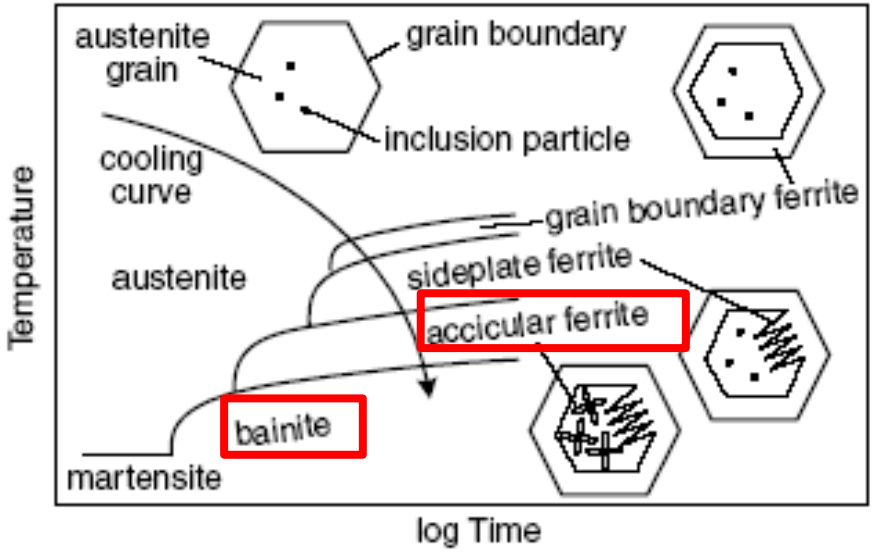
碳鋼與低合金鋼組織

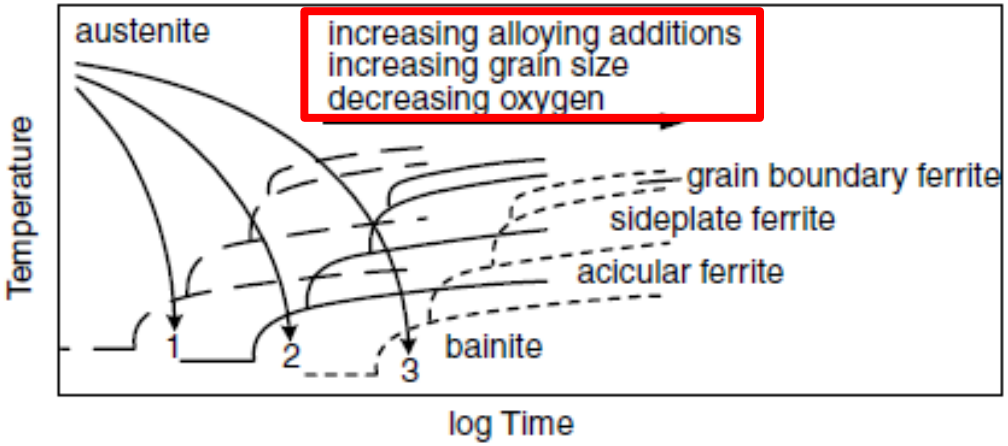
铁素体(F)	先共析铁素体(GBF)	侧板条铁素体(FSP)	针状铁素体(AF)	细晶铁素体(FGF)
				
珠光体(P)	片层珠光体(P_L)	索氏体(P_S)	托氏体(P_T)	
	 片层间距>0.3μm	 片层间距0.1～0.3μm	 片层间距<0.1μm	

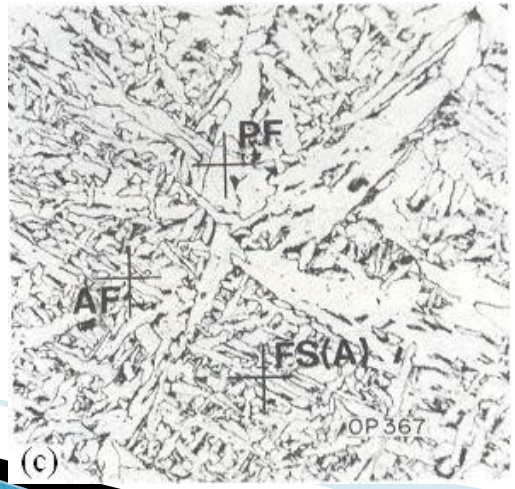
碳鋼與低合金鋼組織

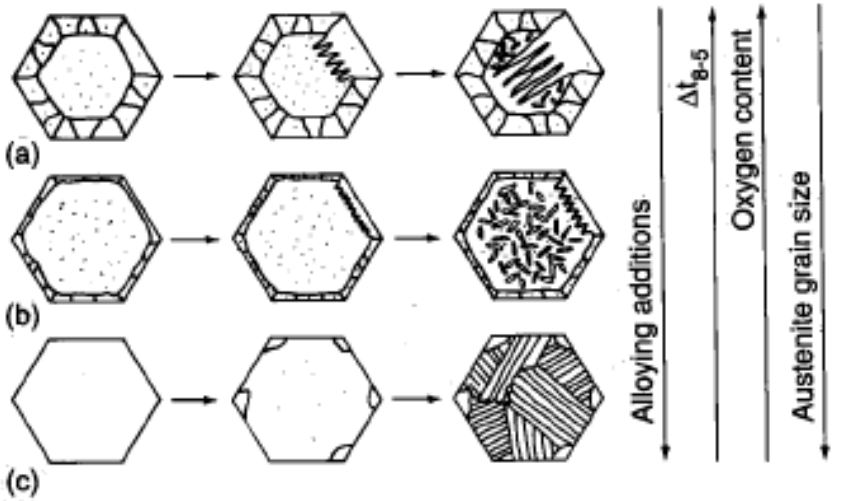
贝氏体(B)	上贝氏体(B_u)		下贝氏体(B_L)		粒状贝氏体(B_g)	条状贝氏体(B_p)
	组织形态	显微结构	组织形态	显微结构		
						
马氏体(M)	板条马氏体(M_D)		片状马氏体(M_T)			
	组织形态	显微结构	组织形态	显微结构		
						

組織變化因素


austenite grain
grain boundary
inclusion particle
cooling curve
grain boundary ferrite
austenite
sideplate ferrite
accicular ferrite
bainite
martensite
Temperature
log Time


austenite
increasing alloying additions
increasing grain size
decreasing oxygen
grain boundary ferrite
sideplate ferrite
acicular ferrite
bainite
1
2
3
Temperature
log Time


PF
AF
FS(A)
OP 367
(c)


(a)
(b)
(c)
Alloying additions
Δt_{8-5}
Oxygen content
Austenite grain size

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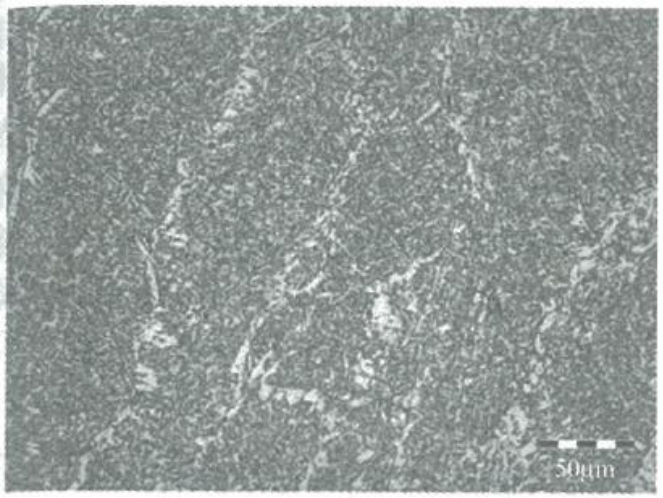
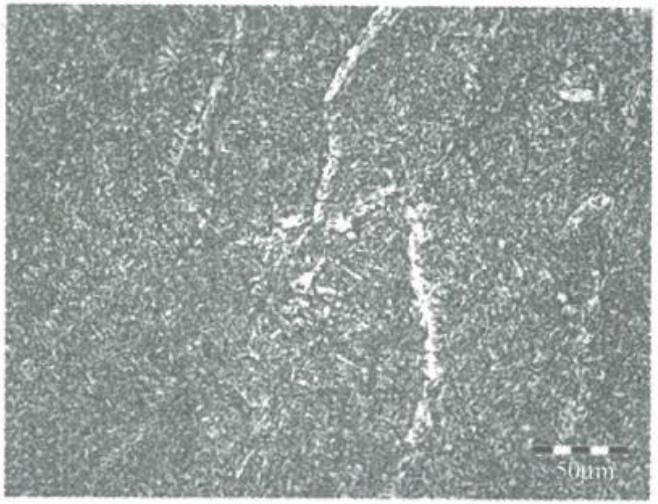
合金元素影響



a) 0.004Ti

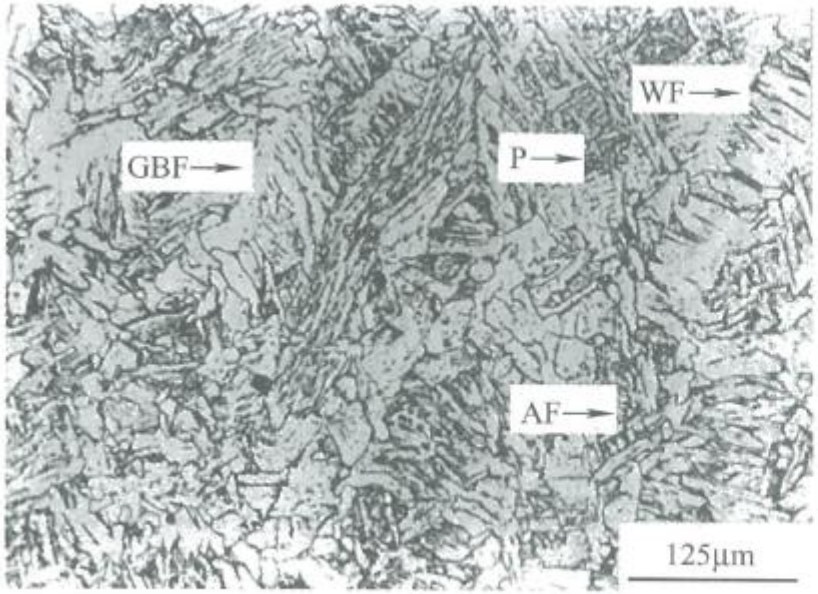


b) 0.02Ti

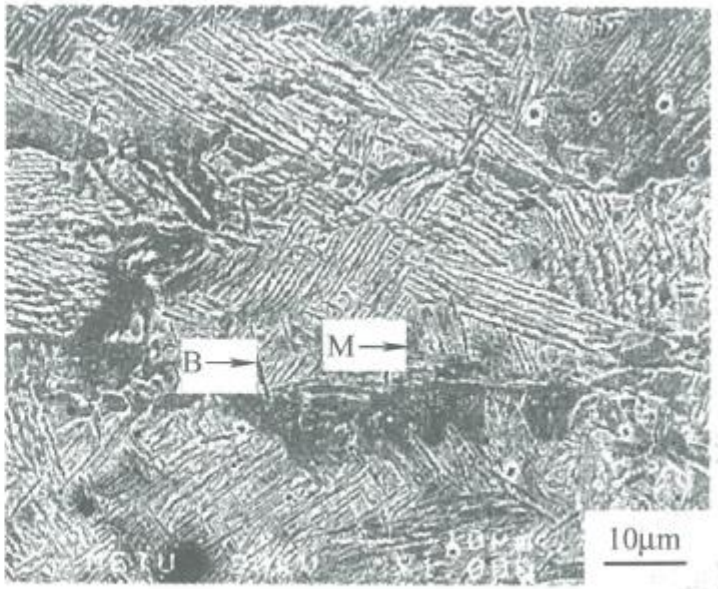
0.05Ti

0.09Ti

入熱量影響

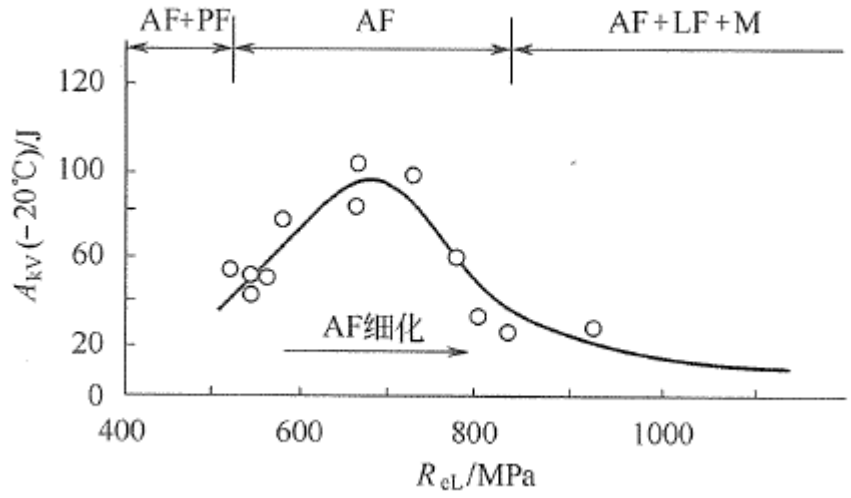


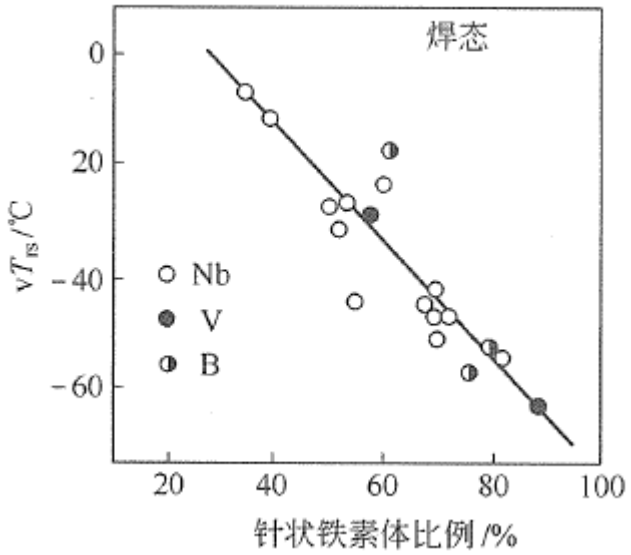
a) E=2kJ/mm

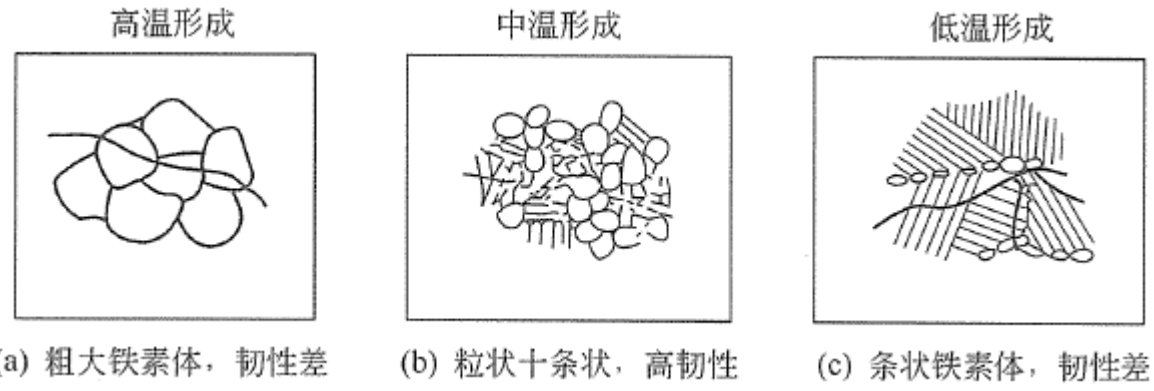


b) E=0.5kJ/mm

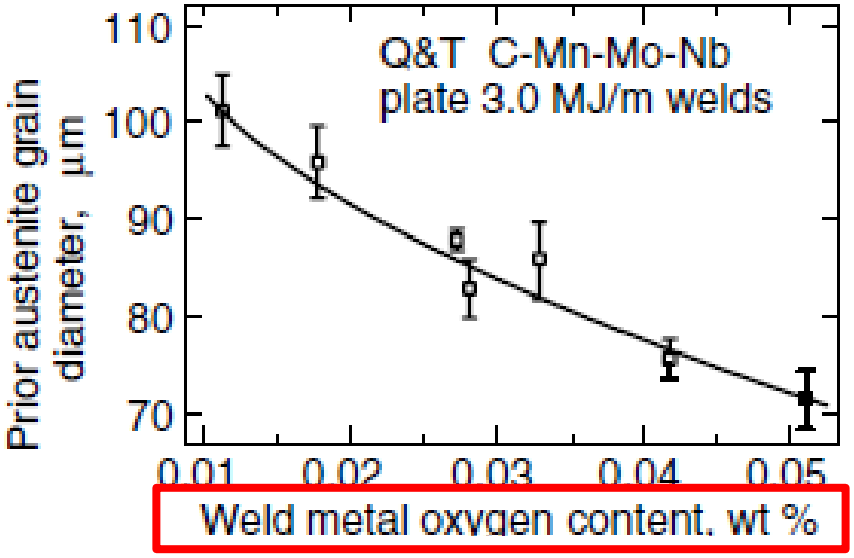
顯微組織與強度韌性關係

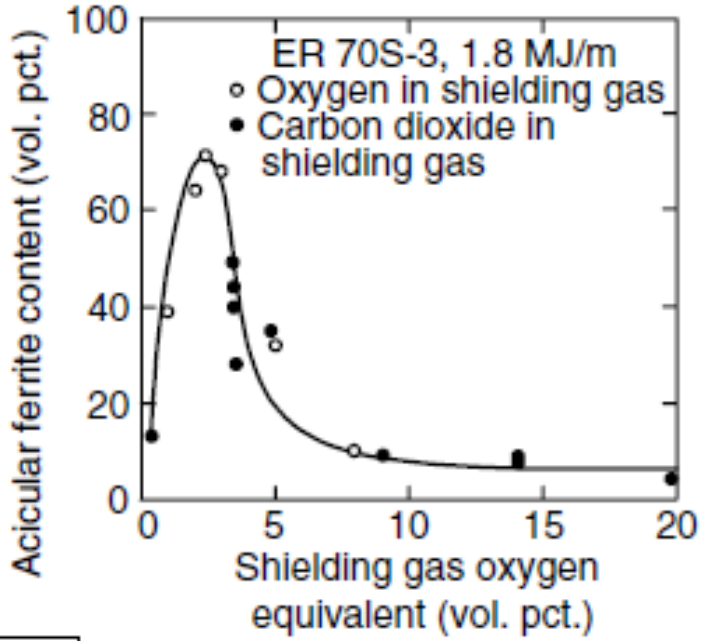


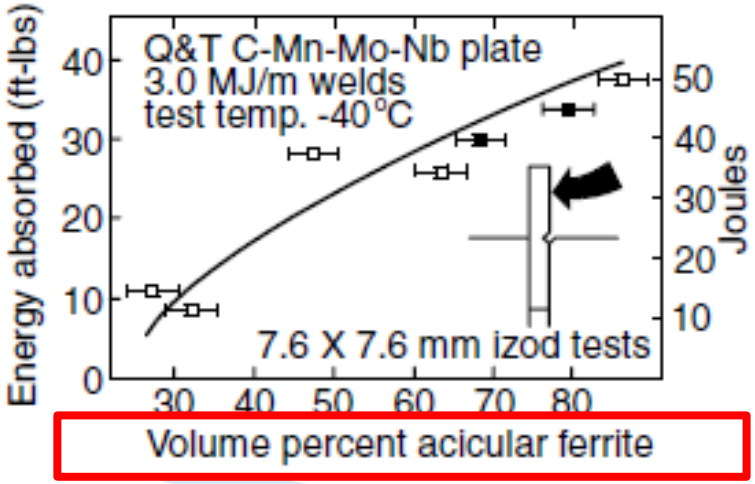




低溫衝擊韌性

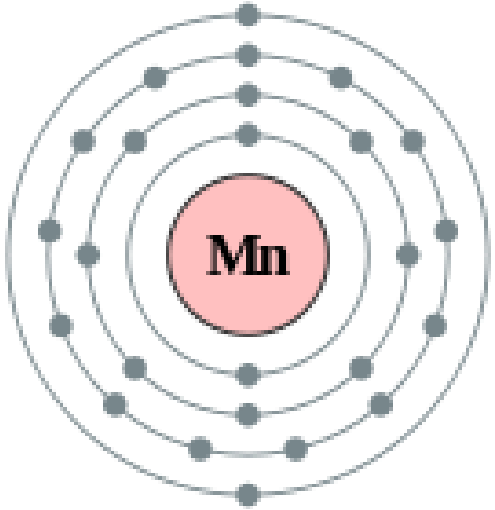






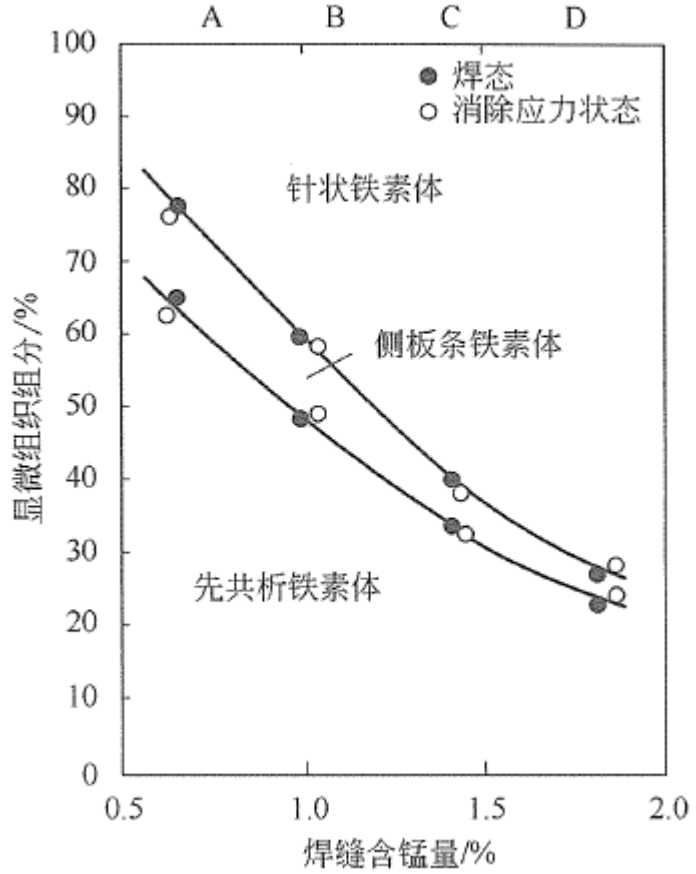
Ref: S. Kou, ... Metallurgy

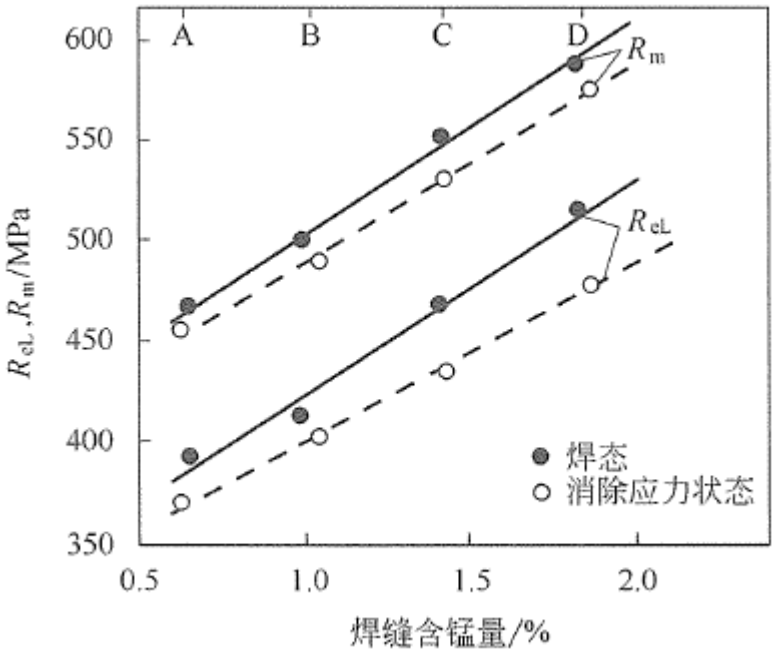
KUANG TAI



合金設計–Mn

錳元素影響–組織&強度

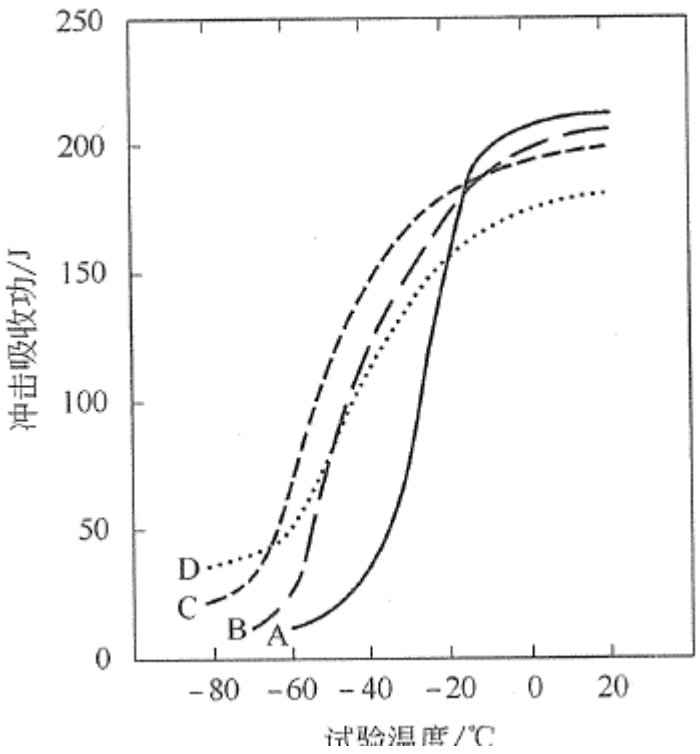


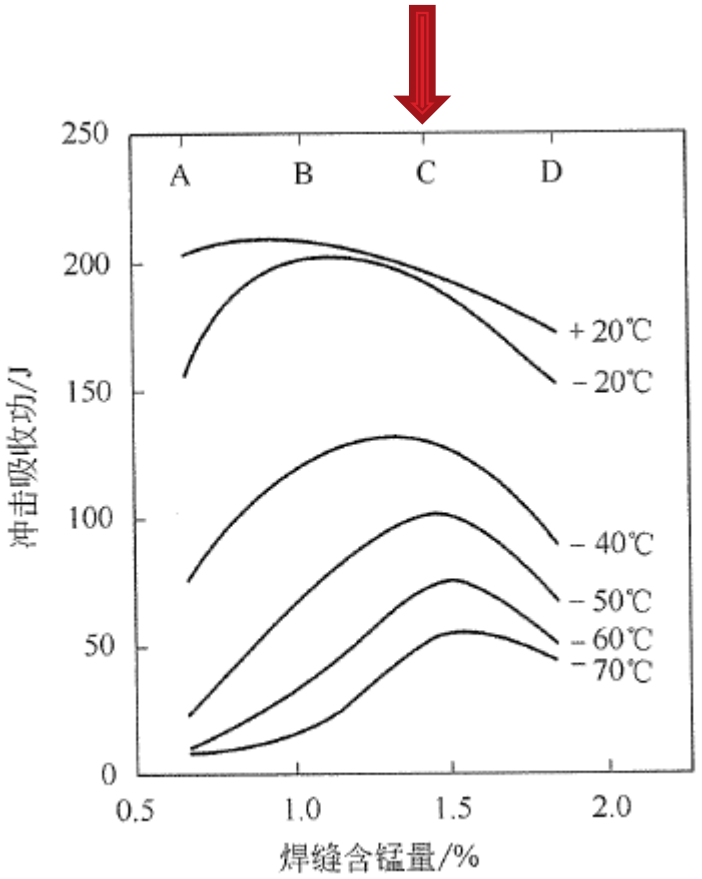


$$R_{eL} = 314 + 108w\ (\mathrm{Mn})$$

$$R_m = 394 + 108w\ (\mathrm{Mn})$$

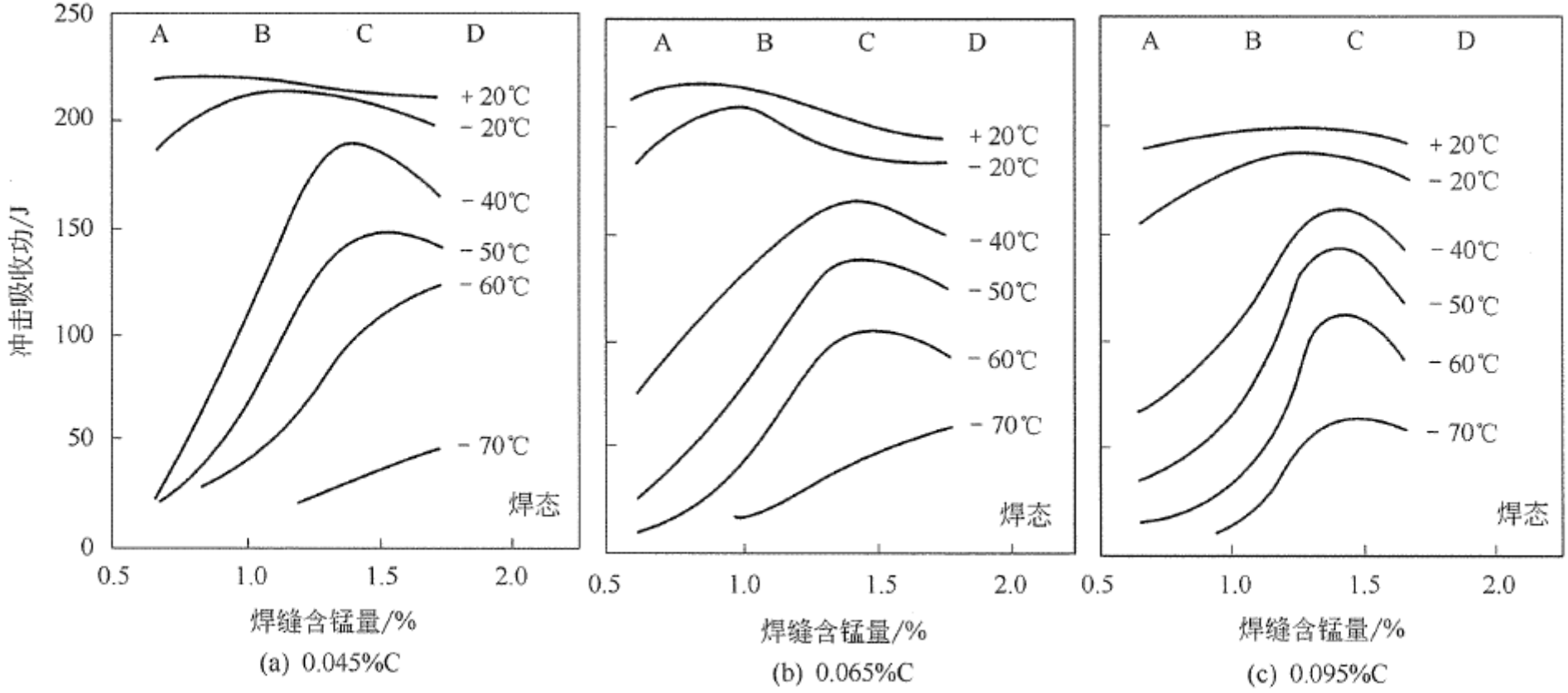
錳元素影響–低溫韌性


250
200
150
100
50
0
冲击吸收功/J
D
C
B
A
-80
-60
-40
-20
0
20
试验温度/℃


250
200
150
100
50
0
冲击吸收功/J
A
B
C
D
+20℃
-20℃
-40℃
-50℃
-60℃
-70℃
0.5
1.0
1.5
2.0
焊缝含锰量/%

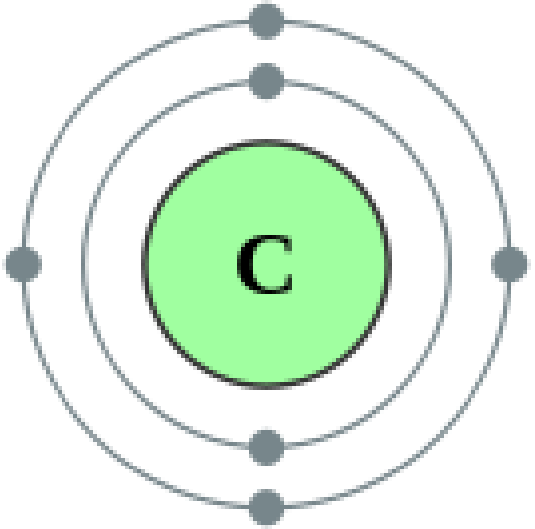
KUANG TAI

不同碳含量錳元素影響



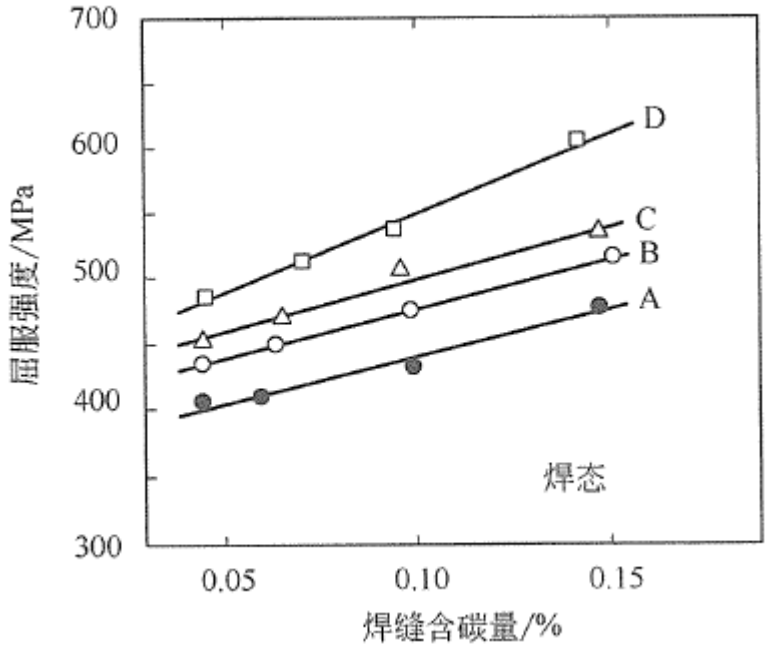
Mn設計在**1.2~1.6**之間

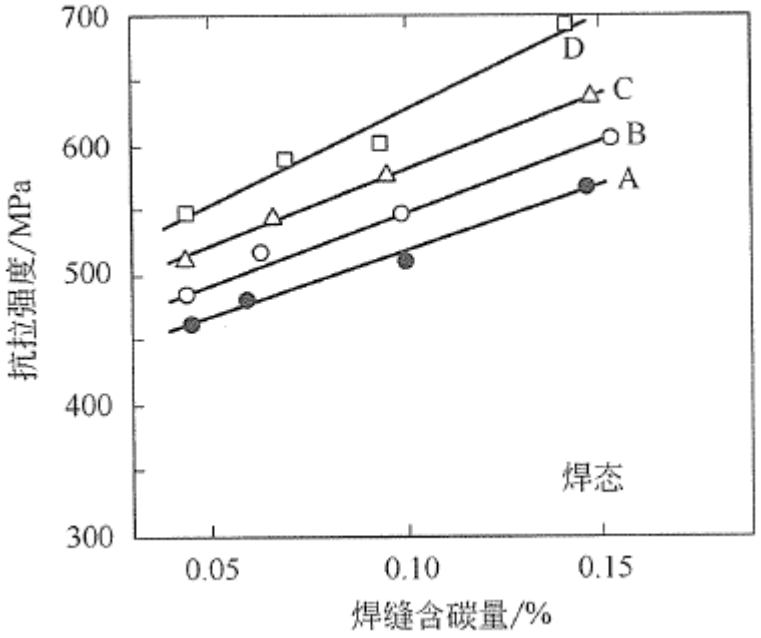
KUANG TAI



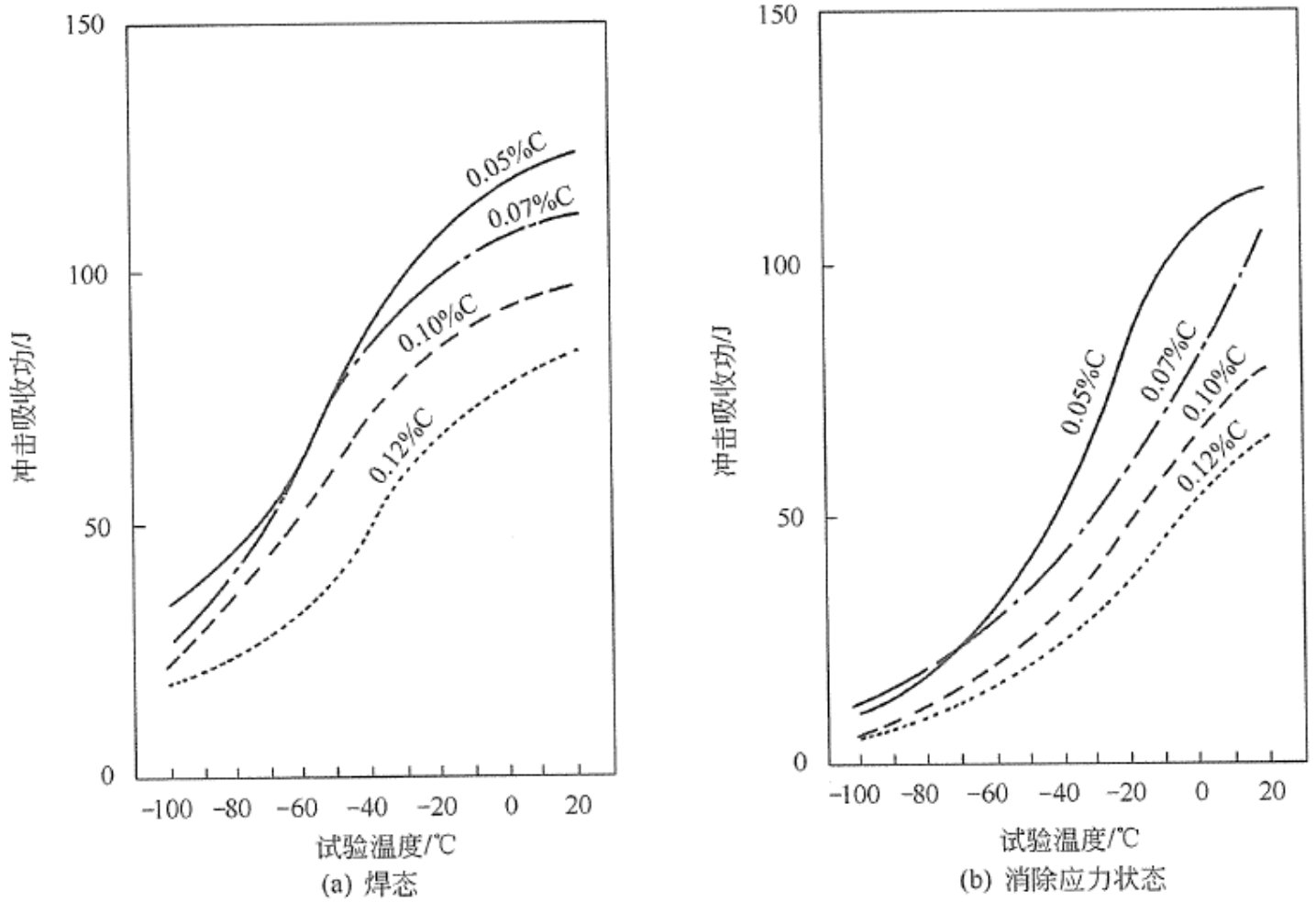
合金設計-C

碳元素影響–強度


700
600
500
400
300
屈服強度/MPa
D
C
B
A
焊态
0.05
0.10
0.15
焊縫含碳量/%

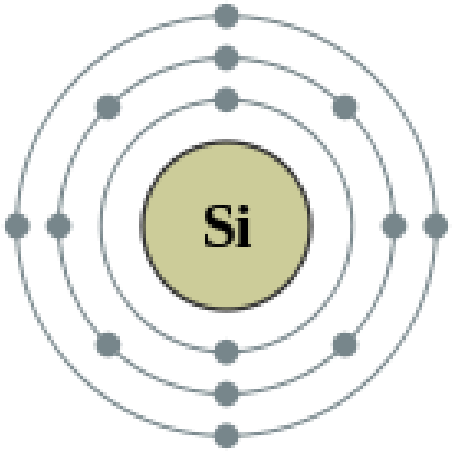

700
600
500
400
300
抗拉強度/MPa
D
C
B
A
焊态
0.05
0.10
0.15
焊縫含碳量/%

碳元素影響–低溫韌性



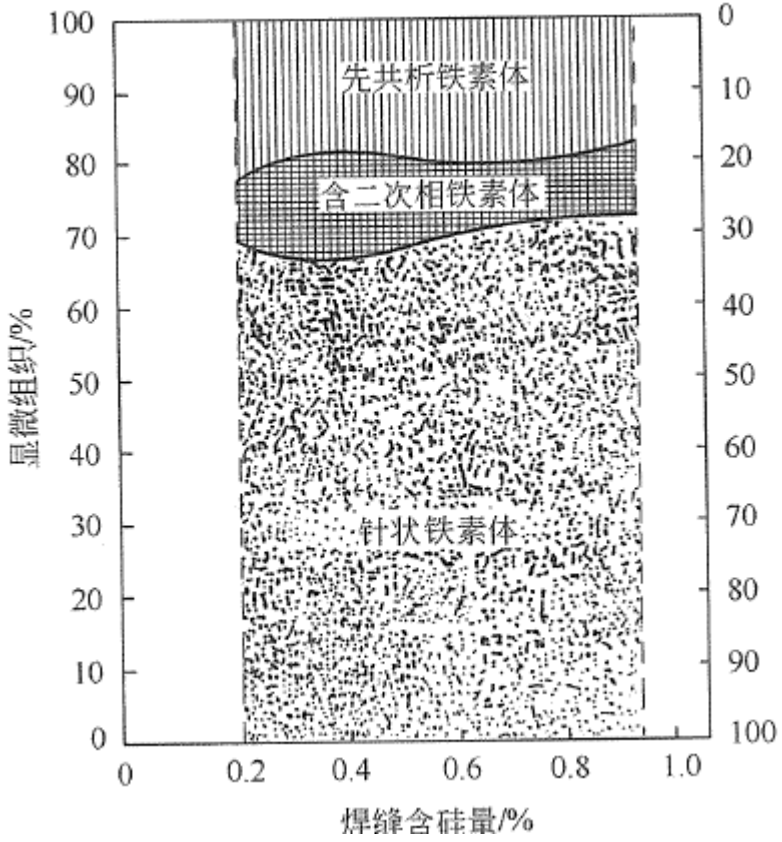
C設計在**0.06**左右

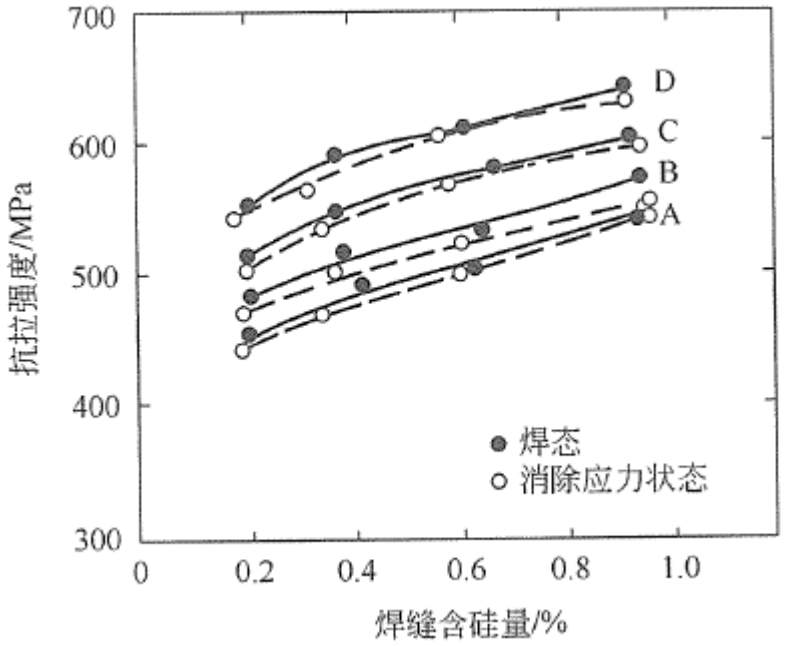
KUANG TAI



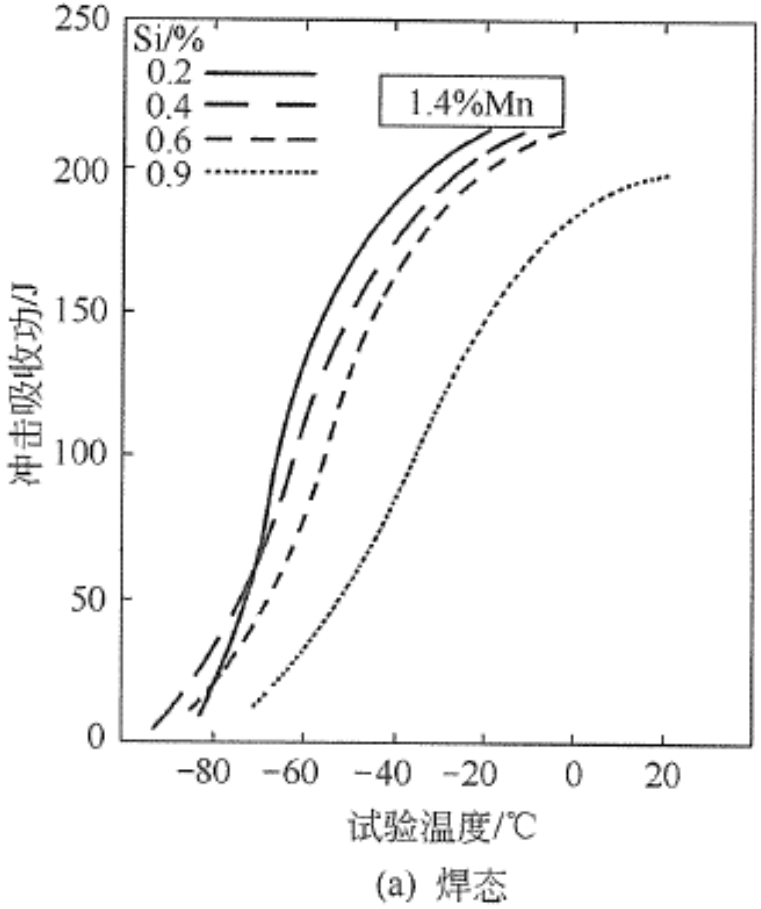
合金設計-Si

矽元素影響–組織&強度

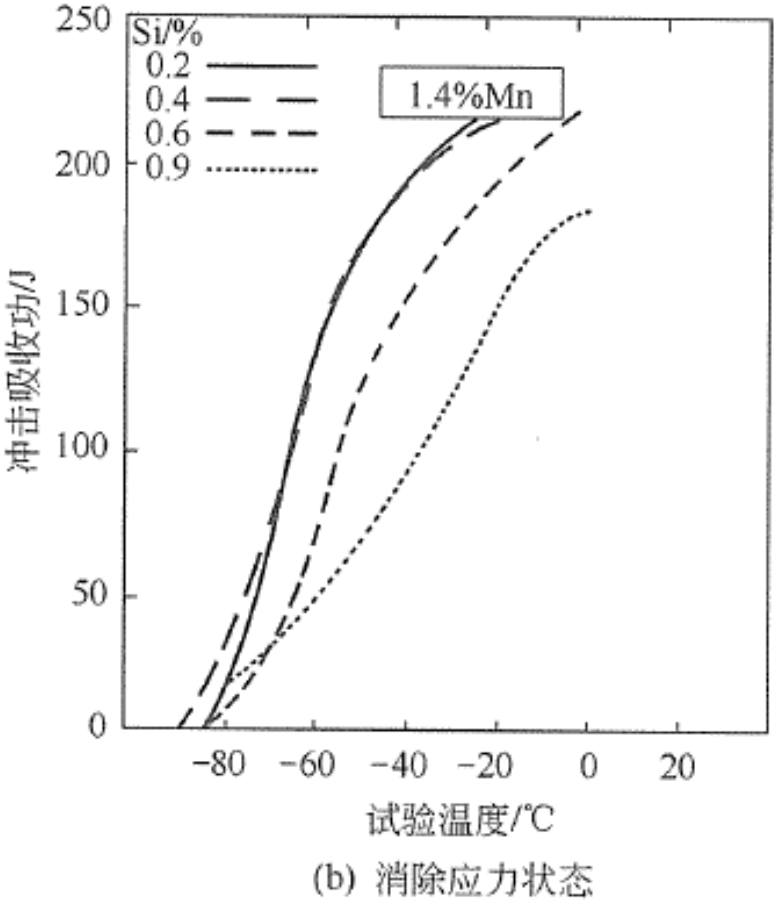

先共析铁素体
含二次相铁素体
针状铁素体
显微组织/%
焊缝含硅量/%
0
0.2
0.4
0.6
0.8
1.0
100
90
80
70
60
50
40
30
20
10
0


D
C
B
A
焊态
消除应力状态
抗拉强度/MPa
焊缝含硅量/%
700
600
500
400
300
0
0.2
0.4
0.6
0.8
1.0

矽元素影響–低溫韌性



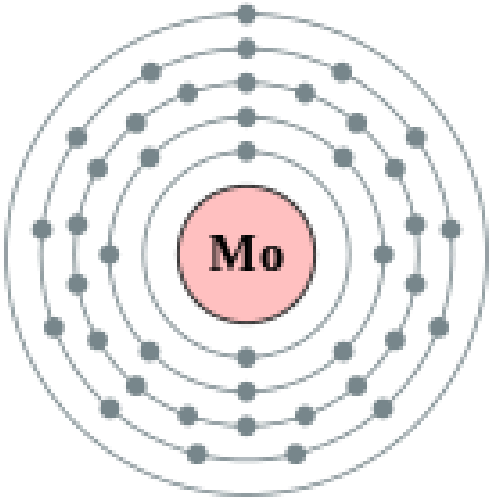
(a) 焊态



(b) 消除应力状态

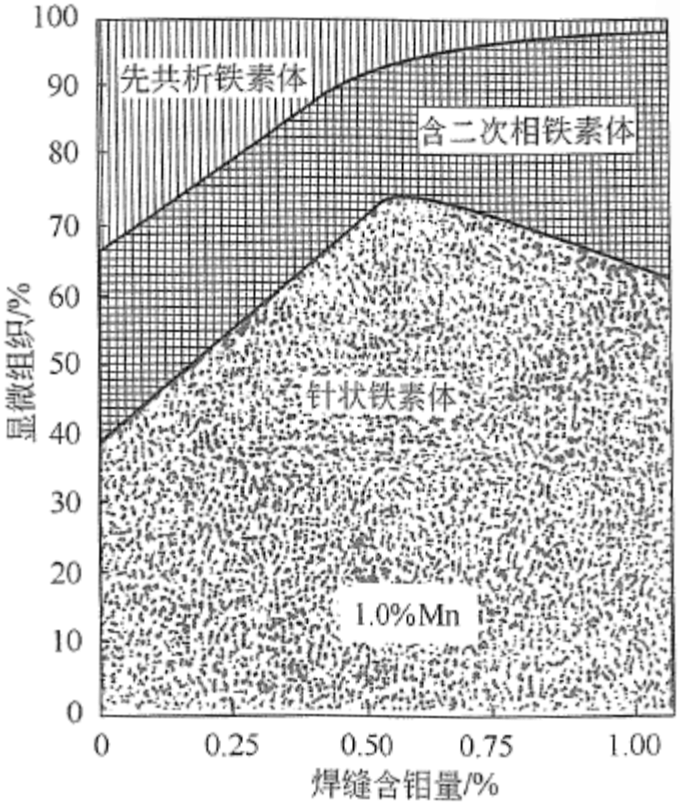
Si設計在**0.2~0.6**之間

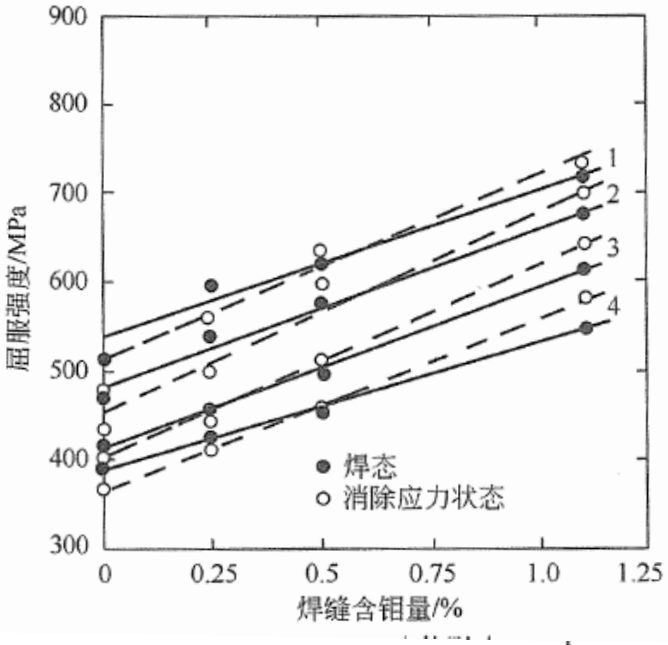
KUANG TAI

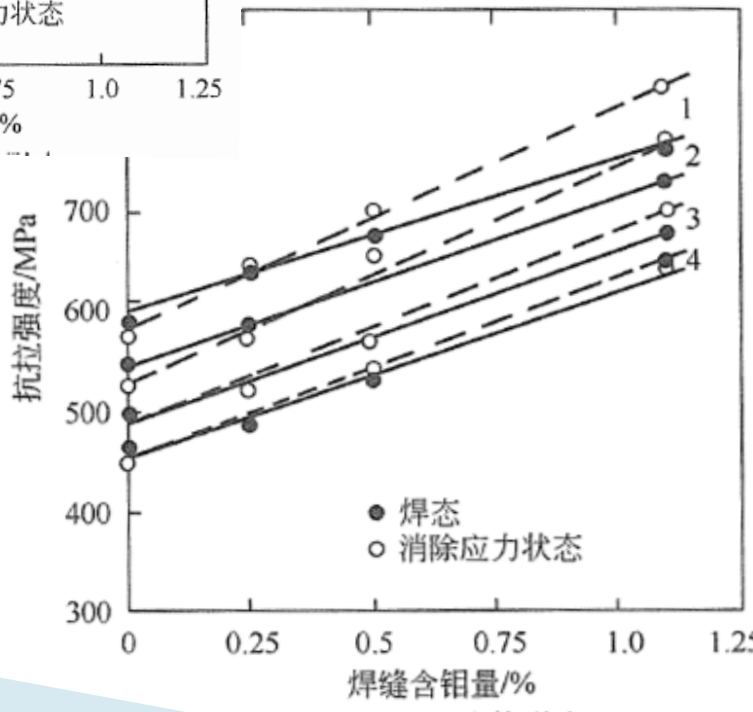


合金設計–Mo

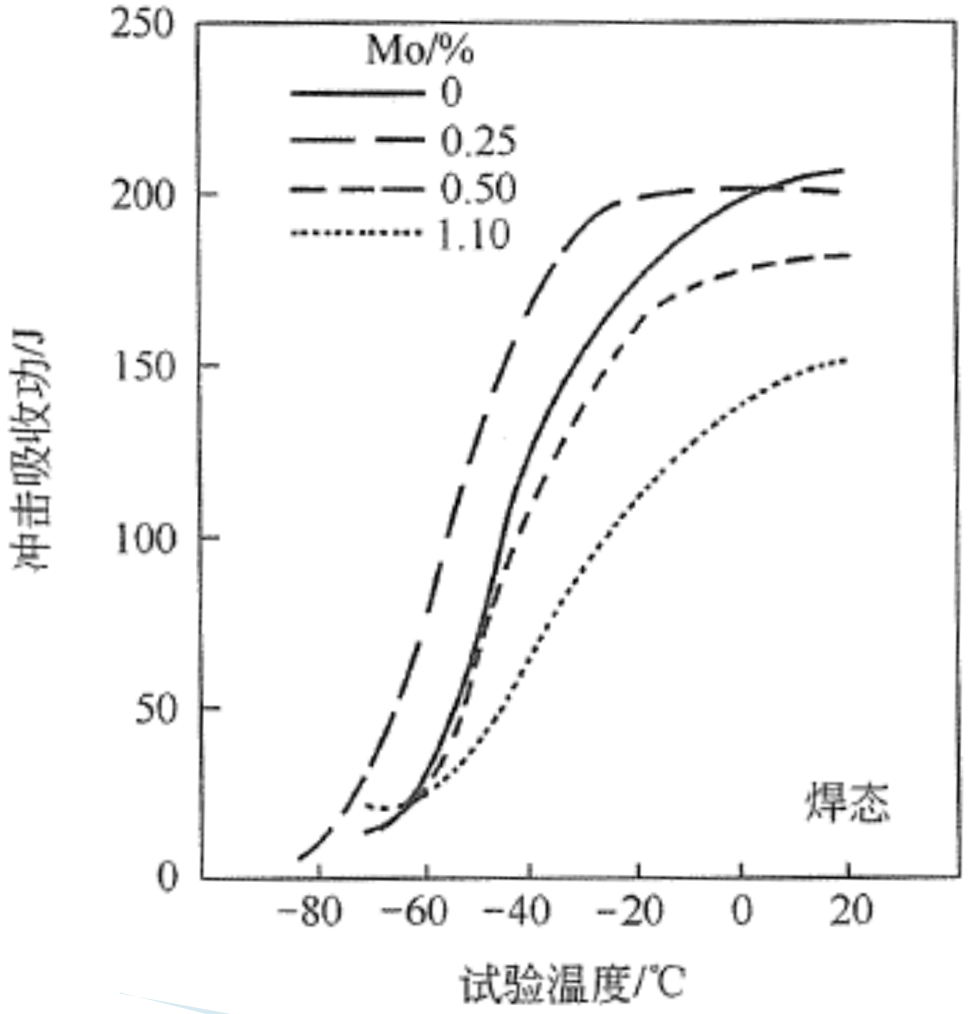
鉬元素影響–組織&強度


先共析铁素体
含二次相铁素体
针状铁素体
1.0%Mn
显微组织/%
焊缝含钼量/%


屈服强度/MPa
焊缝含钼量/%
焊态
消除应力状态


抗拉强度/MPa
焊缝含钼量/%
焊态
消除应力状态

鉬元素影響–低溫韌性

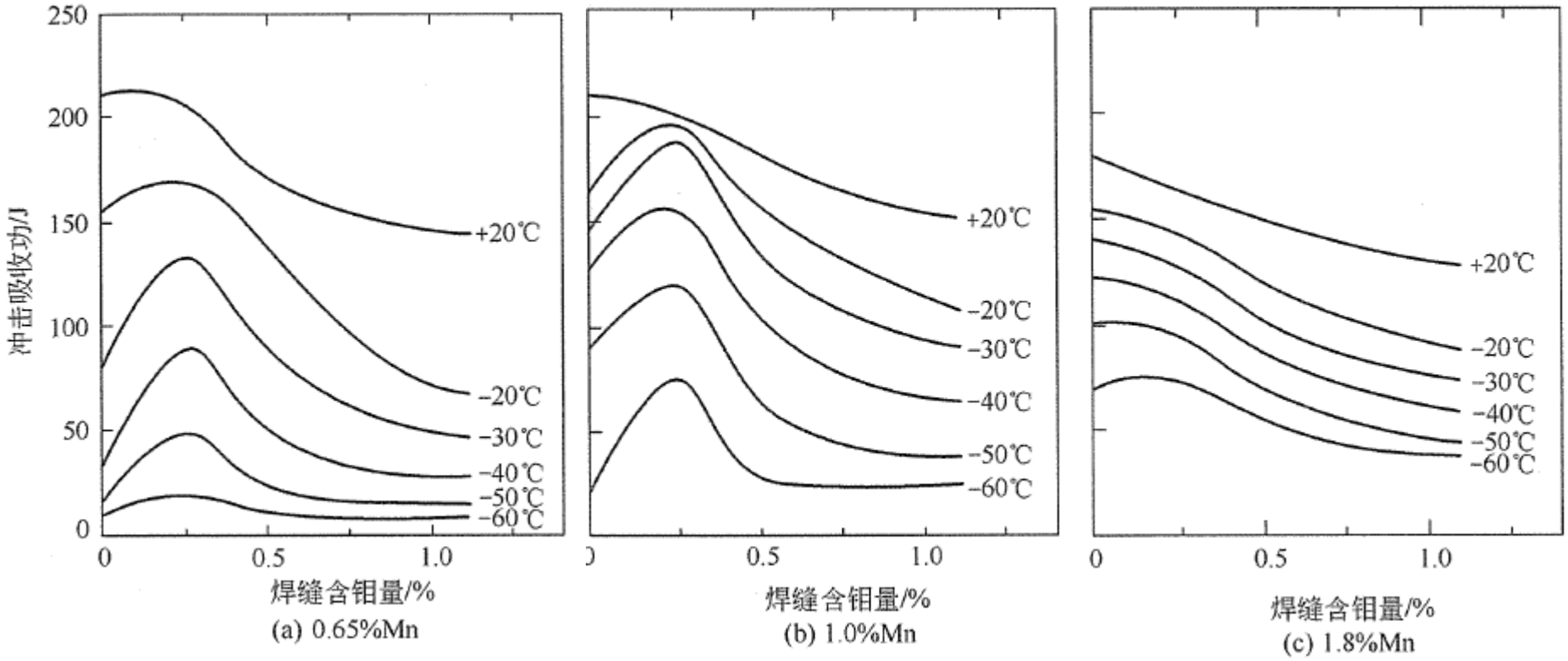


0.25%Mo韌脆轉換溫度最低

1.1%Mo韌脆轉換溫度最高

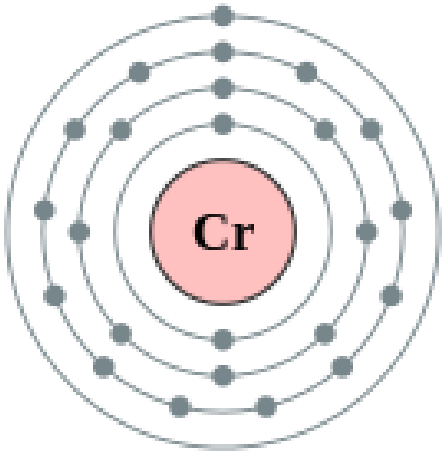
KUANG TAI

不同錳含量鉬元素影響



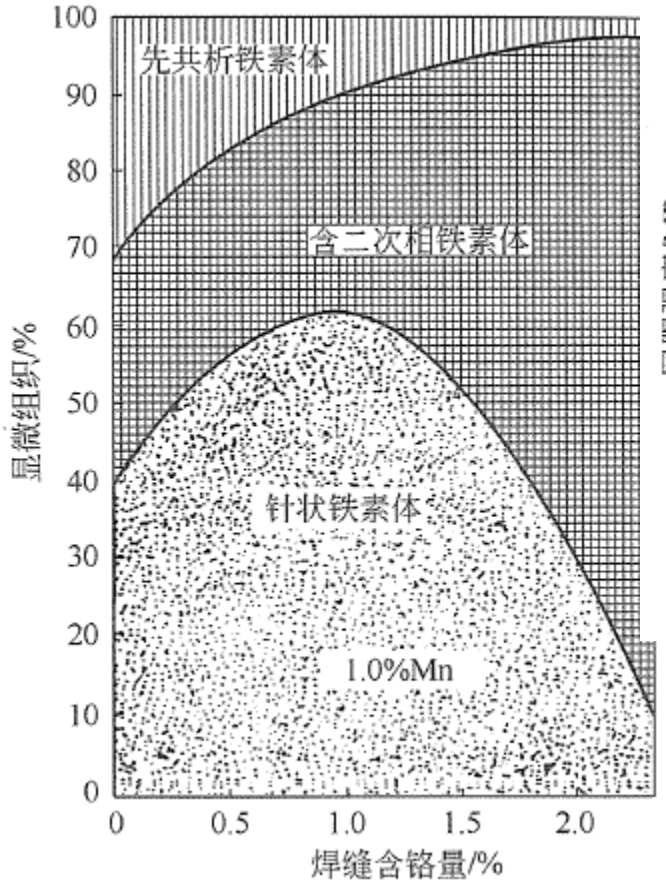
Mo設計在**0.2~0.4**之間

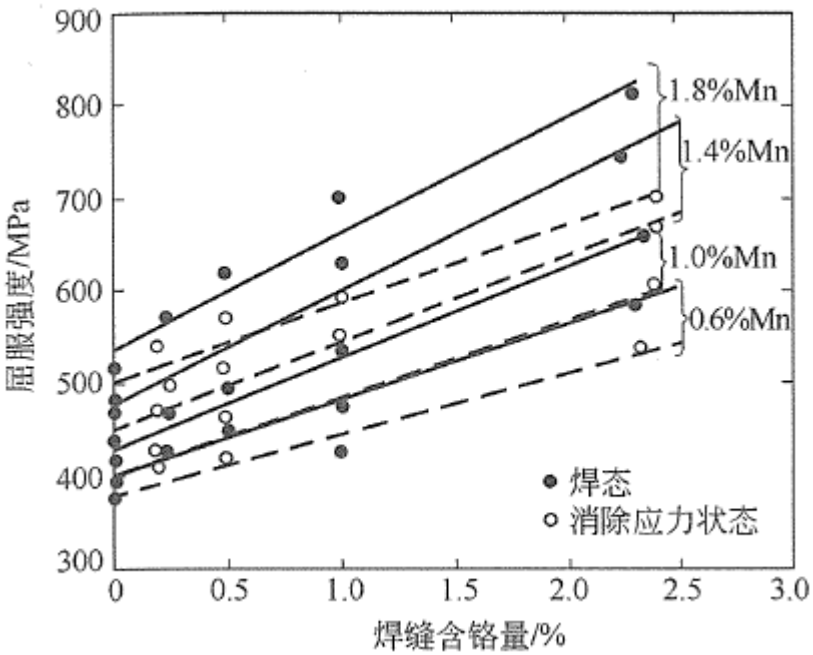
KUANG TAI

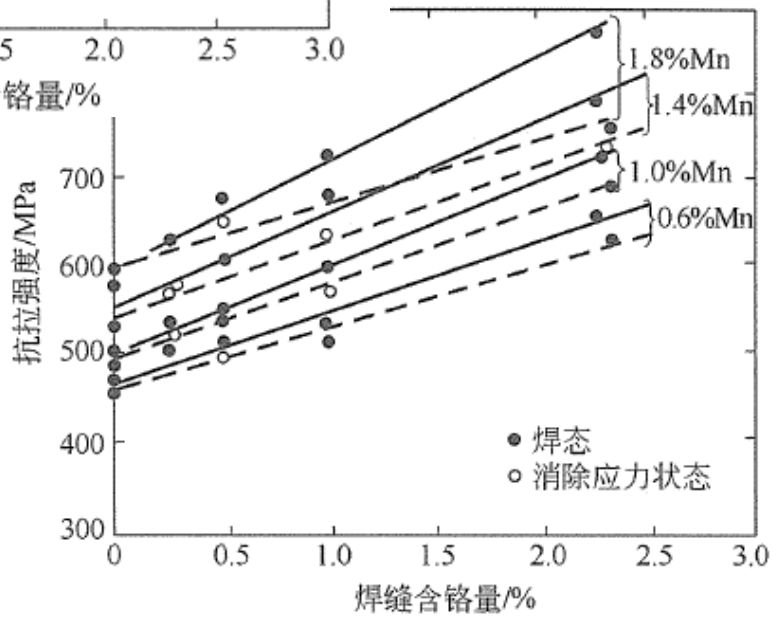


合金設計–Cr

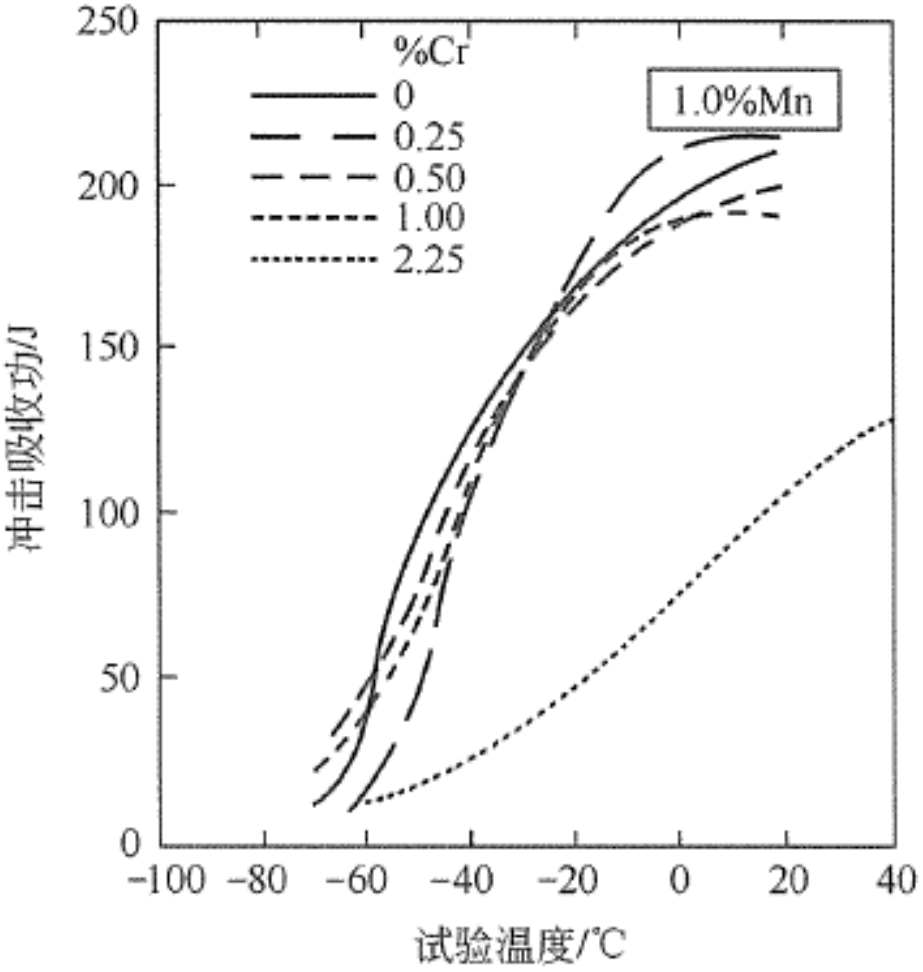
鉻元素影響–組織&強度


先共析铁素体
含二次相铁素体
针状铁素体
1.0%Mn
显微组织/%
焊缝含铬量/%


1.8%Mn
1.4%Mn
1.0%Mn
0.6%Mn
焊态
消除应力状态
屈服强度/MPa
焊缝含铬量/%

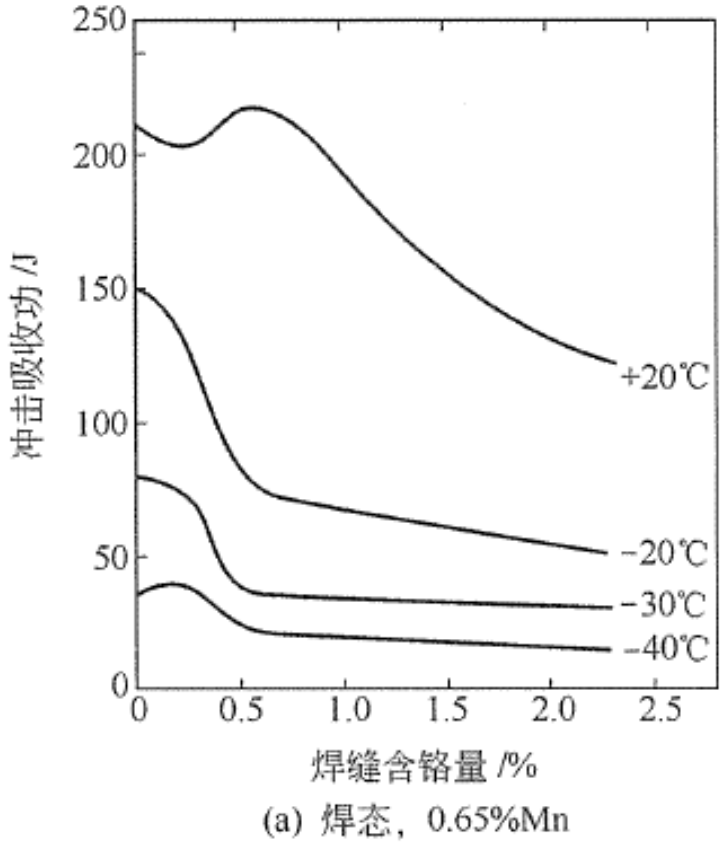

1.8%Mn
1.4%Mn
1.0%Mn
0.6%Mn
焊态
消除应力状态
抗拉强度/MPa
焊缝含铬量/%

鉻元素影響–低溫韌性

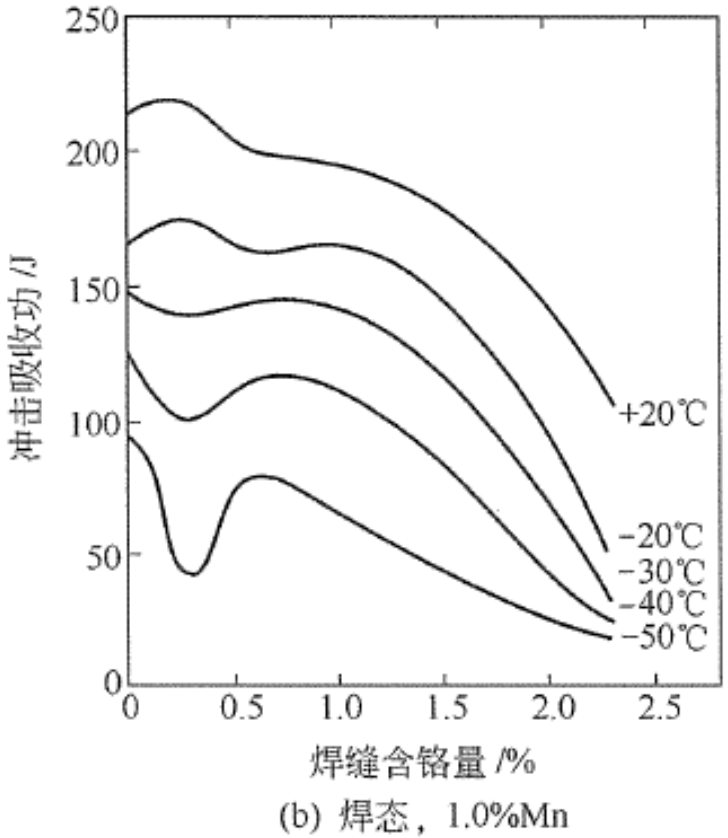


2.25%Cr韌脆轉換溫度最高

不同錳含量鉻元素影響



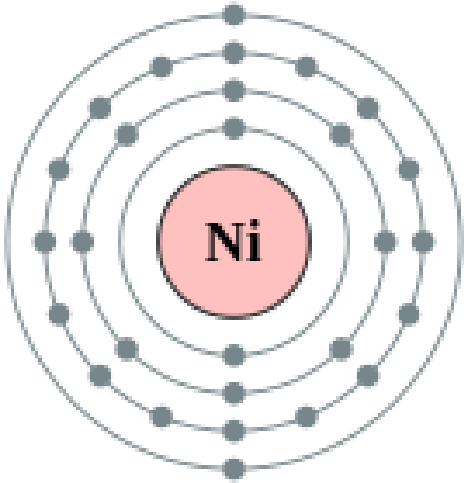
(a) 焊态，0.65%Mn



(b) 焊态，1.0%Mn

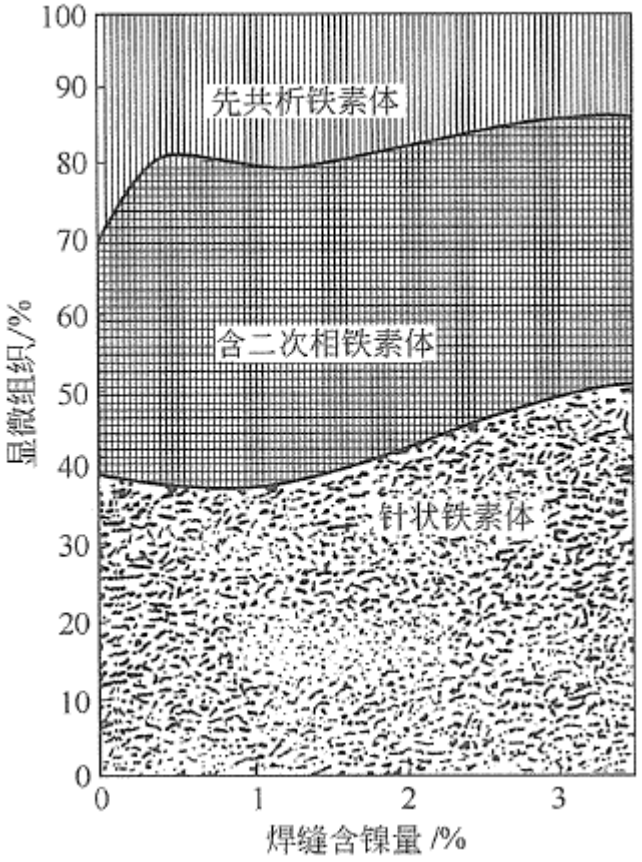
Cr設計在**0.25 以下**

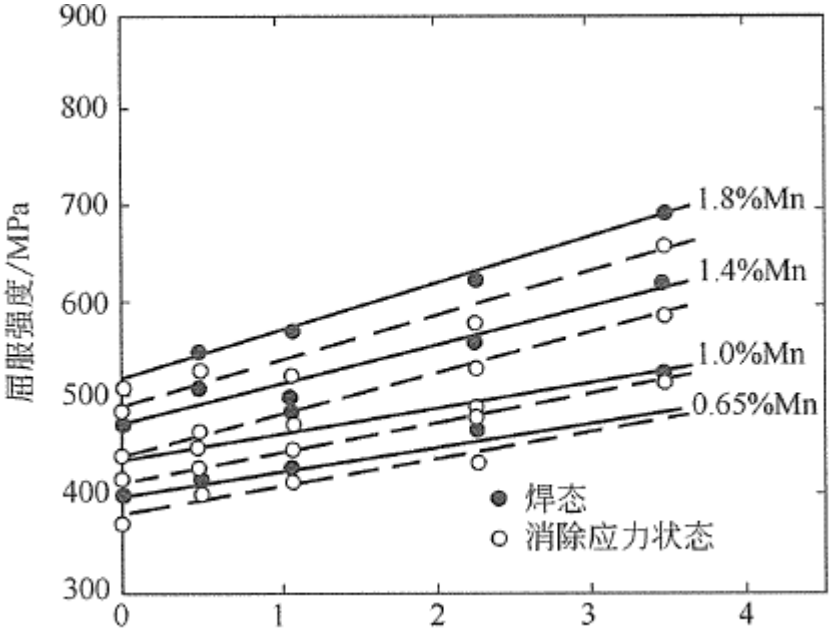
KUANG TAI

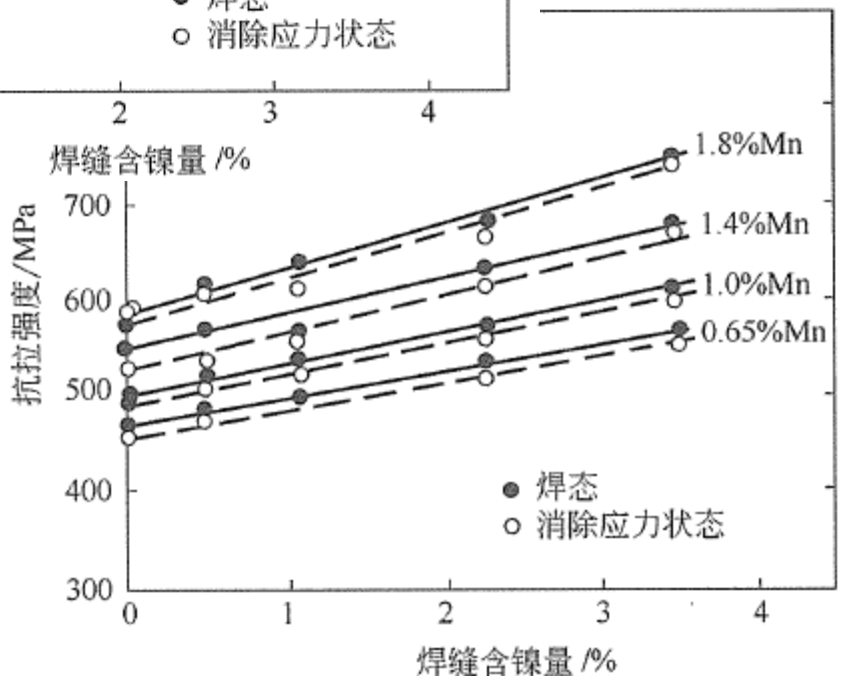


合金設計–Ni

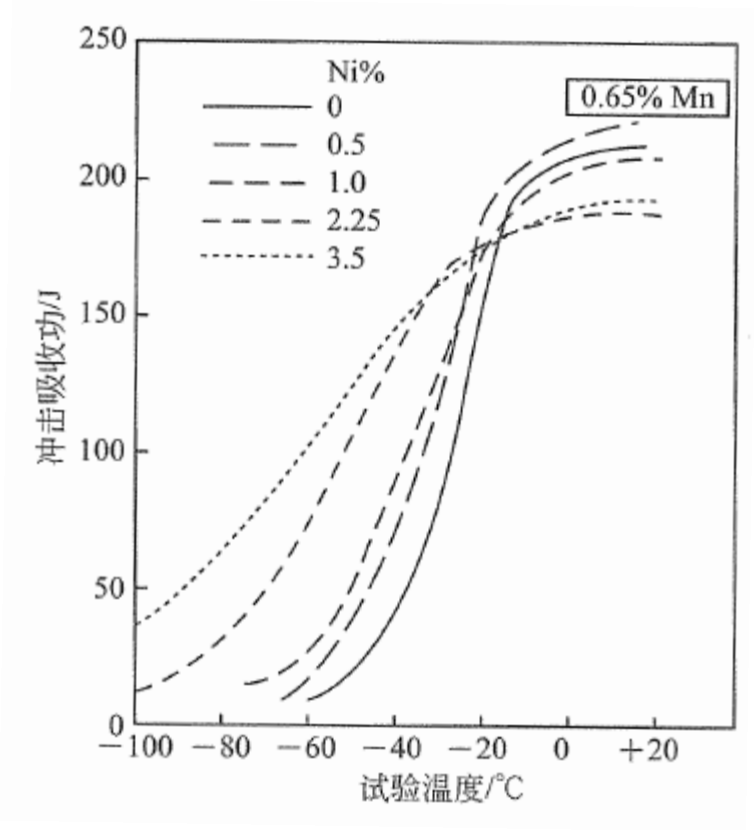
鎳元素影響–組織&強度


先共析铁素体
含二次相铁素体
针状铁素体
显微组织/%
焊缝含镍量 /%


屈服强度/MPa
1.8%Mn
1.4%Mn
1.0%Mn
0.65%Mn
焊态
消除应力状态
焊缝含镍量 /%


抗拉强度/MPa
1.8%Mn
1.4%Mn
1.0%Mn
0.65%Mn
焊态
消除应力状态
焊缝含镍量 /%

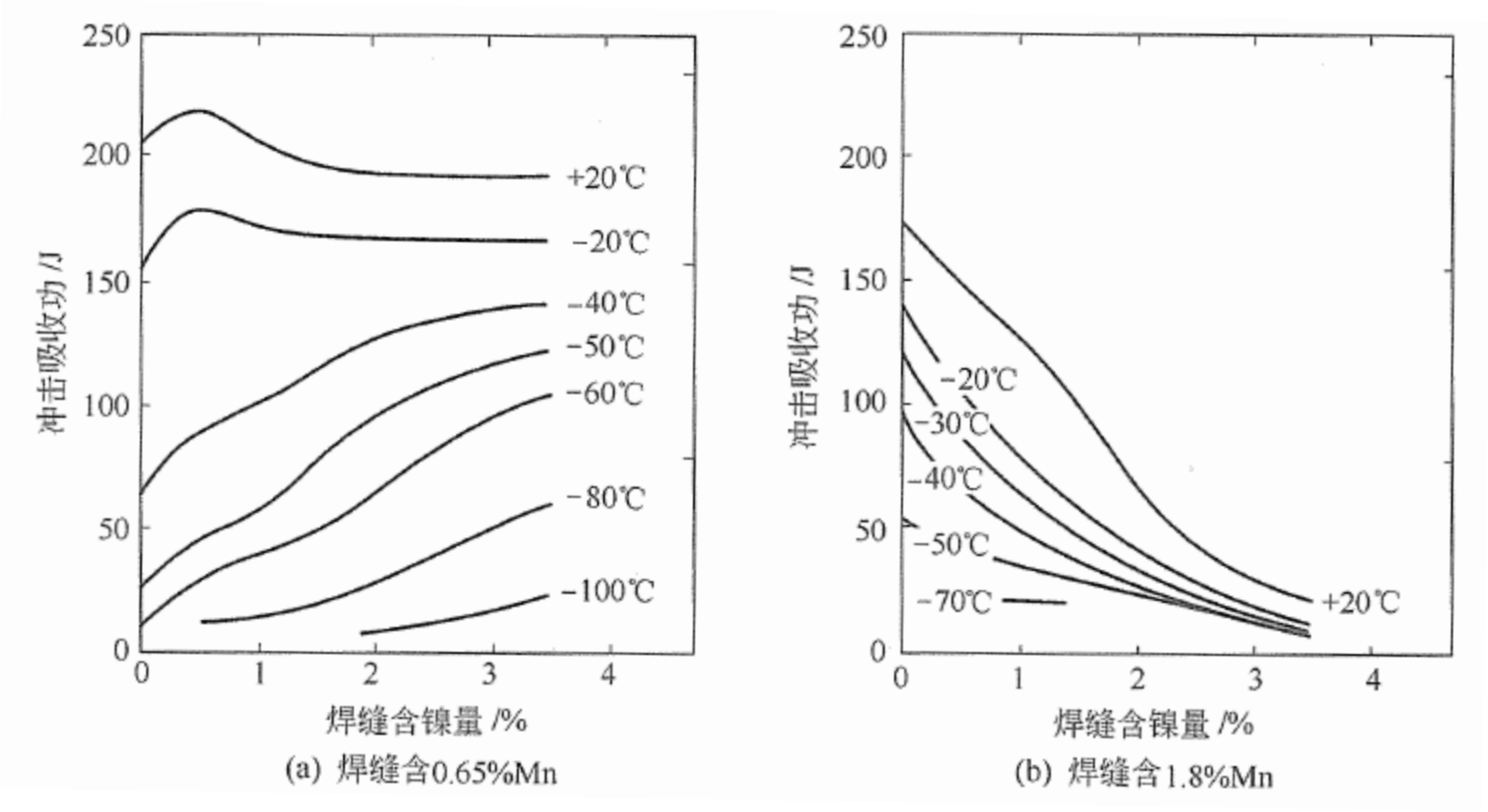
鎳元素影響–低溫韌性



3.5%Ni韌脆轉換溫度最低

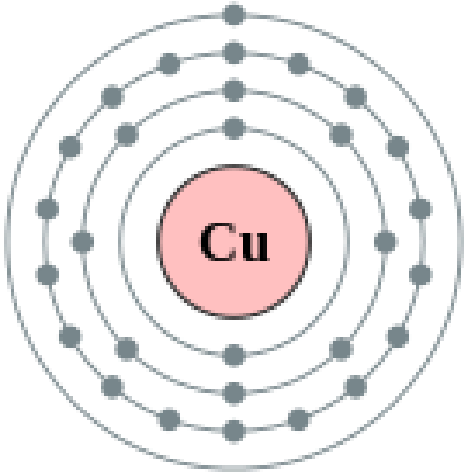
0%Ni韌脆轉換溫度最高

不同錳含量鎳元素影響



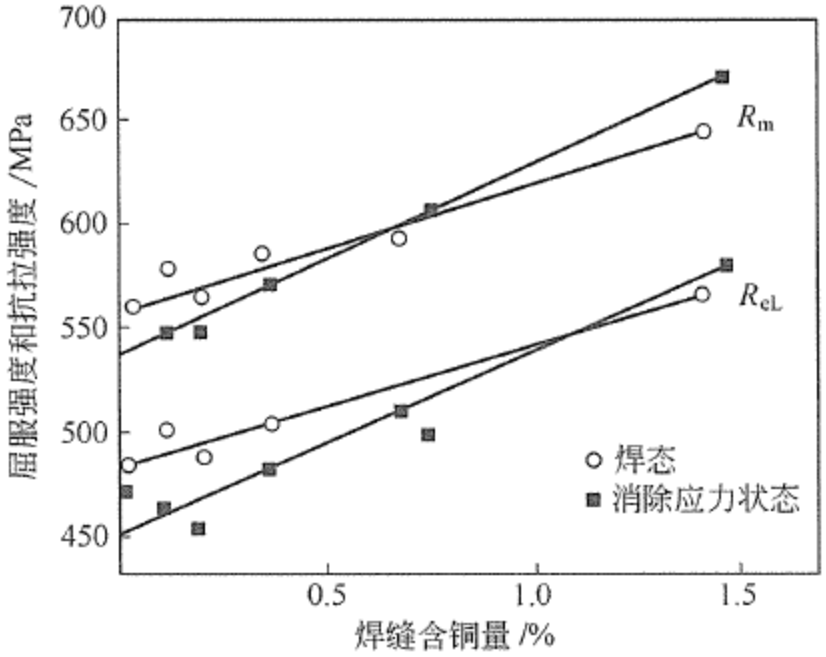
Ni設計在**1.5~2.5 之間**

KUANG TAI

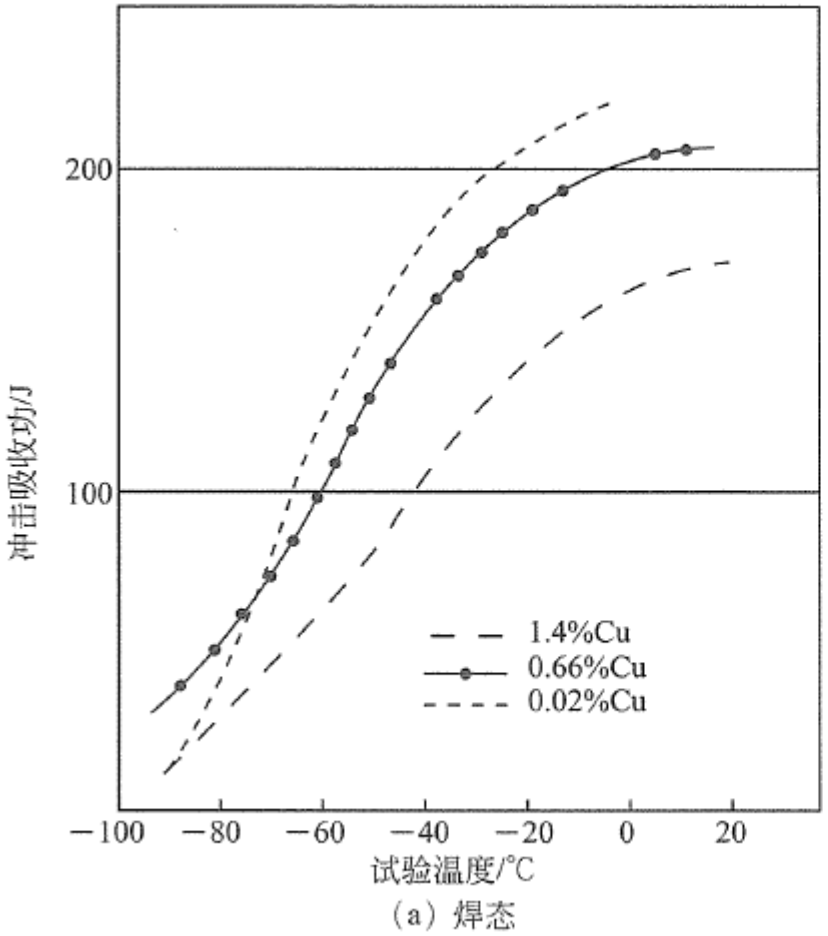


合金設計–Cu

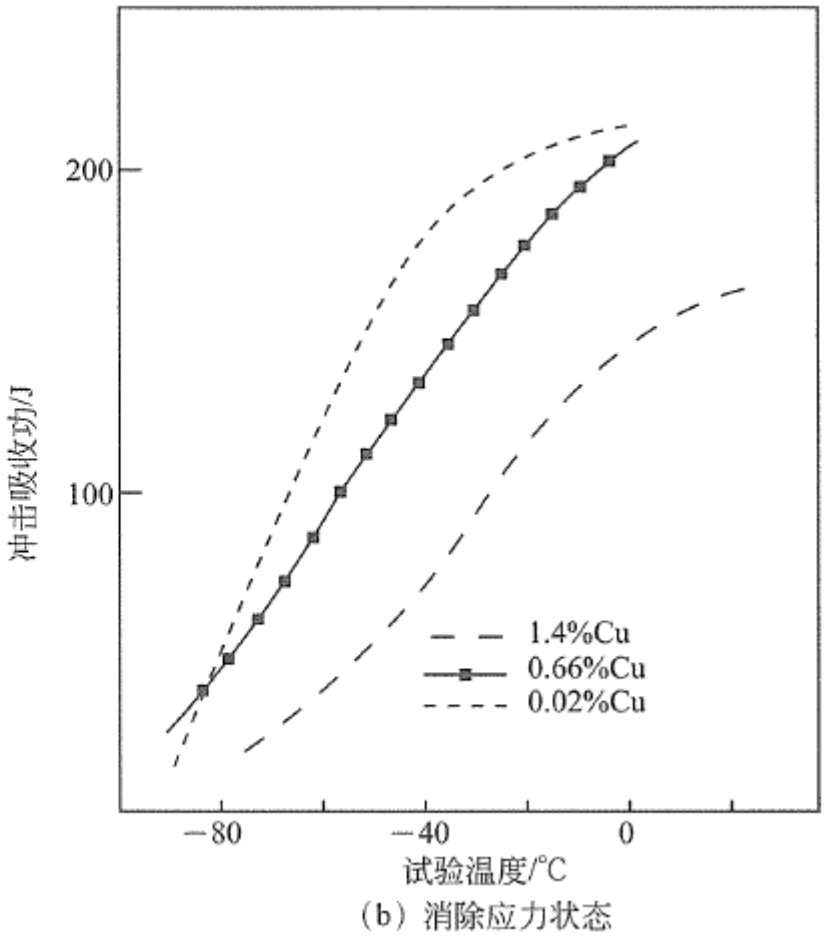
銅元素影響–強度


700
650
600
550
500
450
屈服强度和抗拉强度 /MPa
R_m
R_{eL}
焊态
消除应力状态
0.5
1.0
1.5
焊缝含铜量 /%

銅元素影響–低溫韌性



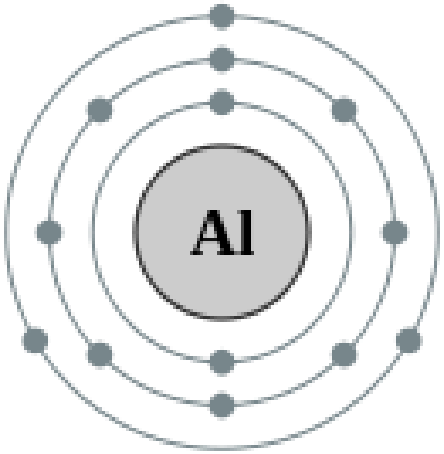
（a）焊态



（b）消除应力状态

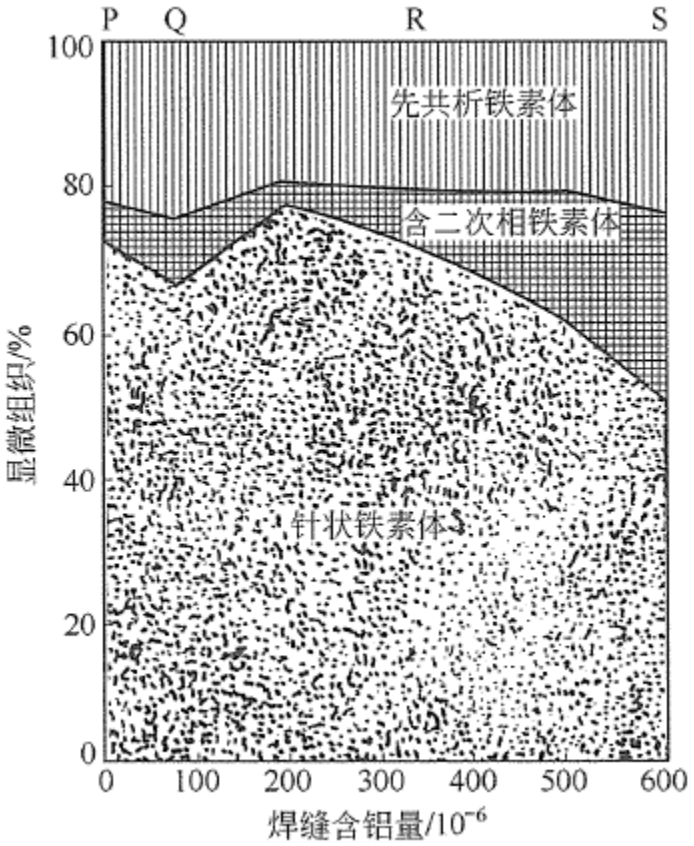
Cu設計在**0.05 以下**

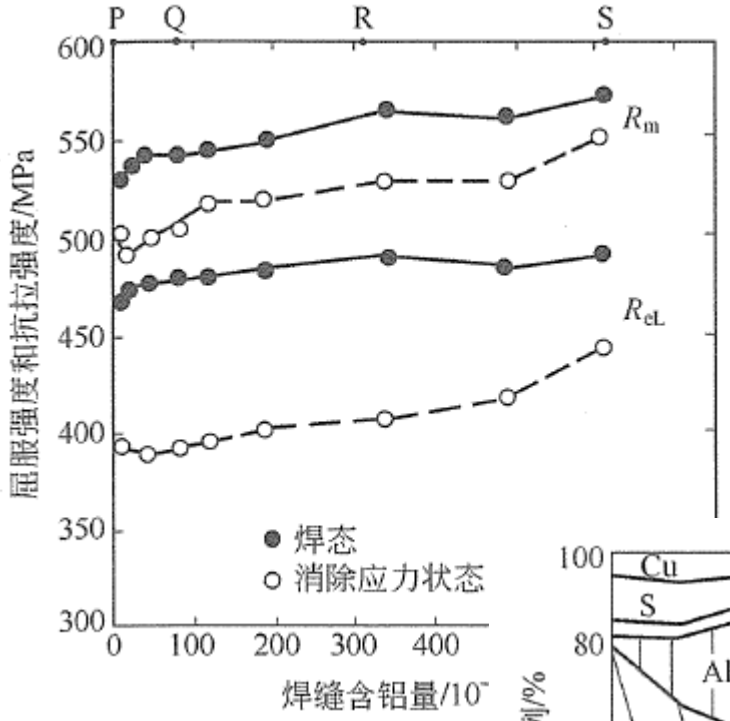
KUANG TAI

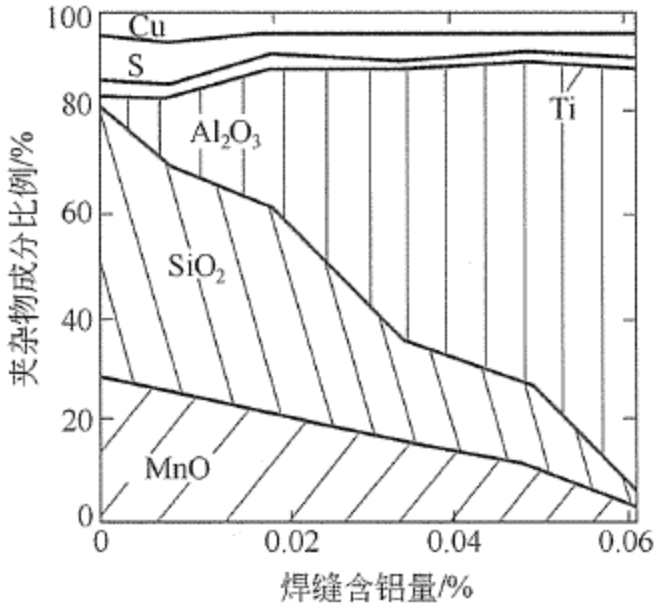


合金設計-Al

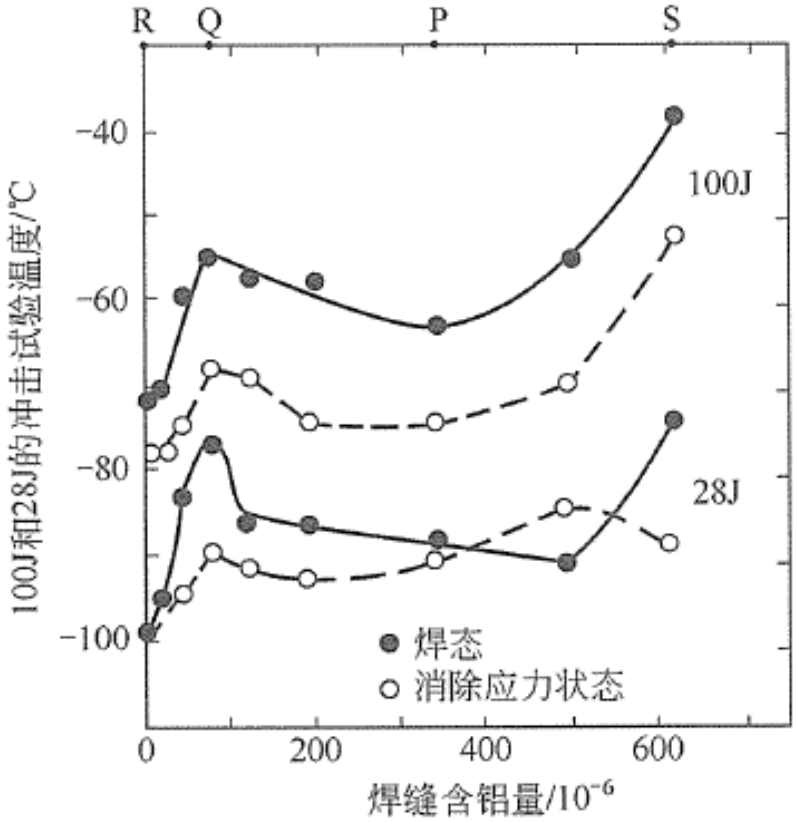
鋁元素影響–組織&強度

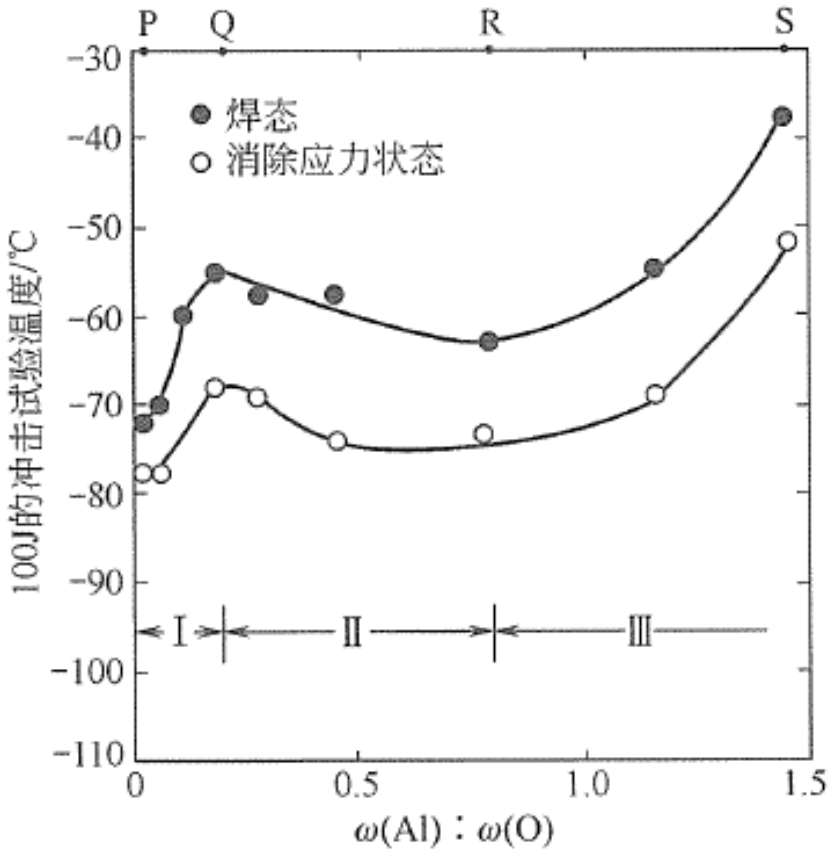

P
Q
R
S
100
80
60
40
20
0
先共析铁素体
含二次相铁素体
针状铁素体
显微组织/%
0
100
200
300
400
500
600
焊缝含铝量/10⁻⁶


P
Q
R
S
600
550
500
450
400
350
300
屈服强度和抗拉强度/MPa
R_m
R_{eL}
焊态
消除应力状态
0
100
200
300
400
焊缝含铝量/10⁻


100
80
60
40
20
0
Cu
S
Ti
Al_2O_3
SiO_2
MnO
夹杂物成分比例/%
0
0.02
0.04
0.06
焊缝含铝量/%

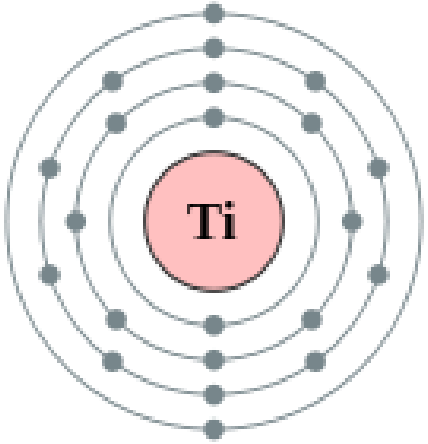
鋁元素影響–低溫韌性

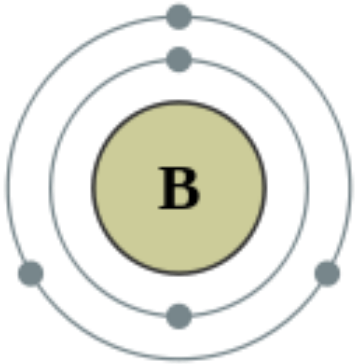




Al設計在**100ppm 以下**

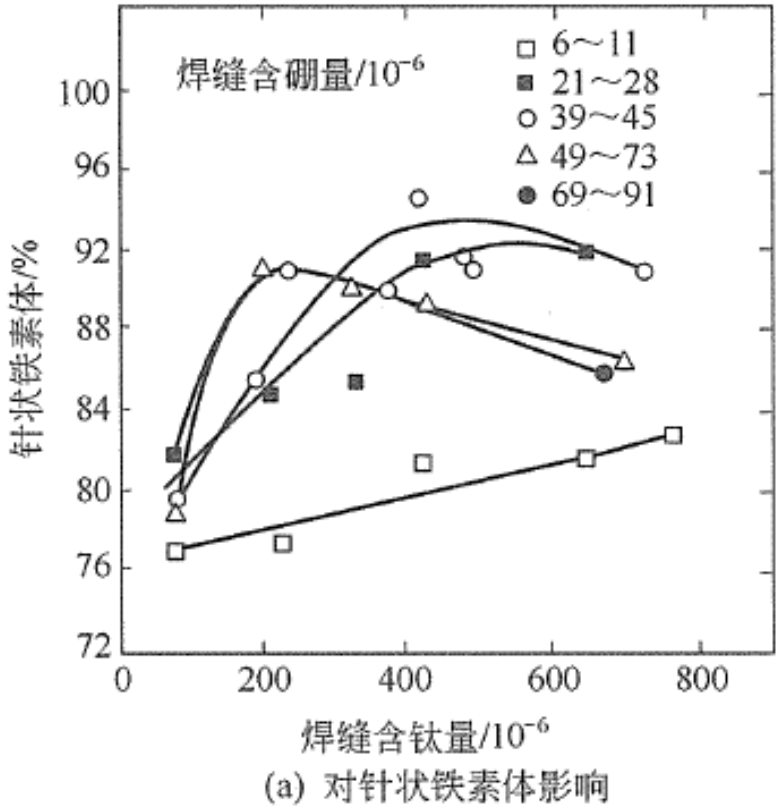
KUANG TAI



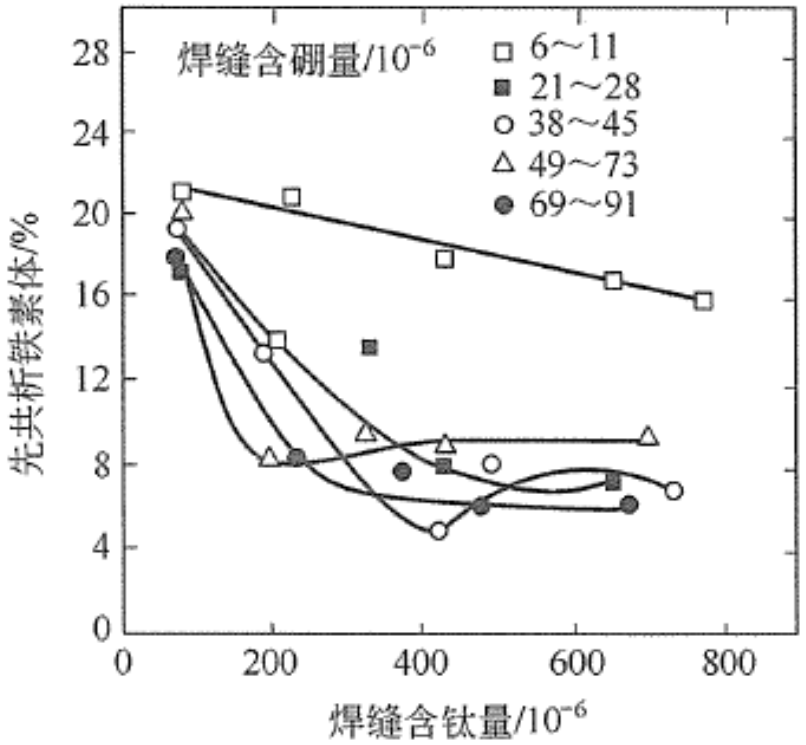


合金設計–Ti & B

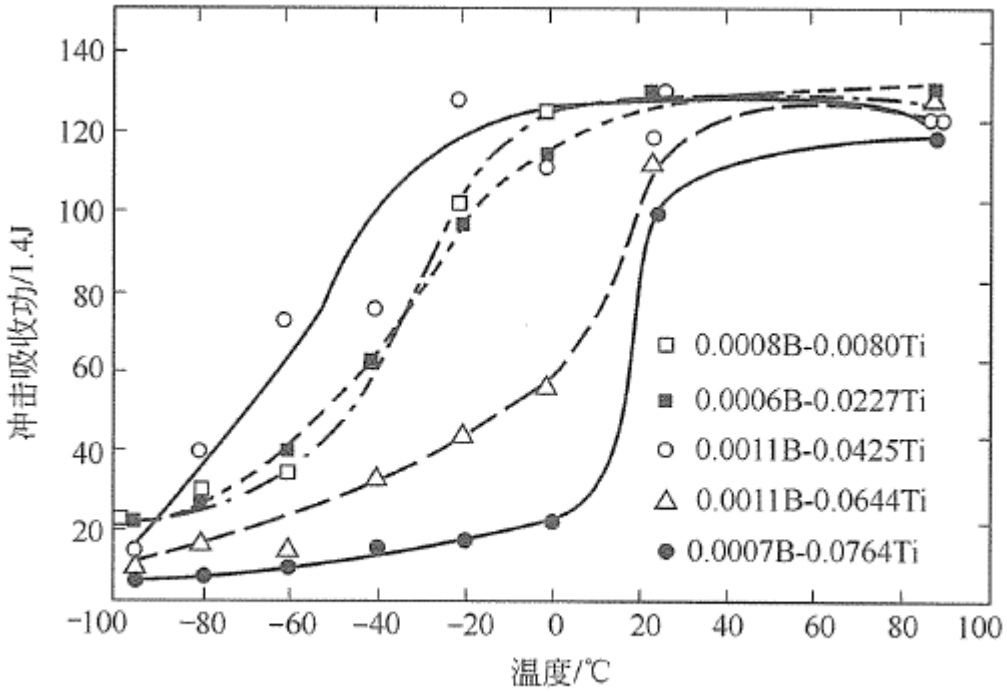
鈦&硼元素影響–組織



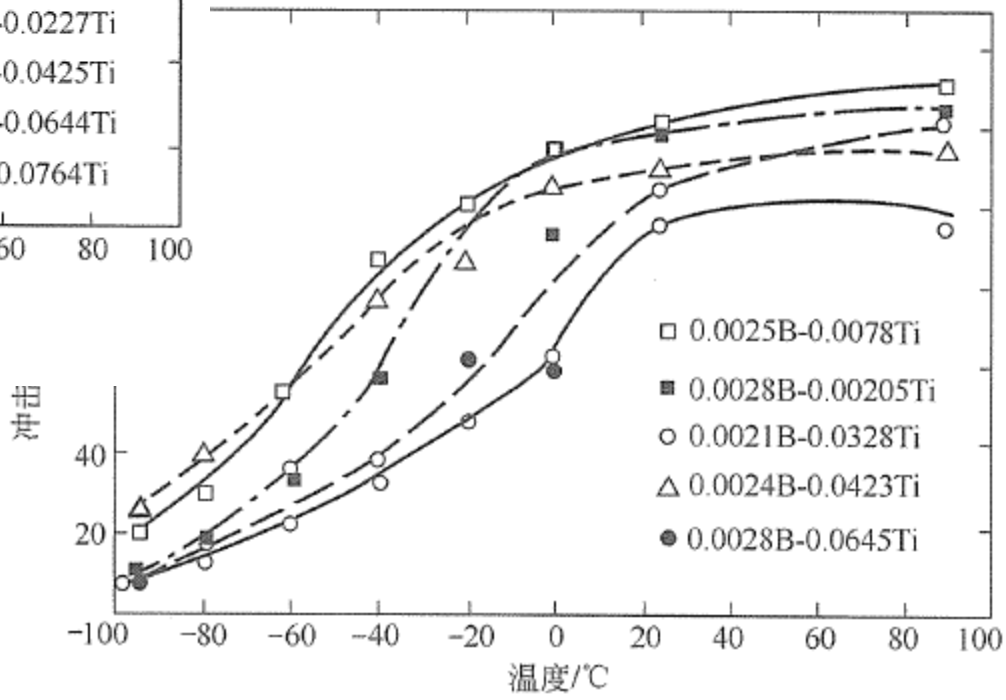
(a) 对针状铁素体影响



鈦&硼元素影響–低溫韌性

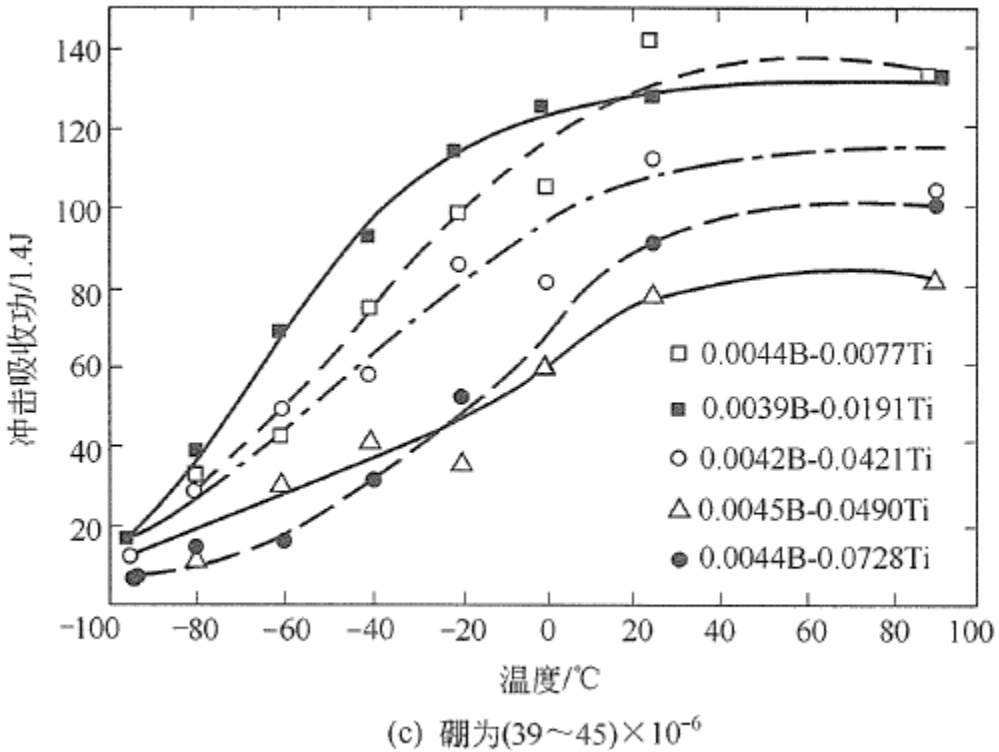


(a) 硼为(8～11)×10^{-6}

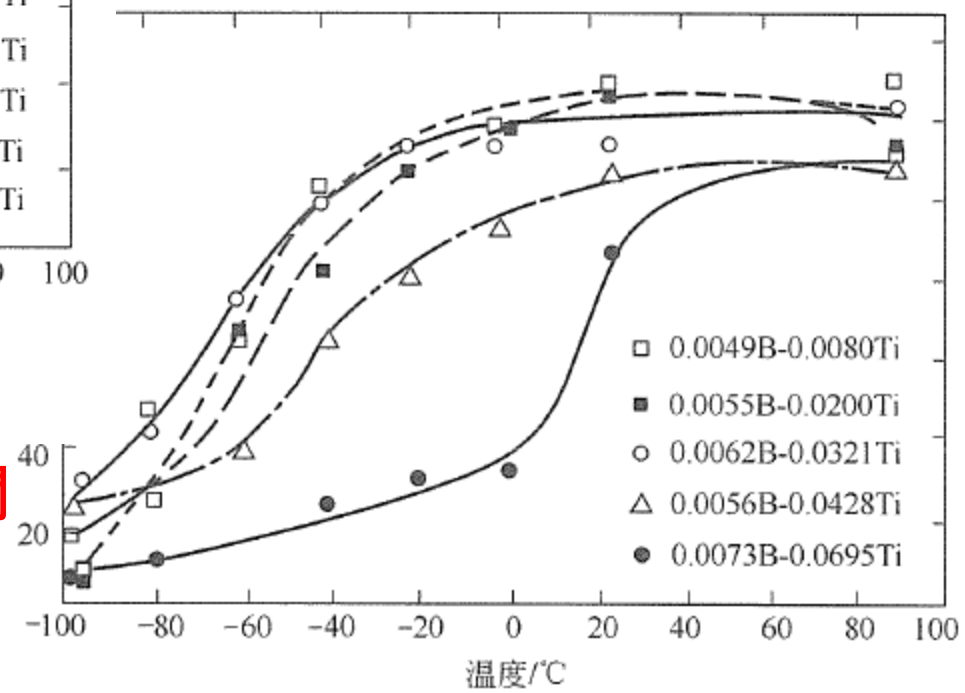


(b) 硼为(21～28)×10^{-6}

鈦&硼元素影響–低溫韌性



(c) 硼为(39～45)×10^{-6}

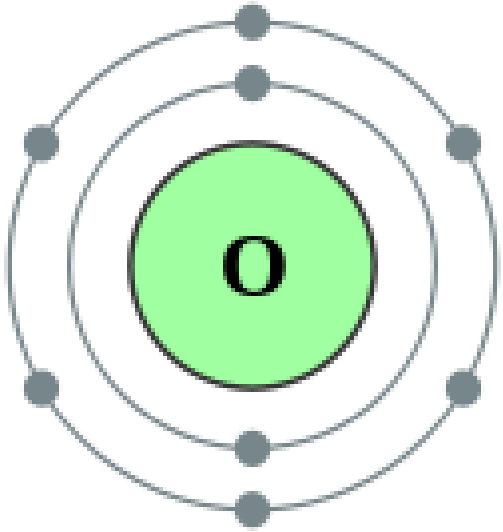


(d) 硼为(49～73)×10^{-6}

Ti設計在**200~400ppm 之間**

B設計在**20-50ppm 之間**

KUANG TAI

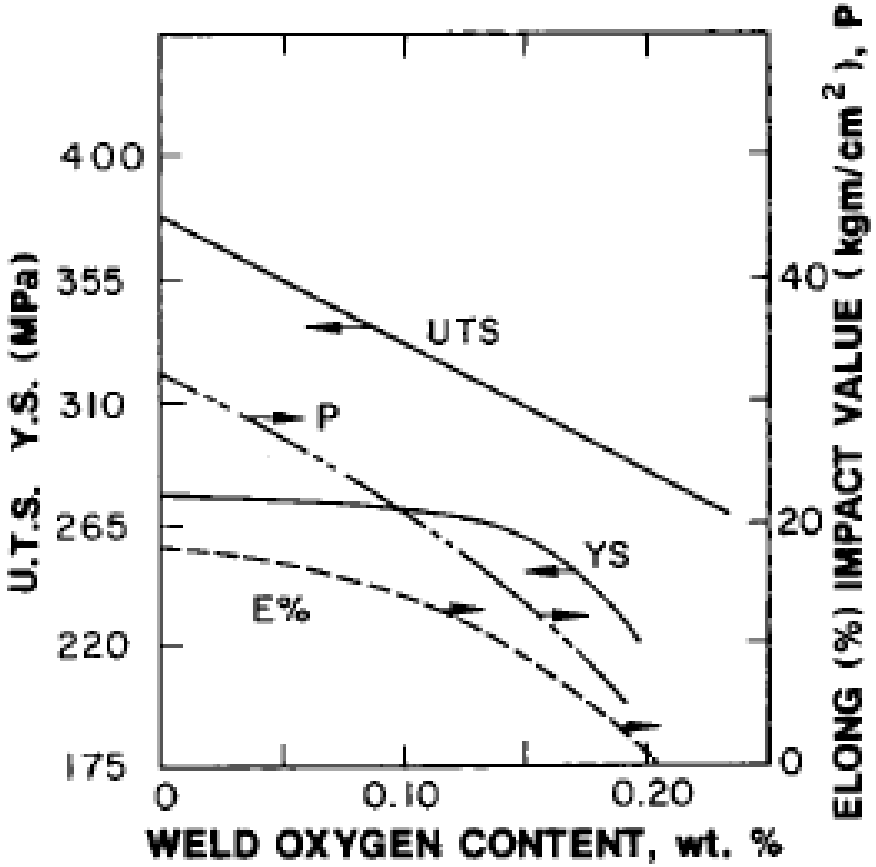


有害氣體控制–O

氧氣對銲接的作用

溶解方式.	銲接性質影響	控制方式
• 以O和FeO兩種形式溶於液態鐵中 • 在室溫中以氧化物與矽酸鹽的形式存在	• 銲道機械性質不佳，強度塑性、韌性下降 • 耗損合金元素 • 氣孔 • 飛濺	• 控制銲接材料 • 控制銲接參數 • 冶金反應

氧與機械性質的關係

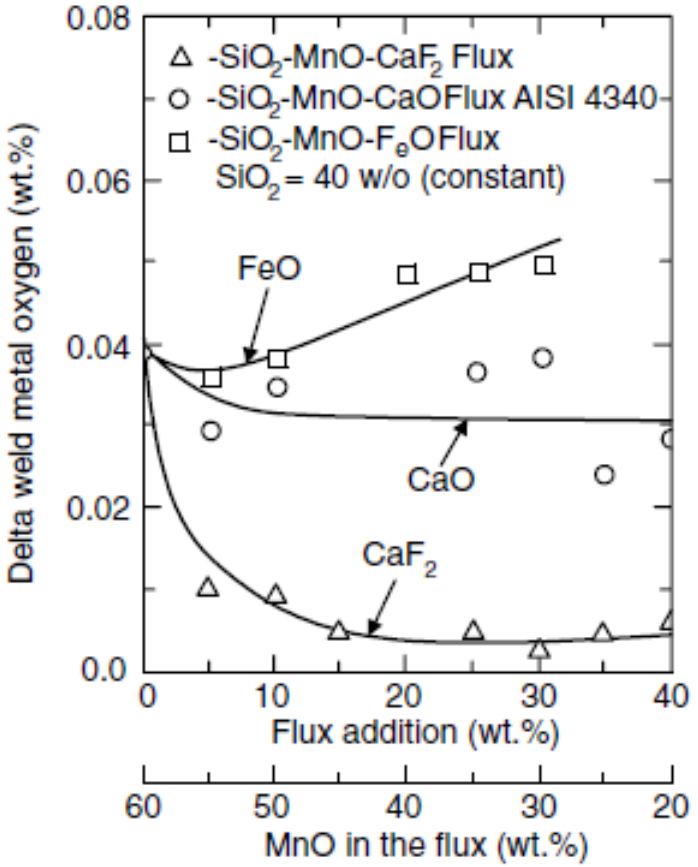


$$CO_2(g) = CO(g) + \frac{1}{2}O_2(g)$$

$$CO(g) = C(s) + \frac{1}{2}O_2(g)$$

脫氧劑

脫氧劑	反應	
Ti Si Mn Al Cr V	先期	$Fe_2O_3 + Ti \rightarrow TiO_2 + 2FeO$ $2FeO + Ti \rightarrow TiO_2 + 2Fe$ $2CaCO_3 + Ti \rightarrow 2CaO + TiO_2 + 2CO$ $2CO_2 + Ti \rightarrow TiO_2 + 2CO$ $2CO + Ti \rightarrow TiO_2 + 2C$ $Ti + O_2 \rightarrow TiO_2$
Mg TiO_2	沉澱	$[M] + [FeO] \rightarrow [Fe] + (MO)$ $[FeO] + [TiO_2] \rightarrow (FeTiO_3)$



脫氧反應

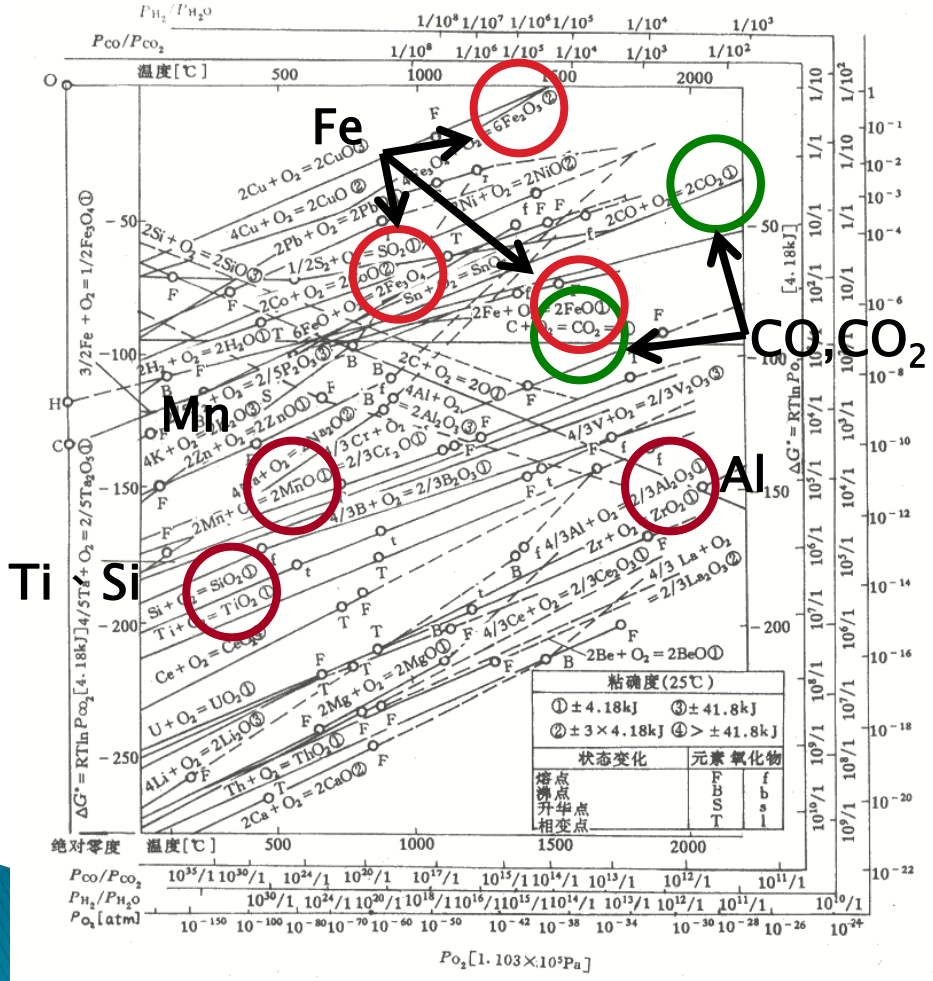


图 10　金属氧化物生成自由能变化与温度的关系

- M + O → MO　　ΔG^o
- 在銲接溫度對氧的親和力比被銲金屬大
- 脫氧的產物不溶於液態金屬，且密度也小於液態金屬

冶金反應除氧

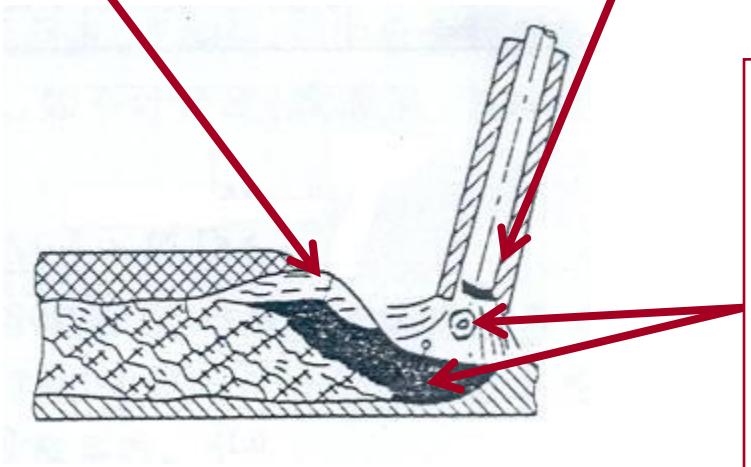
➢**熔渣與液態金屬界面：**

- **擴散脫氧**

➢**藥皮反應區：**

- 以惰性氣體稀釋電弧中的氧
- **先期脫氧**

使用Al、Ti、Si、Mn或其合金等作為脫氧劑



➢**熔滴與熔池反應區：**

- **沉澱脫氧**

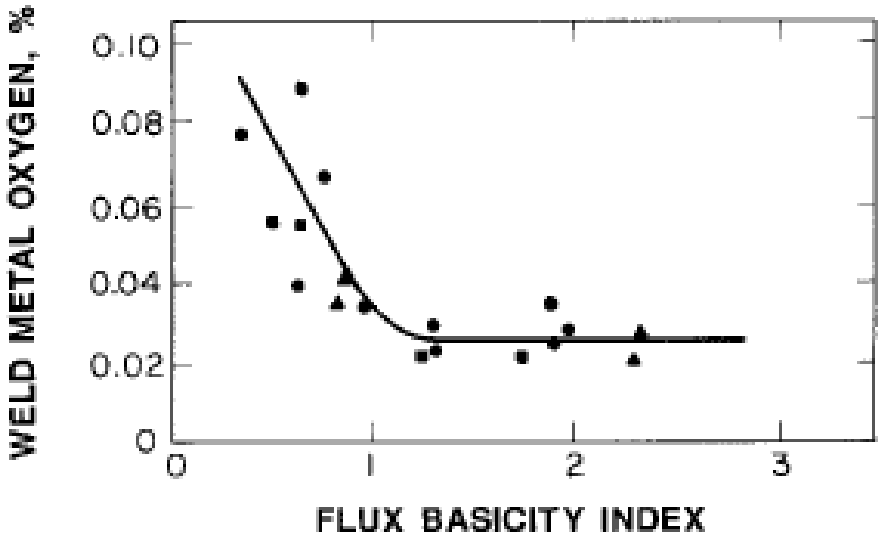
脫氧劑和FeO直接反應，產生的脫氧產物浮出液態金屬

- TiO_2與氧化鐵反應形成鈦酸鹽溶入渣中

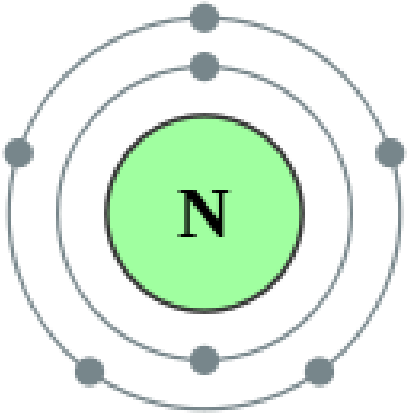
$$[FeO] + [TiO_2] \rightarrow (FeTiO_3)$$

提高銲藥鹼度

$$BI = \frac{CaF_2 + CaO + MgO + BaO + SrO + Na_2O + K_2O + Li_2O + 0.5(MnO + FeO)}{SiO_2 + 0.5(Al_2O_3 + TiO_2 + ZrO_2)}$$



KUANG TAI



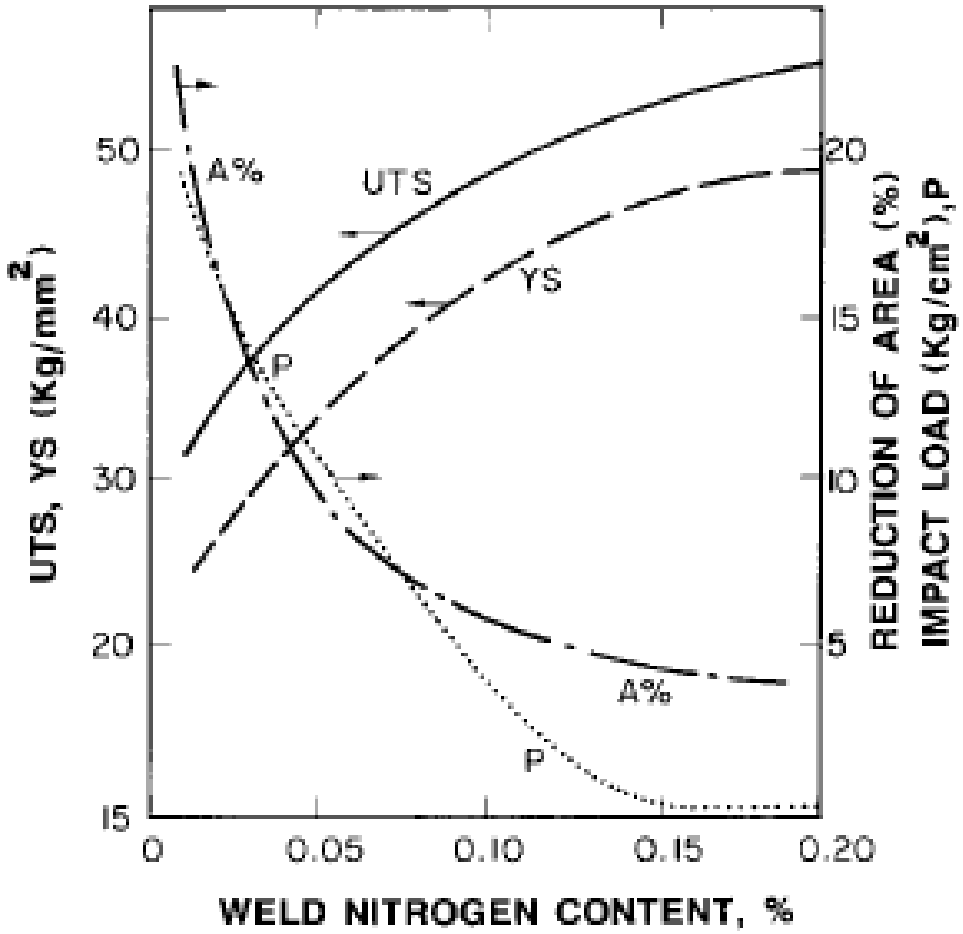
有害氣體控制–N

氮氣對銲接的作用

溶解方式.	銲接性質影響	控制方式
•氣體分子吸附金屬表面後，分解為原子溶入金屬 •室溫中部分過飽和的氮會析出形成 Fe_4N	•氣孔 •強度硬度升高 •塑性韌性下降	•保護銲接區 •控制銲接參數 •冶金反應

KUANG TAI

氧與機械性質的關係

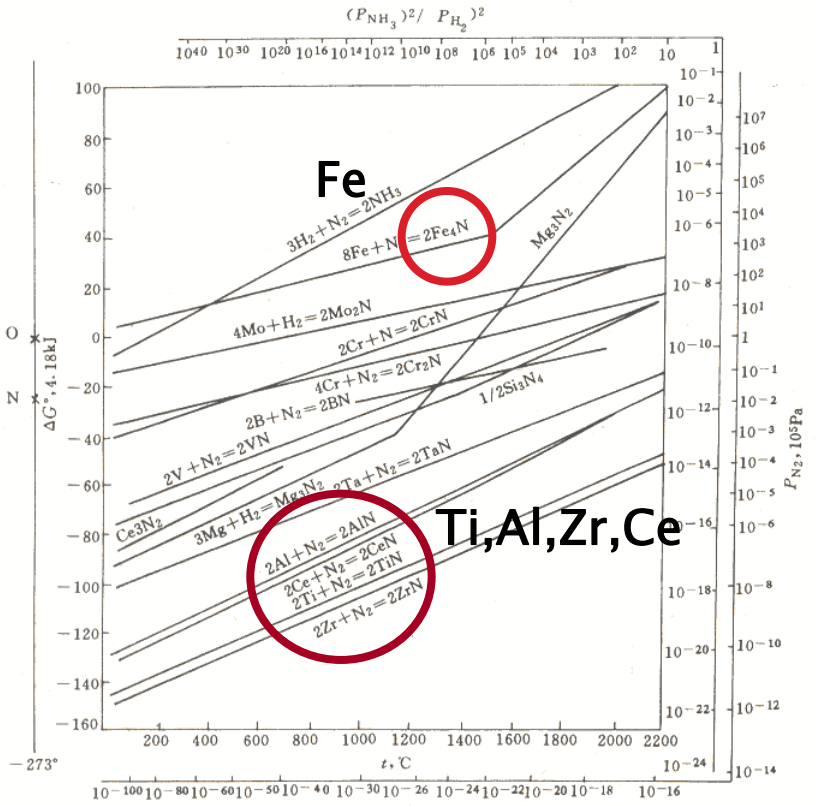


KUANG TAI

脫氮劑

除氮劑	反應
Ti Al Zr Ce V Mg B Cr Mo	$Ti + N \rightarrow TiN$ $Al + N \rightarrow AlN$ $V + N \rightarrow VN$ $2Ti + N_2 \rightarrow 2TiN$ $2Al + N_2 \rightarrow 2AlN$ $2V + N_2 \rightarrow 2VN$

脫氮反應

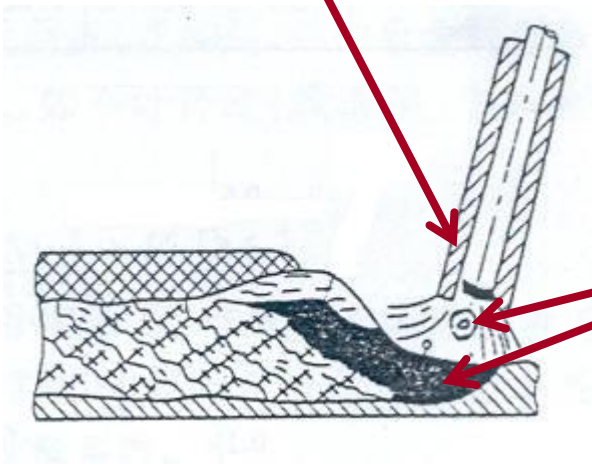


- M + N → MN　　ΔG°
- Ti、Al、Zr和Ce
  - 對氮的親和力大
  - 形成穩定的氮化物
  - 形成的氮化物不熔於液態鐵

冶金反應除氮

- **藥皮反應區：**

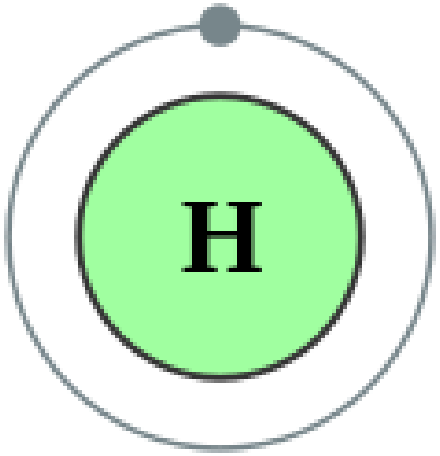
  以惰性氣體稀釋電弧中的氮



- **熔滴與熔池反應區：**

  鈦、鋁、鋯和稀土元素

KUANG TAI



有害氣體控制–H

氮氣對銲接的作用

溶解方式.	銲接性質影響	控制方式
• 通過熔渣或氣相與液態金屬的界面溶入 • 以H、H^+ 或H^- 的形式存在	• 氫脆性 • 氫白點 • 氣孔 • 延遲裂紋	• 限制氫的來源 • 以惰性氣體降低電弧中的氫分壓 • 冶金處理 • 銲後處理

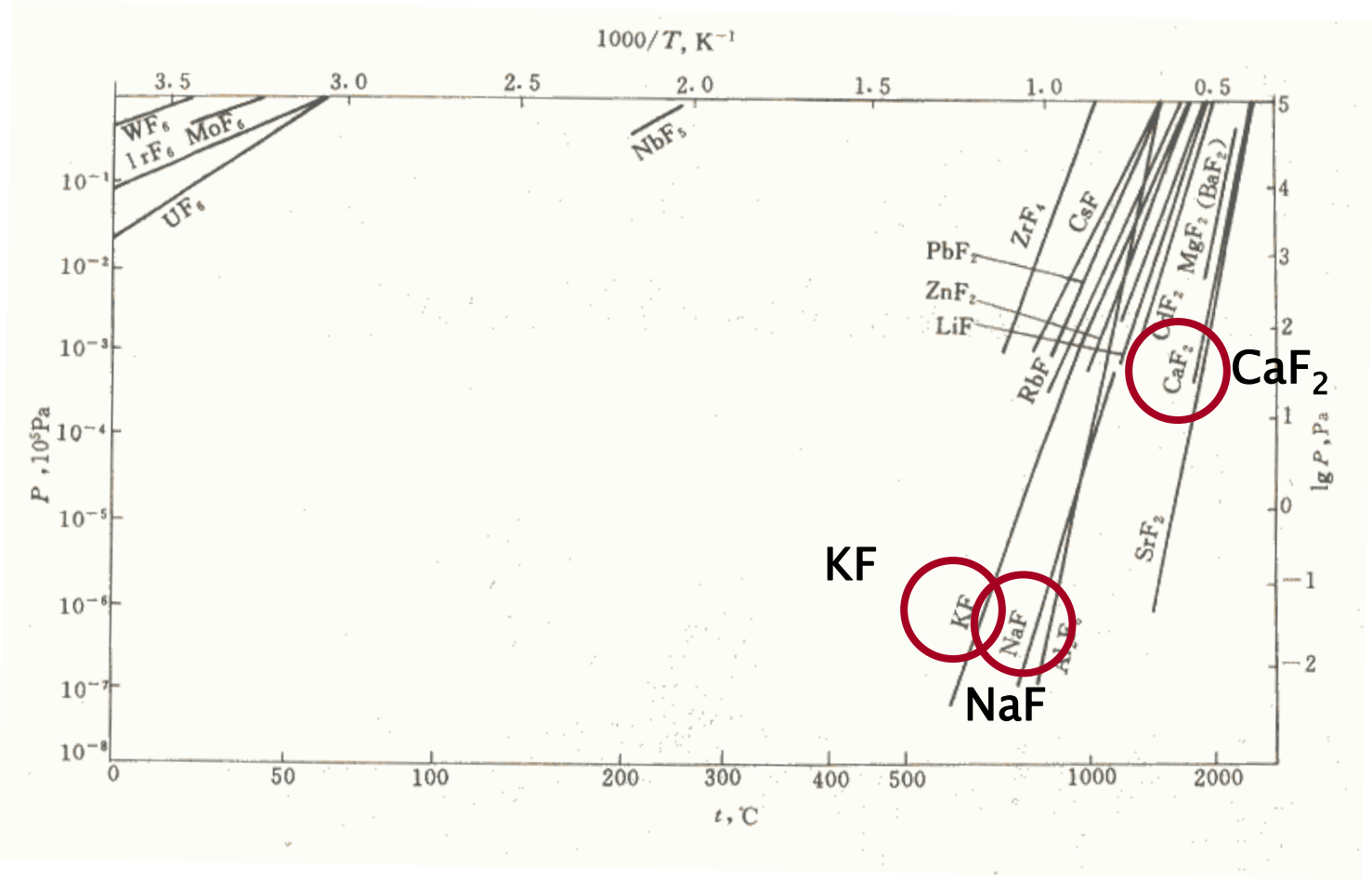
KUANG TAI

脫氫劑

除氫劑		反應
氟化物	CaF_2, BaF_2 K_3AlF_6 Na_2SiF_6 , K_2SiF_6 LiF , NaF AlF_3	$CaF_2+2H \rightarrow Ca+2HF$ $NaF+H \rightarrow Na+HF$ $AlF_3+3H \rightarrow Al+3HF$
氧化性氣體	CO_2 O O_2	$CO_2+H \rightarrow CO+OH$ $O+H \rightarrow OH$ $O_2+H_2 \rightarrow 2OH$

KUANG TAI

脫氫反應



合金-氣體-組織-物性

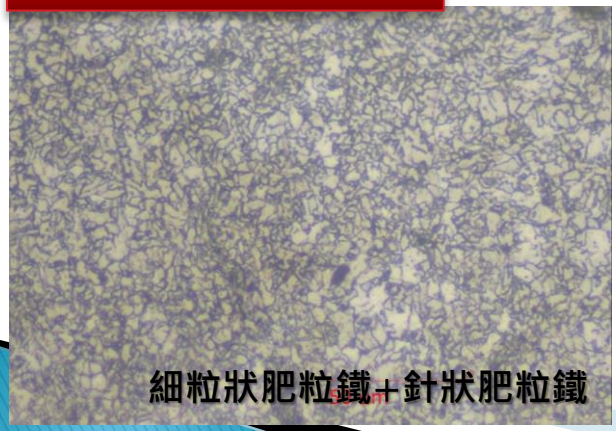
Chemistry

C	Si	Mn	P	S	Cr
0.05~0.07	0.2~0.6	1.2~1.6	0.02 max	0.02 max	0.25 max

Ni	Mo	Al	Cu	Ti	B
1.5~2.5	0.2~0.4	0.01 max	0.05 max	0.02~0.04	20~50 ppm

O	N	Diffusible H (ml/100g)
200~300ppm	80ppm max	4

Microstructure



Mechanical Properties

T.S. (MPa)	Y.P. (MPa)	EL(%)
719	668	22

Impact value @-51°C
96

KUANG TAI

Thanks for your attention