

Opportunities and challenges of super strong 2GPa steel for lightweight automobile

Dr. Mingxin Huang

The University of Hong Kong, Hong Kong

Dr. Jeff Wang

General Motors China Science Lab, Shanghai

Dr. Hongliang Yi, Dr. Xiaochuan Xiong

EasyForming (EF) Co. Ltd., Suzhou



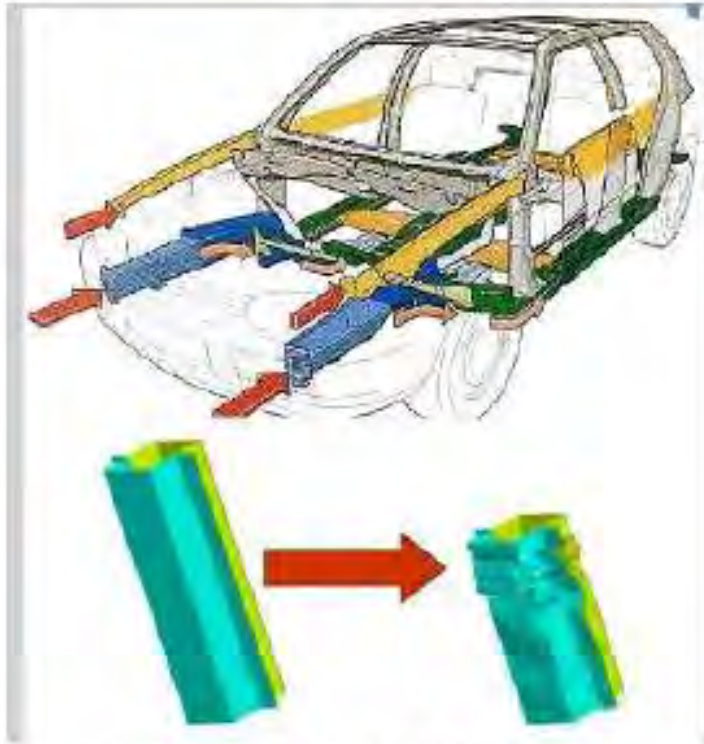
香港大學

THE UNIVERSITY OF HONG KONG



Rationale of high strength steels for automobiles

weight reduction and high passenger safety



$$\frac{\Delta m}{m} = -\frac{1}{4} \cdot \left(\frac{\Delta UTS}{UTS} \right)$$



$$\frac{\Delta m}{m} = -\frac{2}{7} \cdot \left(\frac{\Delta YS}{YS} \right)$$

The **strength** determines the weight reduction ratio, while the **ductility and fracture resistance** governs the formability & crash worthiness.

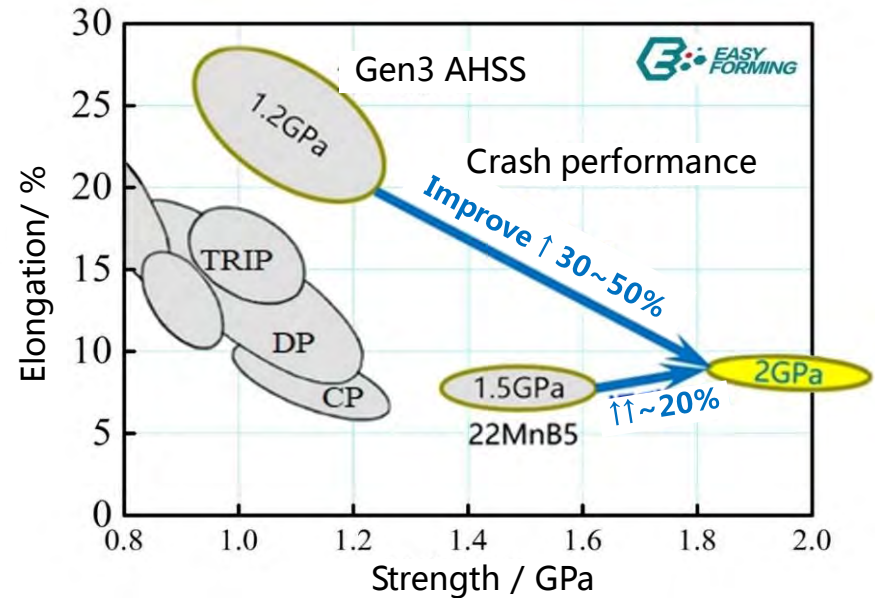
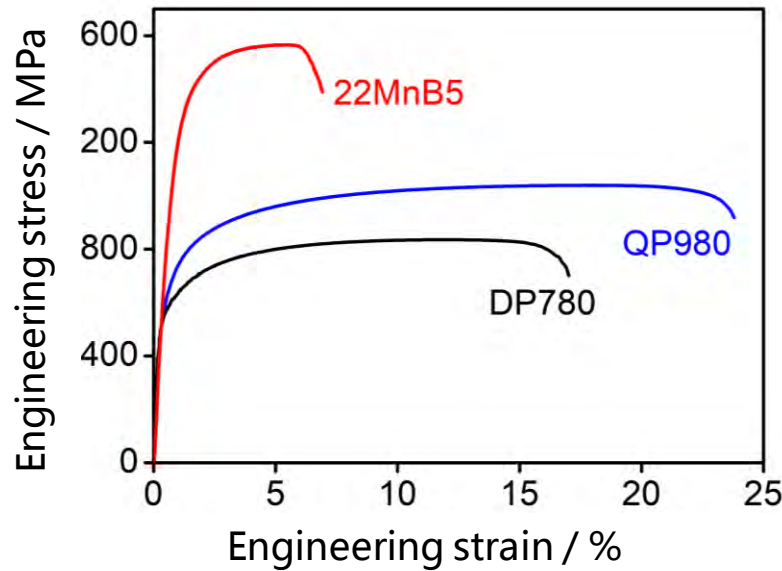


香港大學

THE UNIVERSITY OF HONG KONG

Ref: Huang et al, Steel Res. Int., 2013.

AHSS and PHS

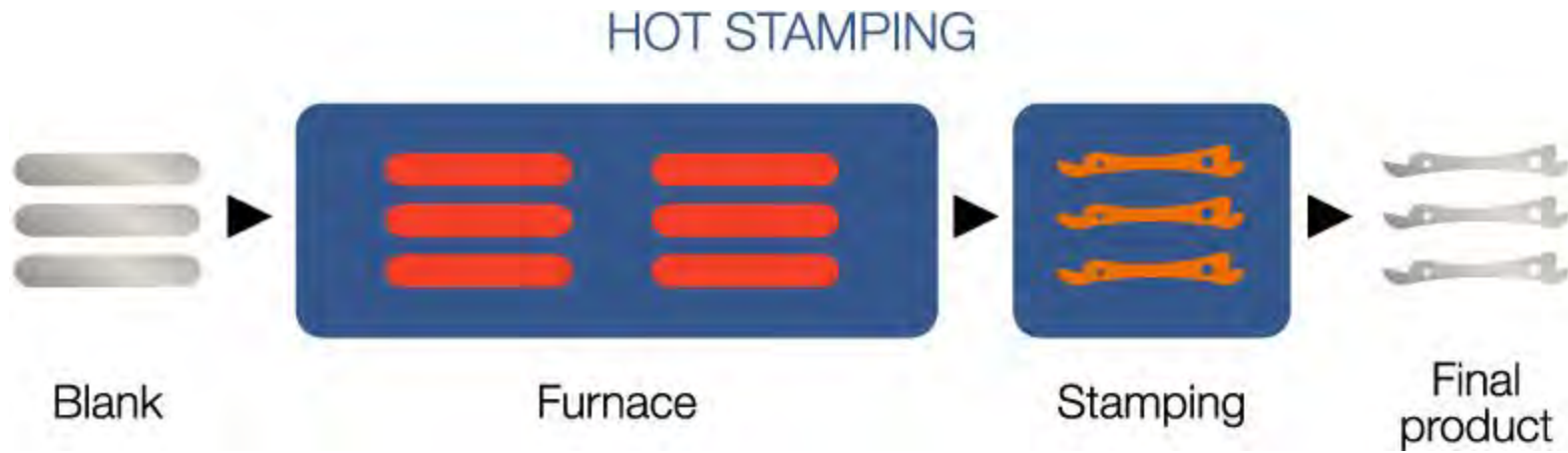


AHSS: Advanced High Strength Steel (tensile strength ≥ 600 MPa), for cold forming

PHS: Press Hardening Steel (tensile strength 1500-2000MPa), for hot forming

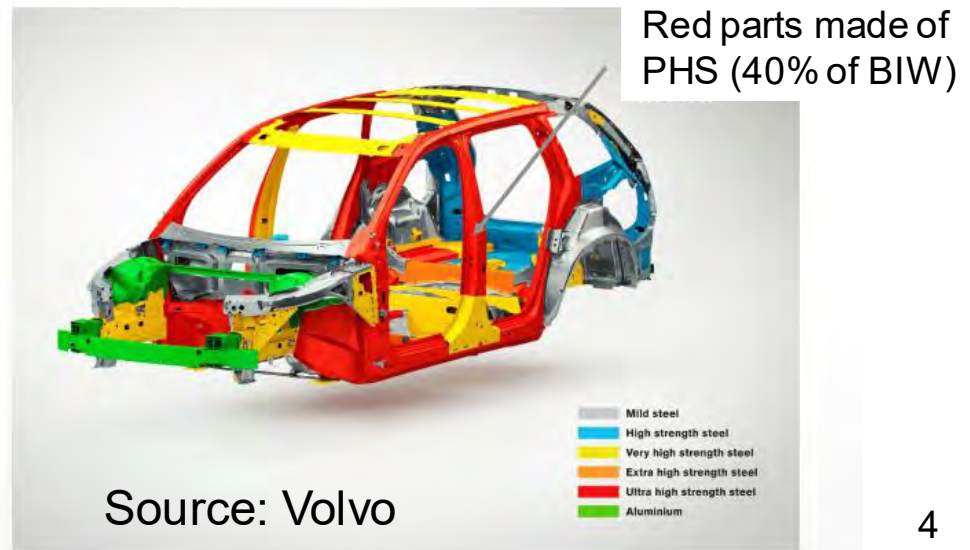


Hot stamping process of PHS



Source: gestamp

- Volvo XC90



香港大學

THE UNIVERSITY OF HONG KONG

First generation PHS

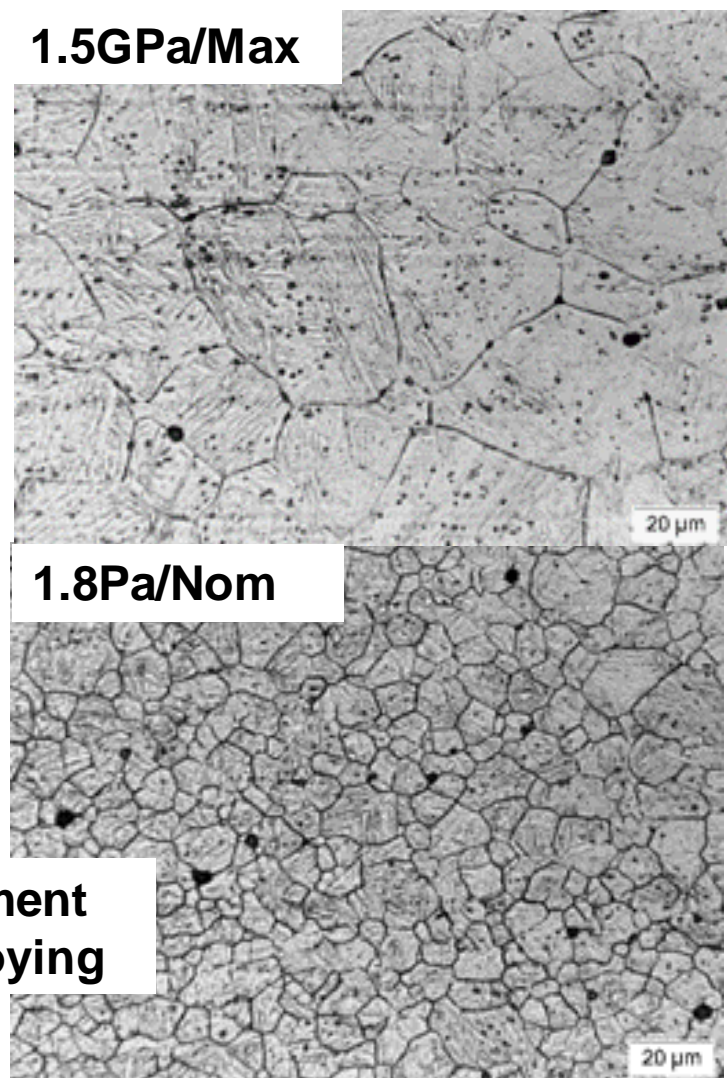
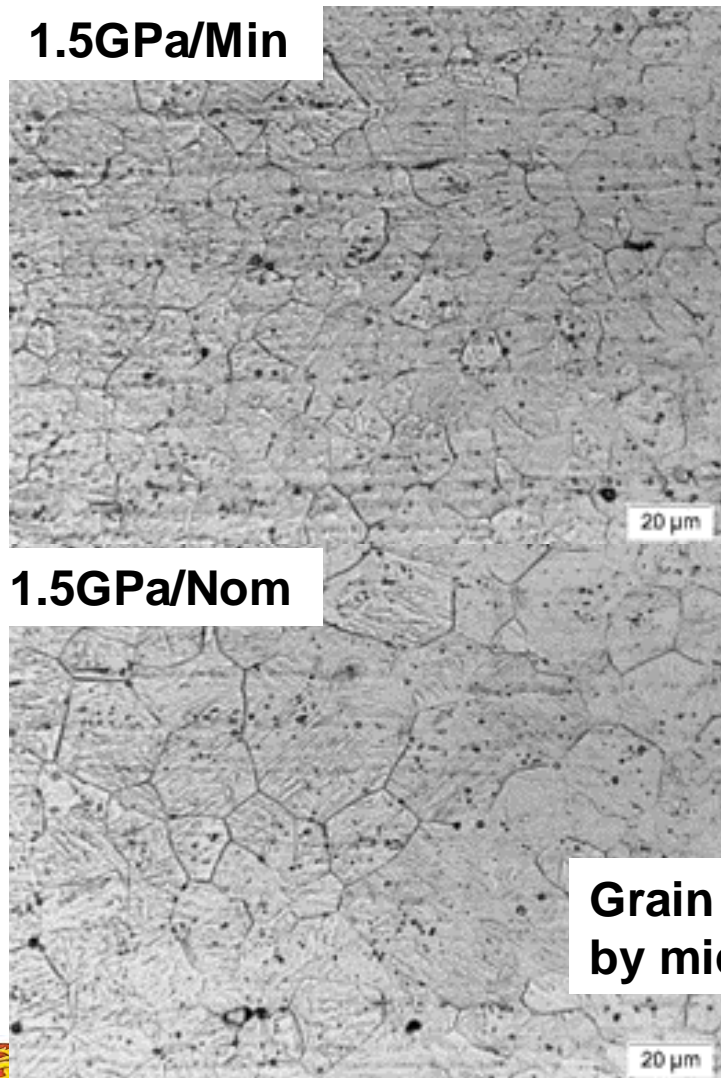
Grade	Coating	Gage (mm)	Chemical Composition (wt.%)					
			C	Mn	Ti	N	B	Nb
1.5 GPa	AlSi	1.6	0.23	1.2	0.033	0.008	0.003	None
1.8 GPa	AlSi	1.6	0.30	1.3	0.03	NR	0.002	Added

1.5 GPa PHS: widely used with annual turnover 3 Million Tons

1.8 GPa PHS: very limited applications but very attractive to OEMs



Prior Austenite Grain Growth and Refinement via Micro-Alloying

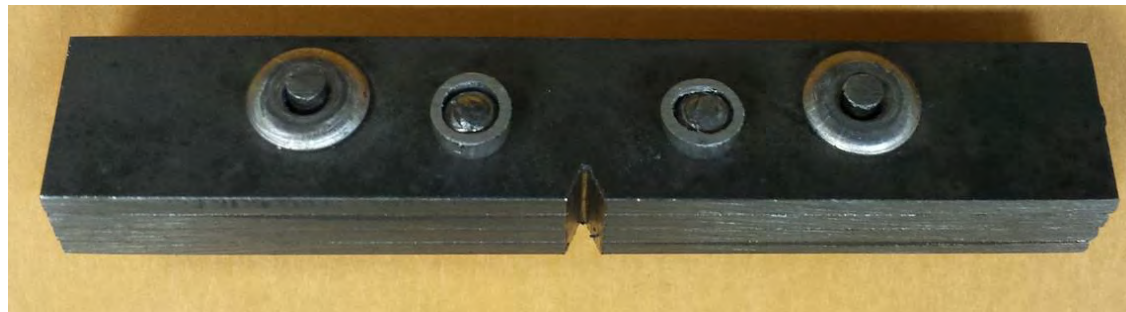
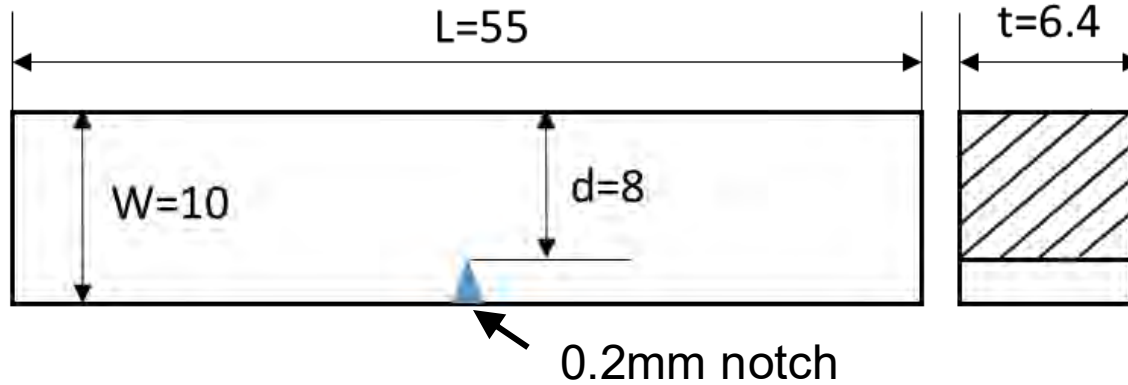


**Grain refinement
by micro-alloying**



Method – Stacked Charpy V-Notch Impact Test

Sample Geometry (Unit: mm)



4 × 1.6mm stack

Impact Tester



Test temperatures:

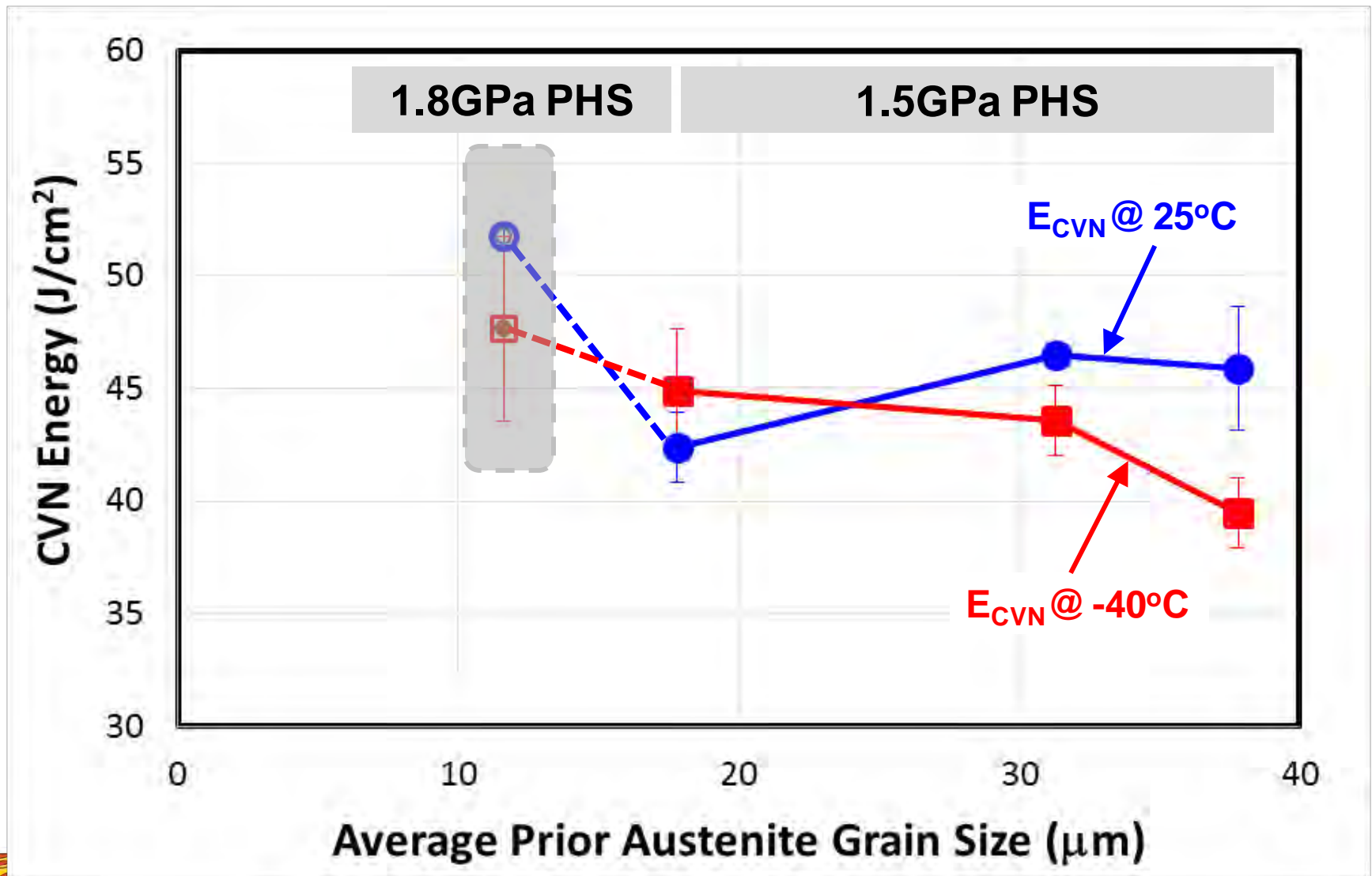
-125°C, -75°C, -40°C, -25°C, 0°C, 25°C and 75°C



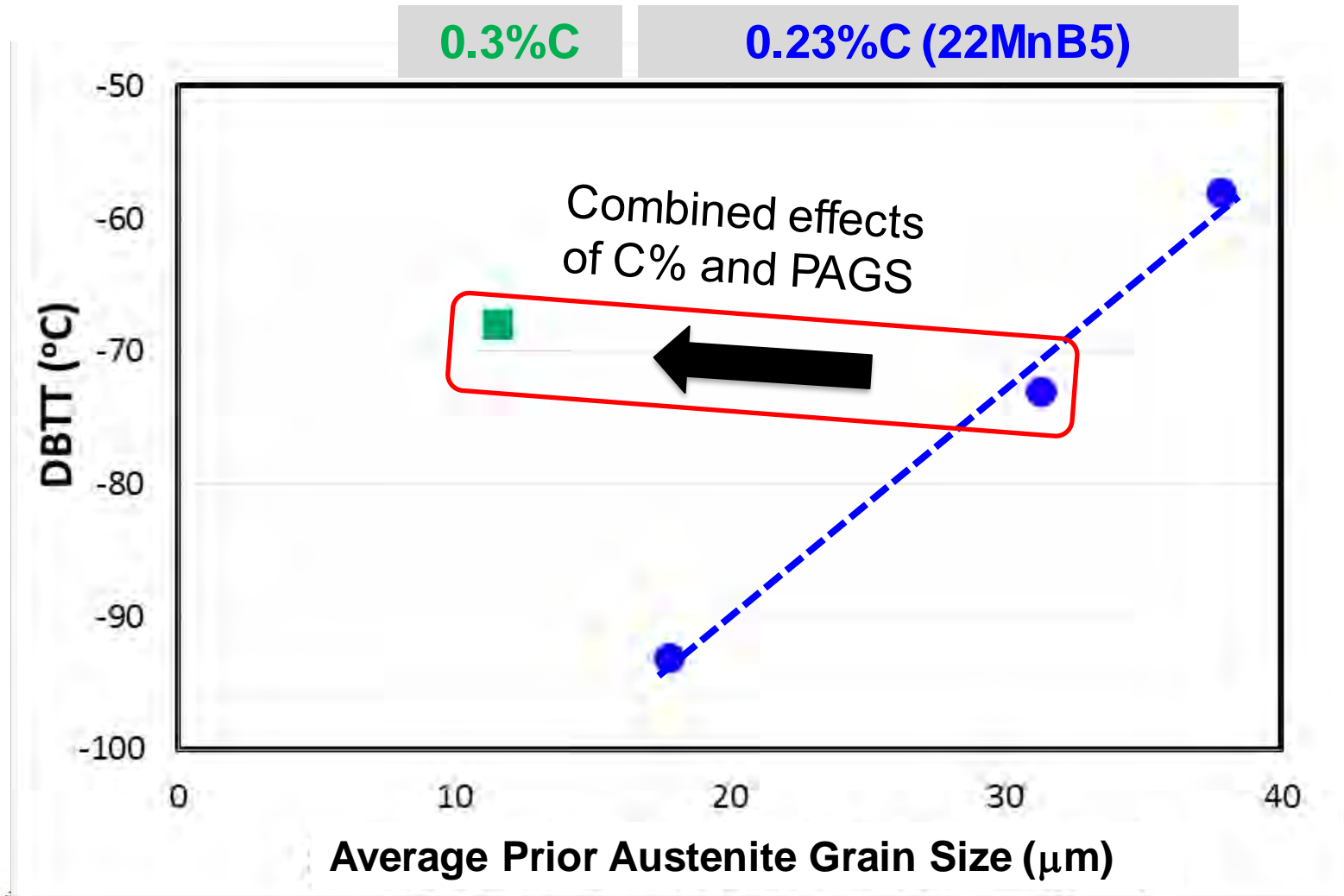
香港大學

THE UNIVERSITY OF HONG KONG

Results – Impact Energy vs Prior Austenite Grain Size



Results – DBTT vs Prior Austenite Grain Size



Summary 1

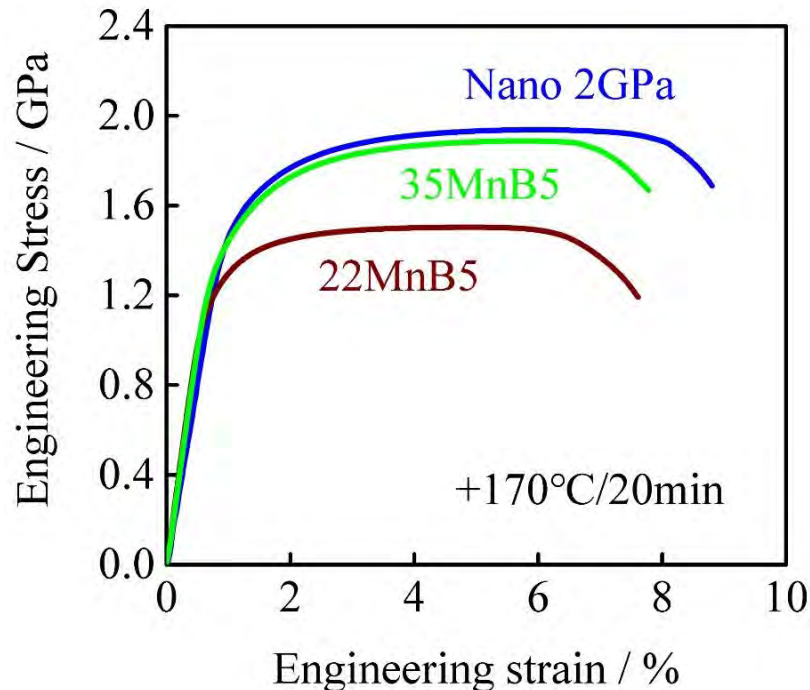
- Nb addition promotes grain refinement, resulting in better impact toughness
- Lower Ductile-to-brittle temperature DBTT increases from -93°C to -58°C



New generation PHS –

Enhanced toughness & resistance to delayed fracture

Vanadur® 2GPa



Material	A _{kv} (D.Q) / J	A _{kv} (D.Q+Bake) / J
Vanadur®2GPa	23.0 ± 0.7	31.5 ± 0.6
35MnB5	18.1 ± 1.4	28.8 ± 1.7
22MnB5	24.9 ± 1.1	32.5 ± 2.3

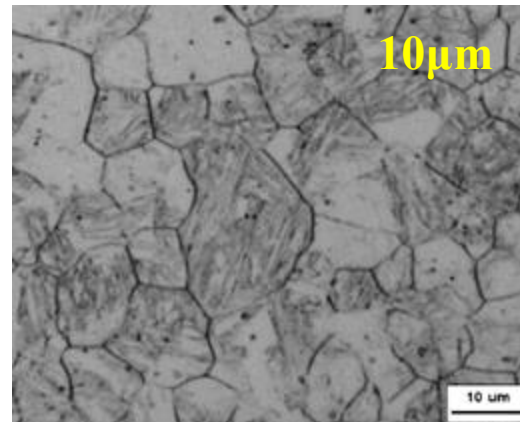
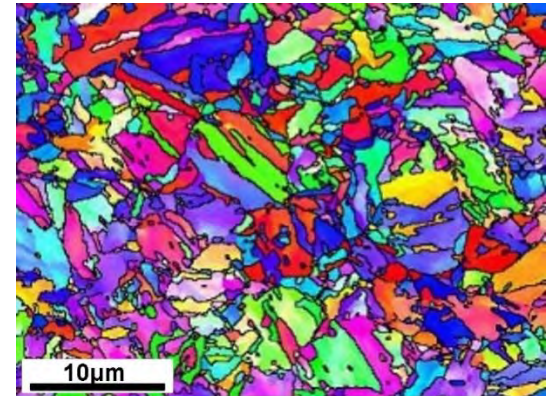
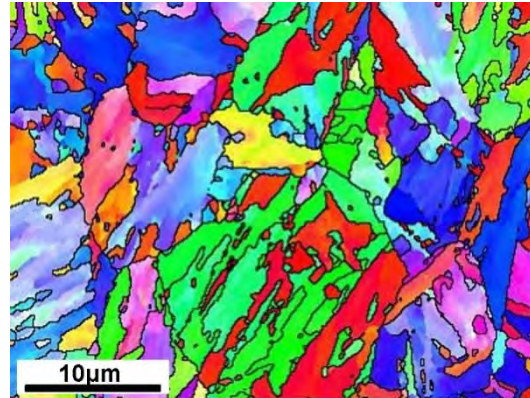


香港大學

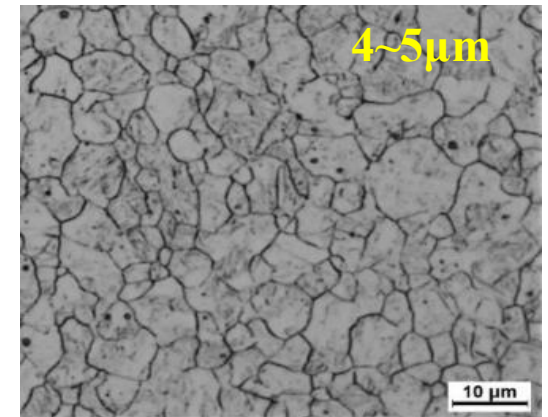
THE UNIVERSITY OF HONG KONG

Vanadur® 2GPa

- Grain refinement by VC



22MnB5



Nano VC 2GPa



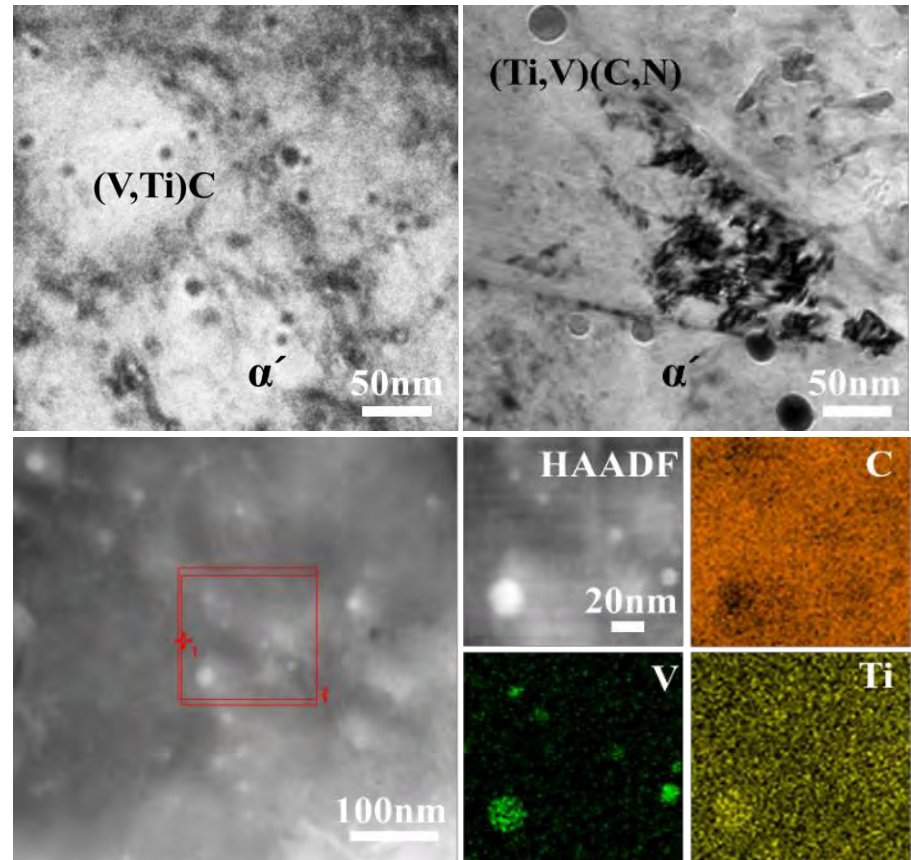
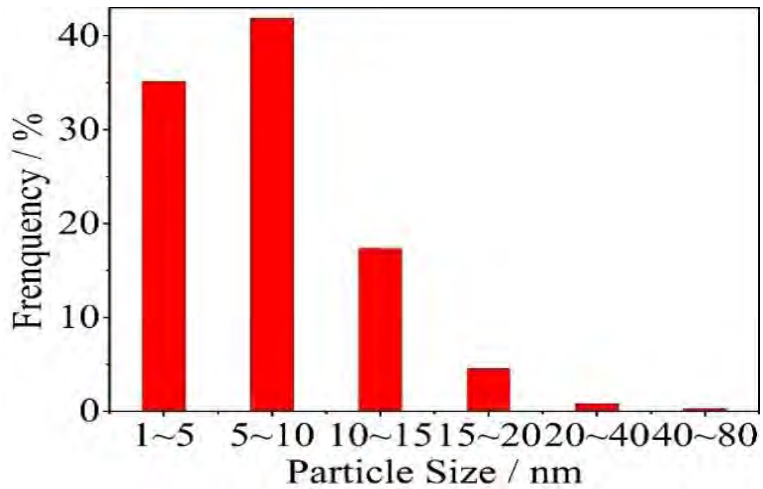
香港大學

THE UNIVERSITY OF HONG KONG

Vanadur® 2GPa

- VC precipitates :

- Toughening by grain refinement
- Toughening by reducing carbon in martensite (lath)
- Precipitate strengthening

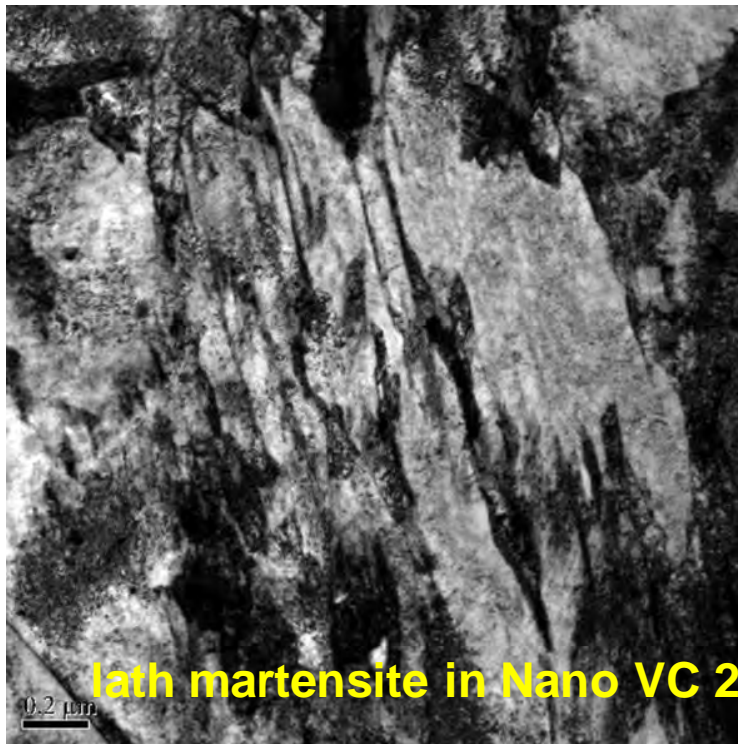


香港大學

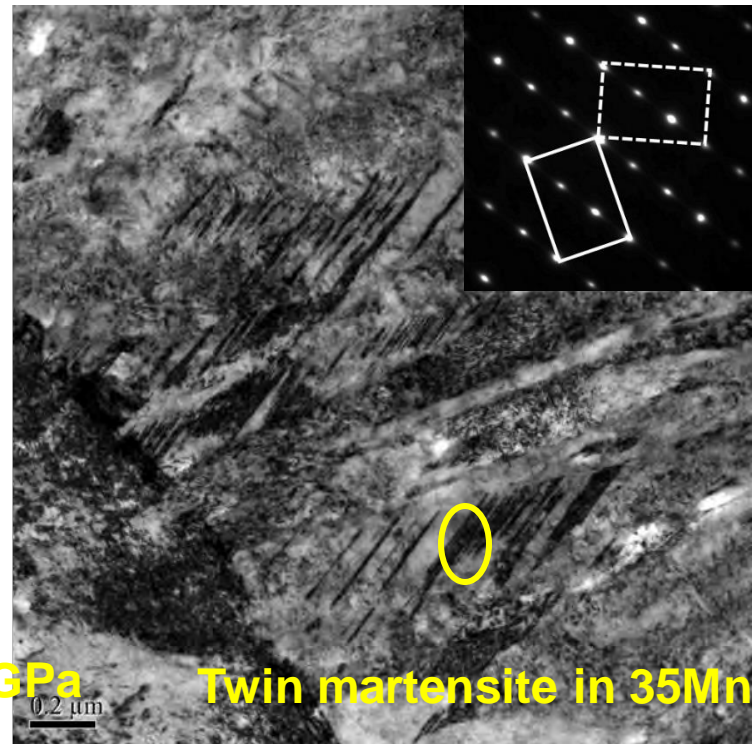
THE UNIVERSITY OF HONG KONG

Vanadur® 2GPa

- Vanadur® 2GPa: VC precipitates ~0.21 vol.%



lath martensite in Nano VC 2GPa



Twin martensite in 35MnB5



Vanadur® 2GPa

- First commercial application of 2GPa steel

Beijing Auto ARCFOX LITE 2017



香港大學

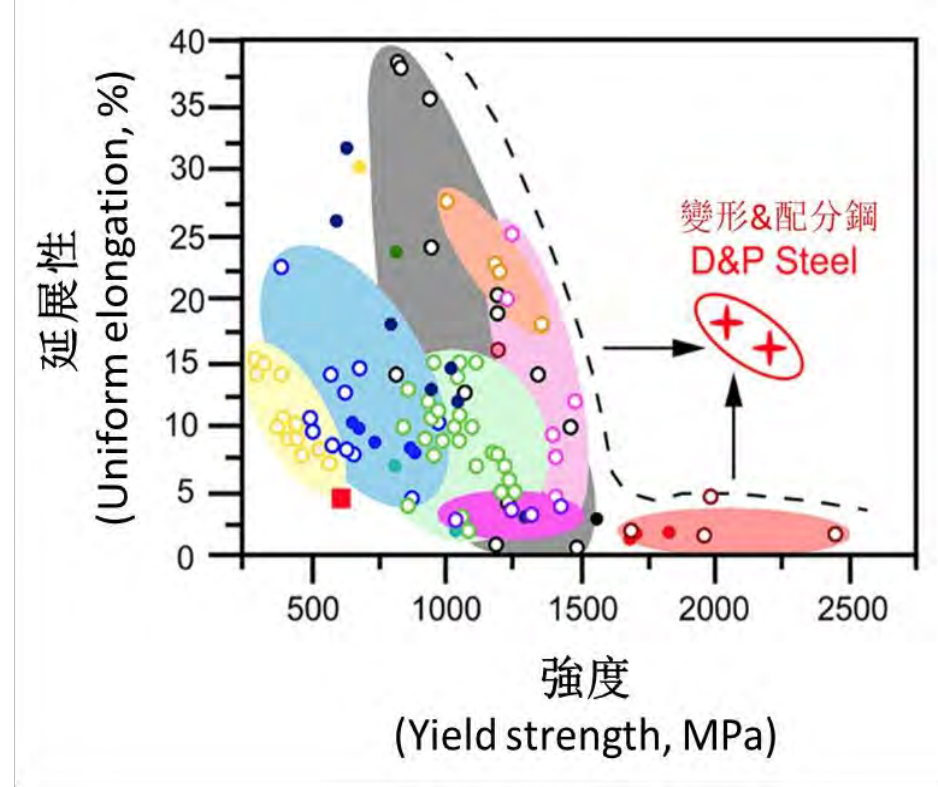
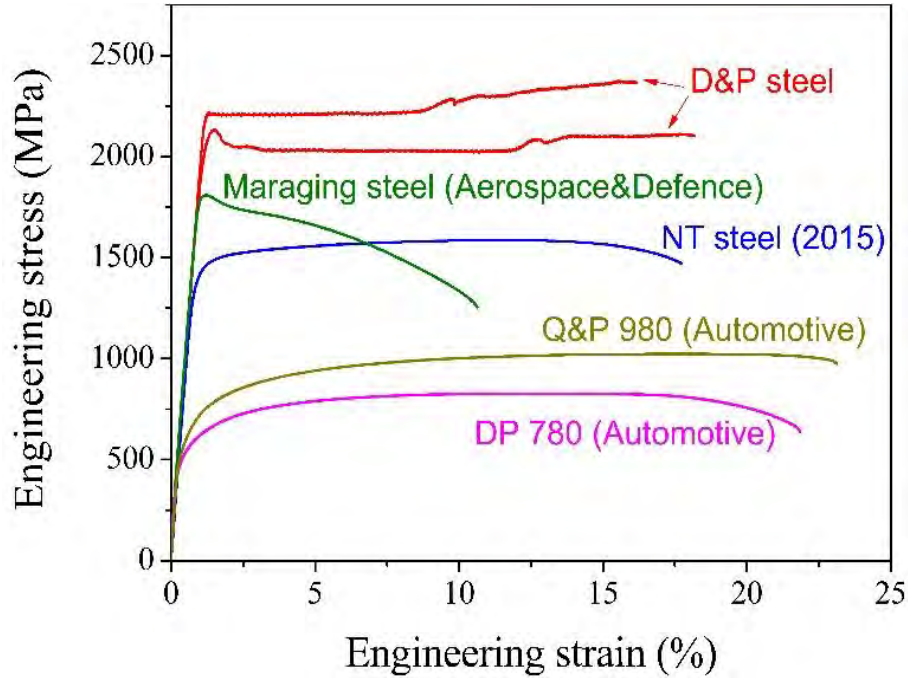
THE UNIVERSITY OF HONG KONG

Summary 2

- 2GPa strengthened by VC is a new generation PHS
- Good impact toughness, large ductility
- Good delayed fracture due to VC nanoprecipitates (detailed experiments are on ongoing)



Breakthrough AHSS



High dislocation density-induced large ductility in deformed and partitioned steels

B.B. He¹, B.Hu², H.W.Yen³, G.J.Cheng³, Z.K.Wang⁴, H.W.Luo^{2*}, M.X.Huang^{1*}



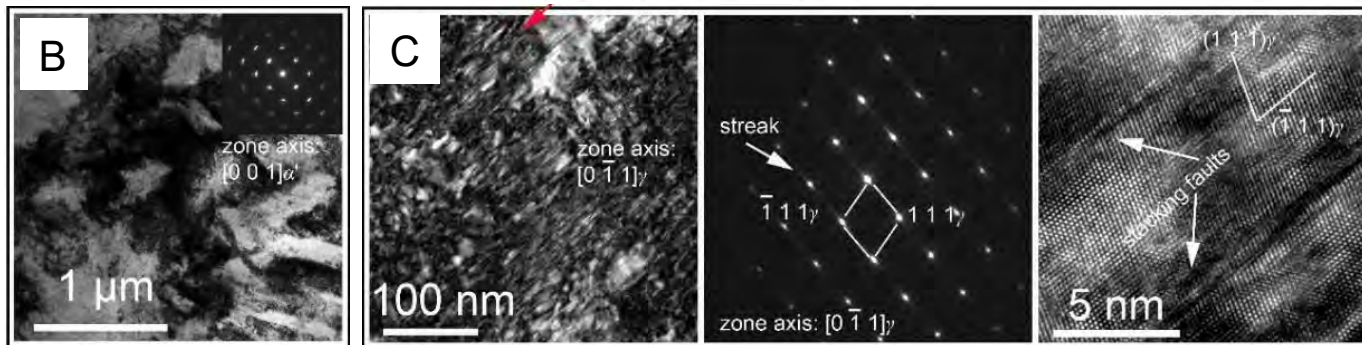
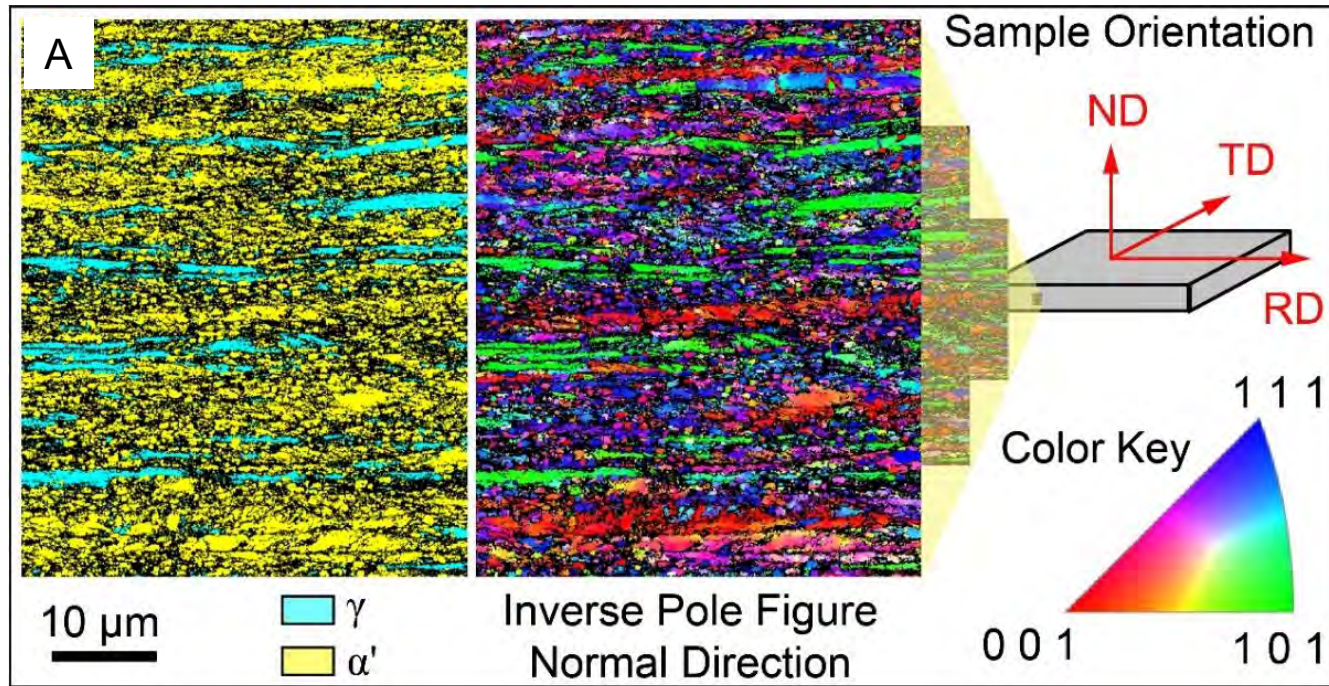
香港大學

THE UNIVERSITY OF HONG KONG

Science 357, 1029-1032 (2017)

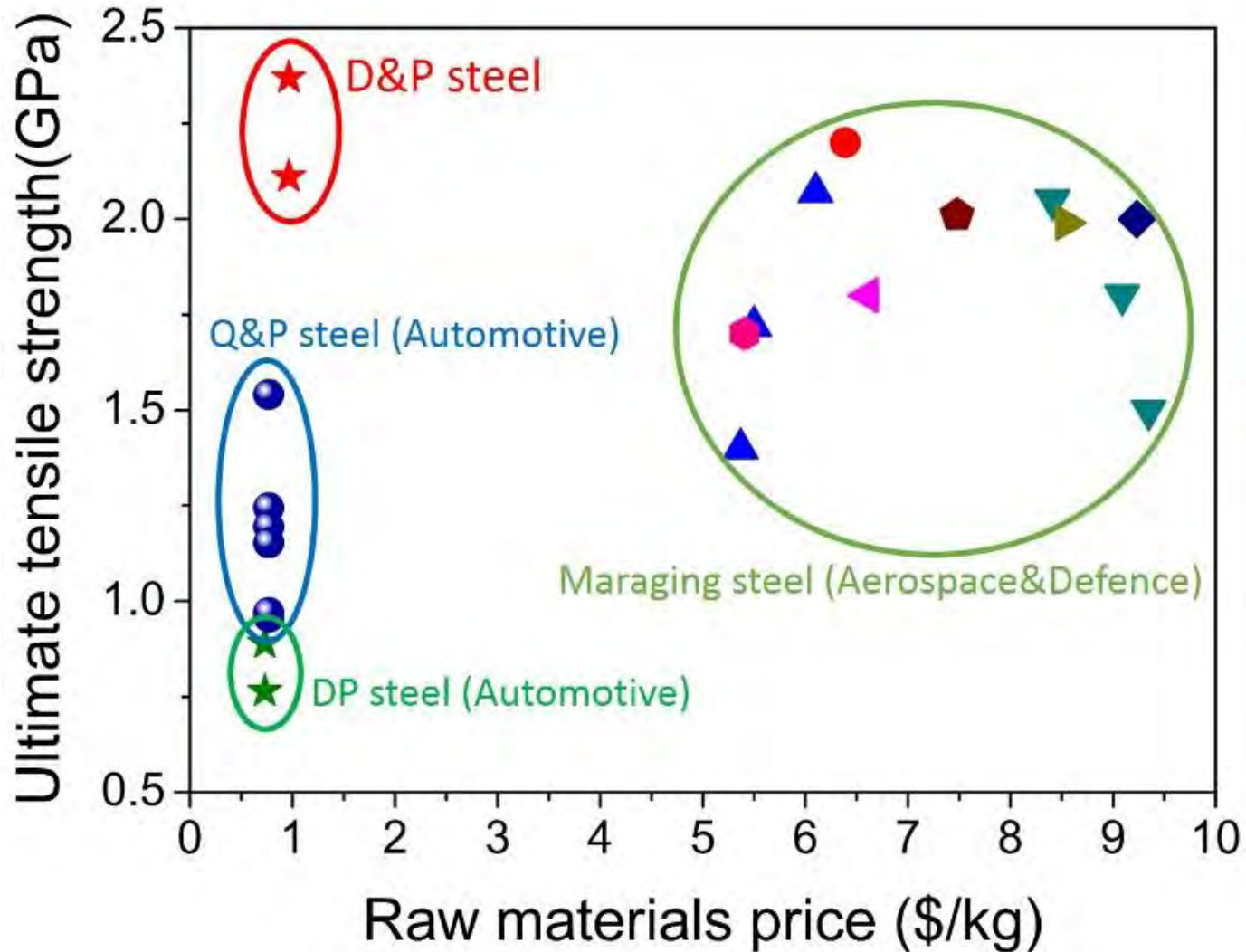


Microstructure of deformed and partitioned (D&P) steel



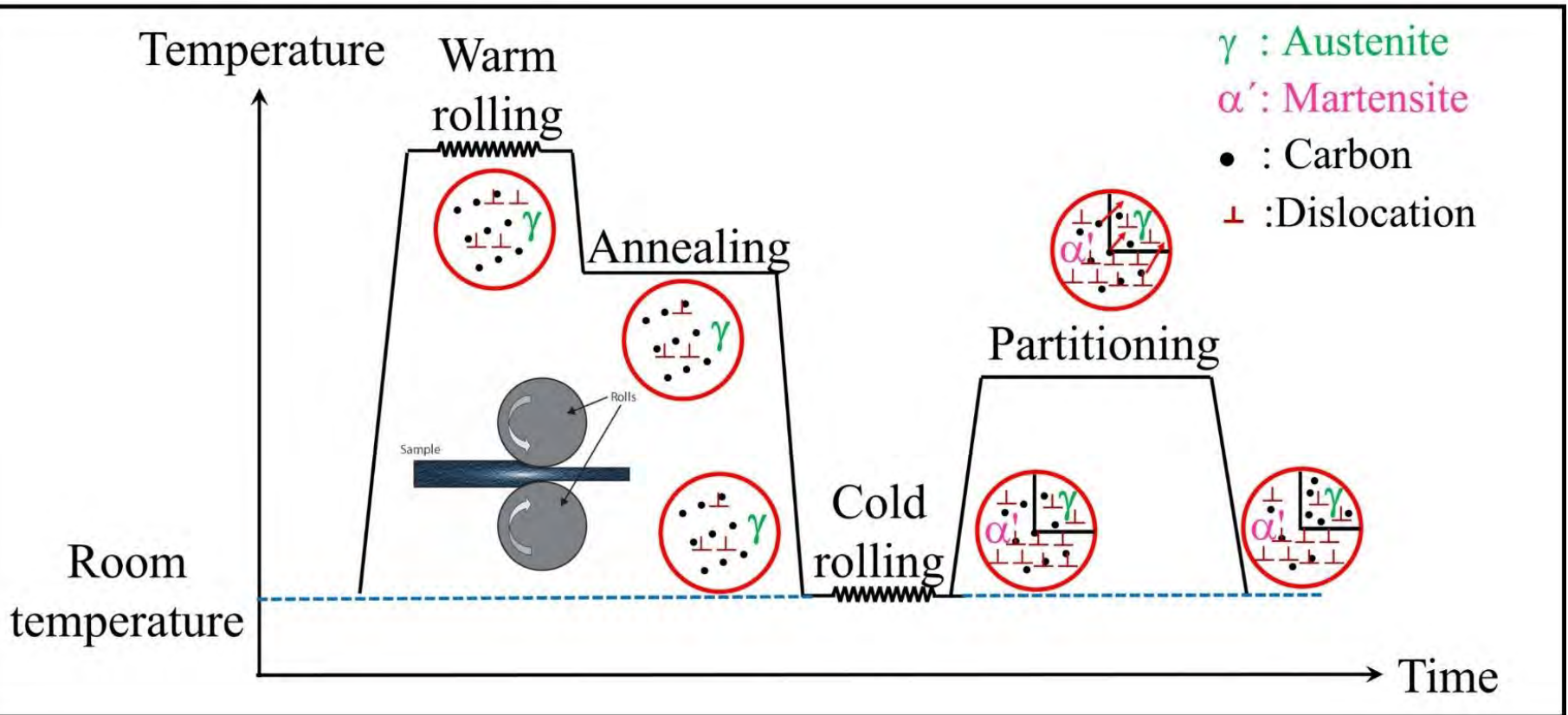
Advantages of the D&P steel

1) **Low raw-materials cost.** Fe-10Mn-0.47C-2Al—0.7V (wt%)

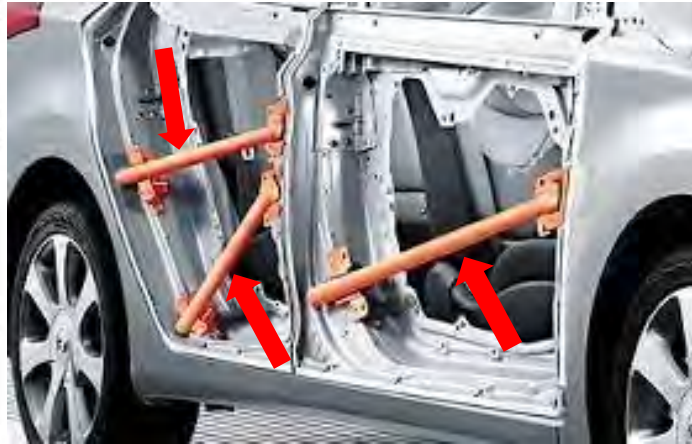
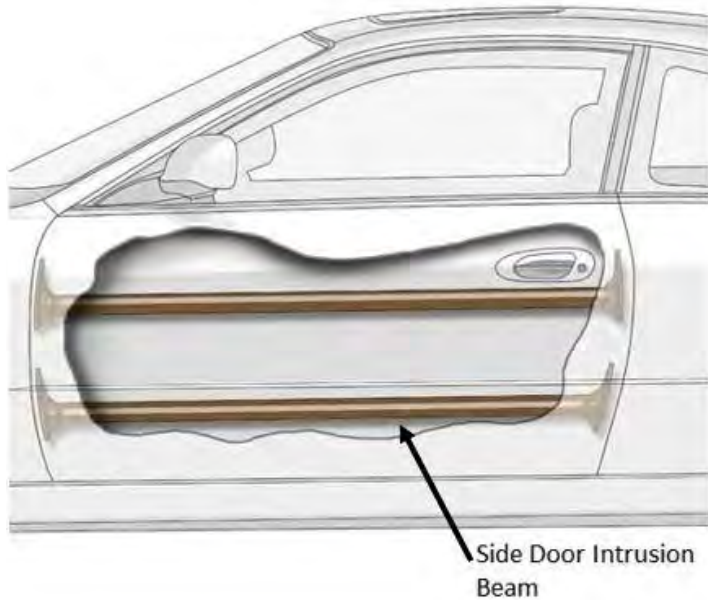


Advantages of the D&P steel

2) Simple processing routes suitable for massive production



Targeted application of D&P steel



Ref: Y.K. Nichit et al, IJSART 2017

Steel grade	Price	Weight reduction of door beam	Cost and safety for door beam
Q&P 980 steel	0.9 \$/kg	0%	Similar
D&P steel	1.2\$/kg	30%	

The application of the D&P steel can provide an **additional benefit of weight reduction** for automobile.



香港大學

THE UNIVERSITY OF HONG KONG

Summary 3

- Breakthrough steel with a yield stress of 2.2 Gpa and a uniform elongation of 16%
- Potential roll forming for automobile application
- High fracture toughness
- Good delayed fracture due to VC nanoprecipitates (detailed experiments are on ongoing)



Thank you!
Q&A



香港大學

THE UNIVERSITY OF HONG KONG