Does Ms temperature increase or decrease after deformation of austenite?

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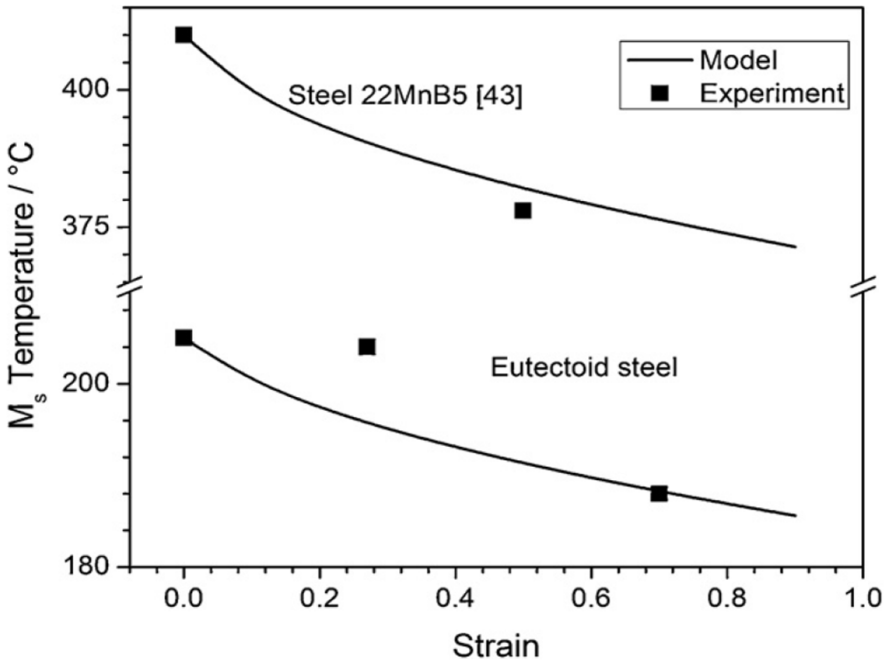
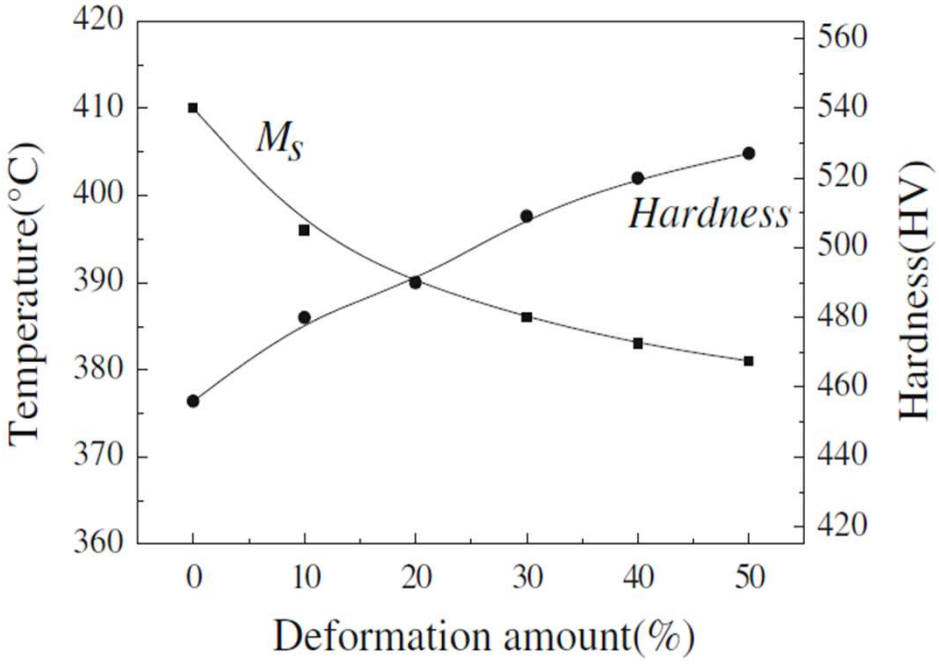
Introduction

Most results in literature show that deformation austenite at high temperature leads to the decrease of Ms temperature due to mechanical stabilation.



Fe-**0.75C**-1.02Mn-0.28Si-0.11Cr-0.05Ni (wt%) [1]



Fe-0.96C-1.71Si-1.64Mn-0.028Ti-0.0076B (at.%) [2]

Why deformation can affect Ms?

Can austenite deformation increase Ms temperature?

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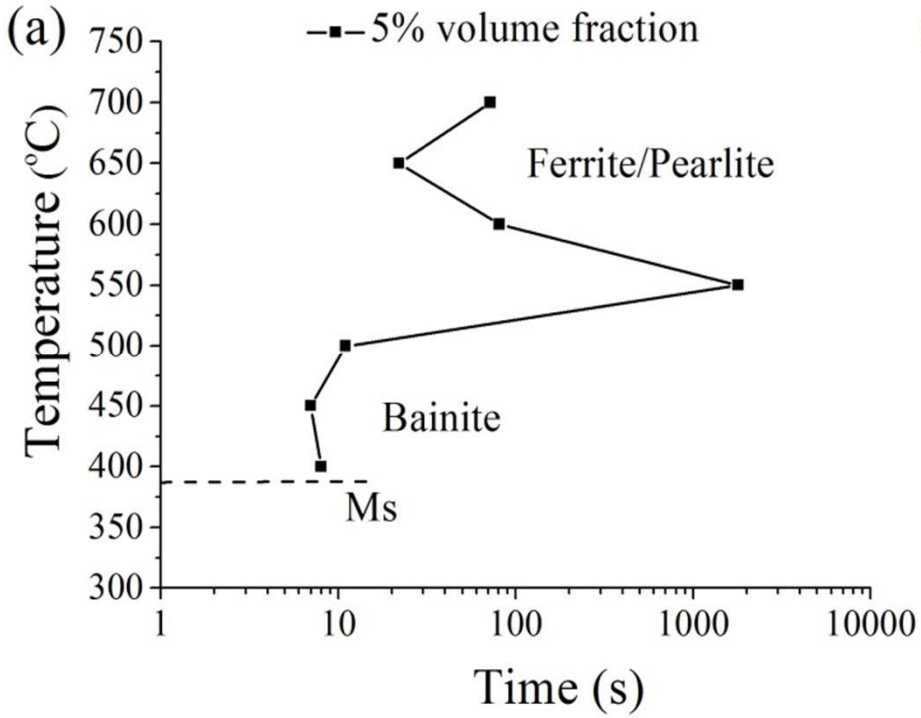
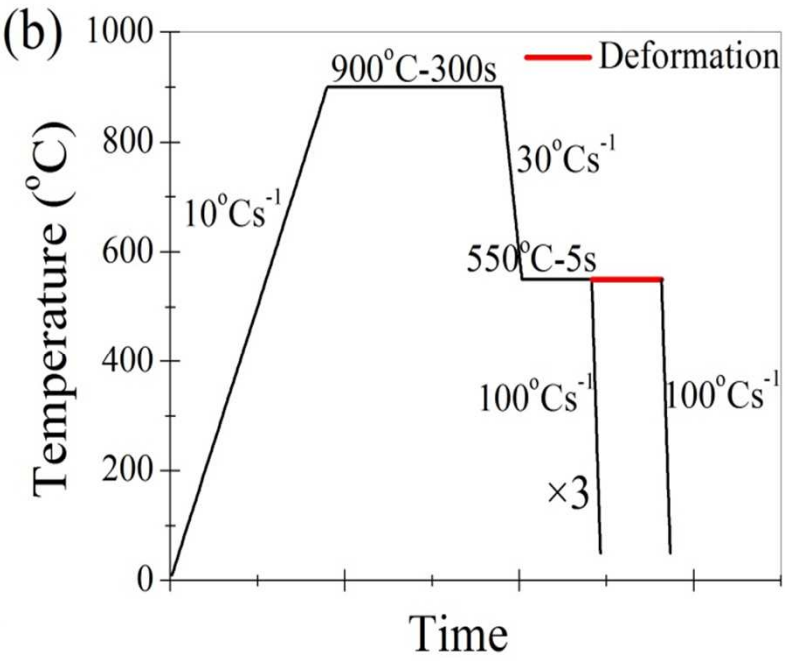
[1] M.Maalekian et al. Mater. Sci. Eng., A 2011

[2] Z.M. Shi et al. Metall. Mater. Trans. A 2013

Experiments

Fe-0.2C-1.5Mn-2Cr (wt%)





(a) The TTT diagram of the present steel. The ideal deformation temperature 550 °C. No bainite transformaiton, no dynamic recrystallization

(b) Temperature- deformation program

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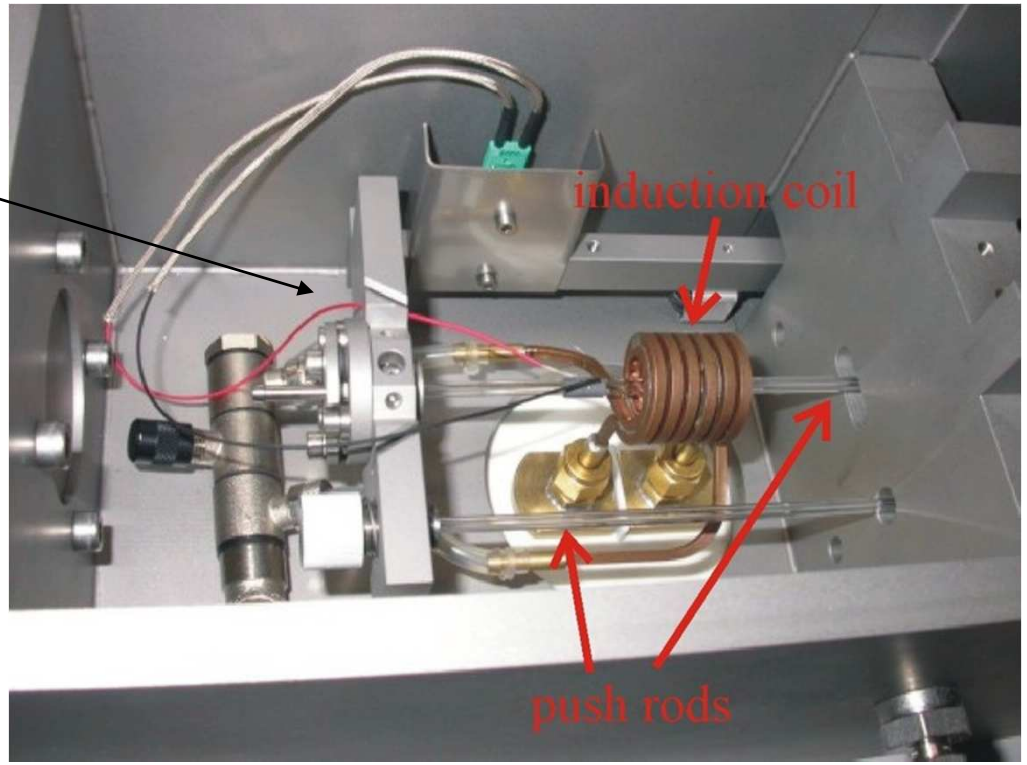
Experiments

Fe-0.2C-1.5Mn-2Cr (wt%)

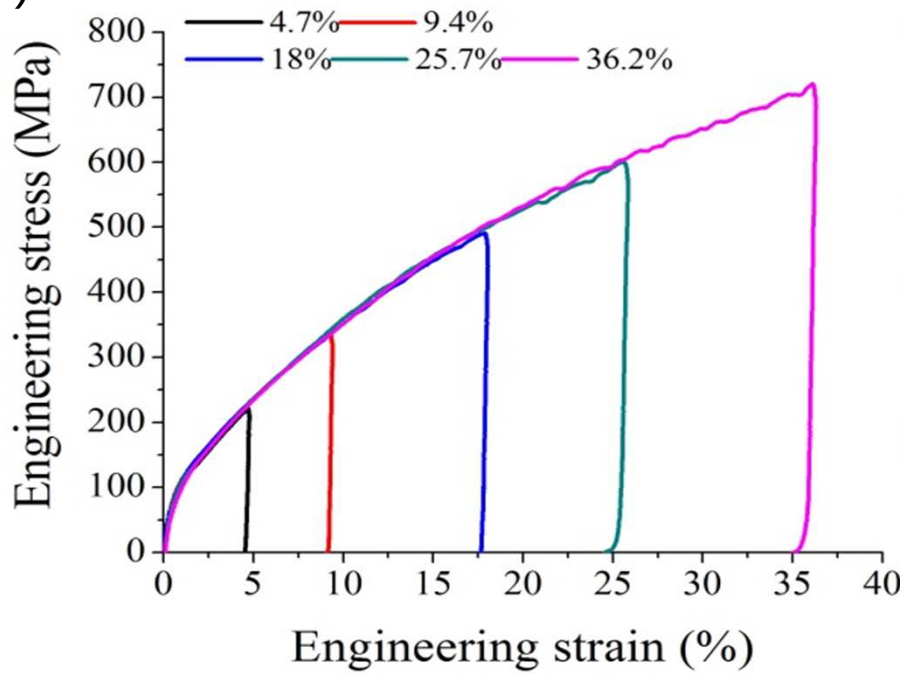
Dilatometer



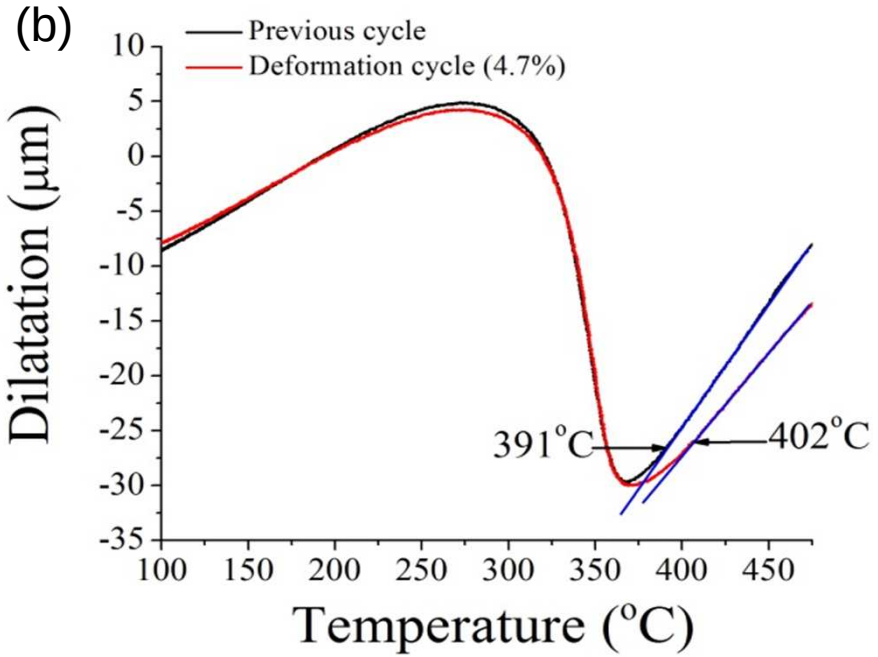
Dilatometer sample: D: 5 mm; L: 10 mm

Experimental results

(a)

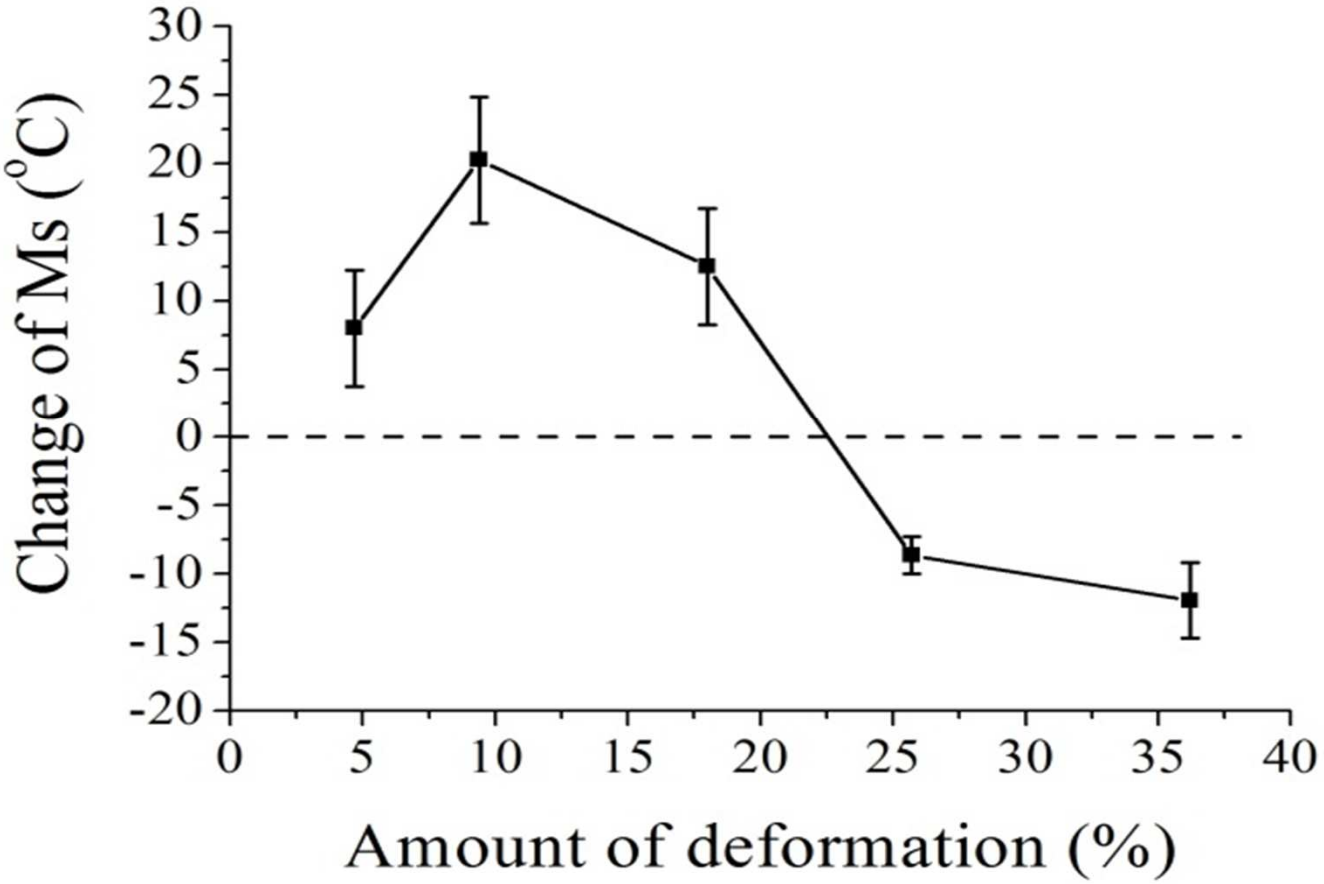


(b)



Experimental results

(c)



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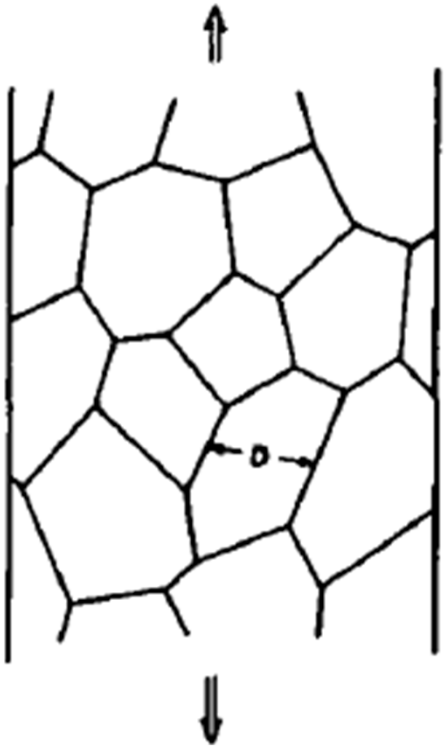
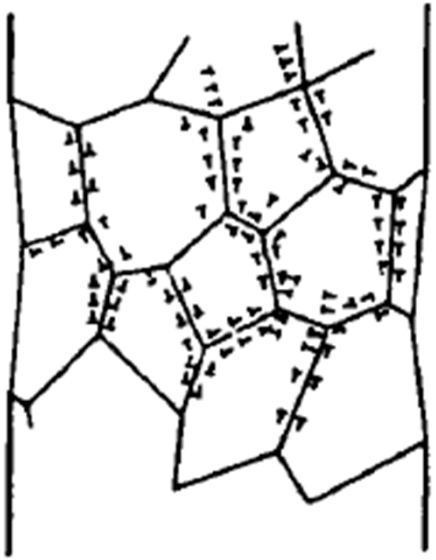
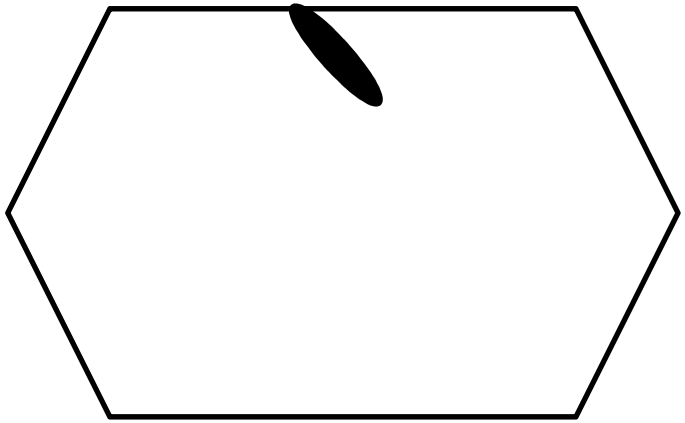
Geometrically necessary dislocations (GND) at grain boundaries



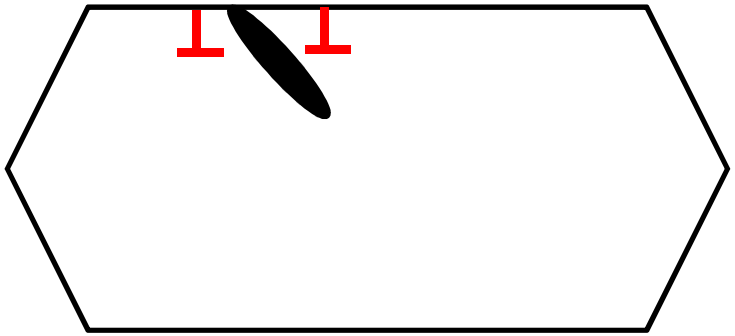


M.F. Ashby, Philosophical Magazine 21 (1970) 399

Why Ms increases with strain?



Ms 391 oC



Ms 402 ^{o}C

According to Kaufman and Cohen, the martensite embryo may pre-exist at austenite grain boundaries.

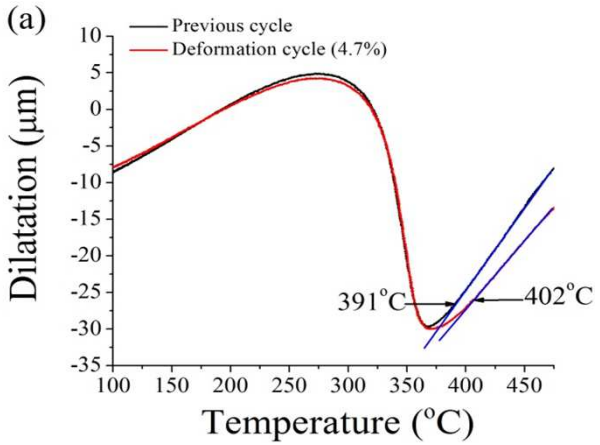
GND at grain austenite grain boundaries increase Ms, why ?

L. Kaufman, M. Cohen, Prog. Metal Phys., 7 (1958) 165-246.

Why Ms increases with strain?

$$f = n_0 V \exp(-\frac{\Delta G_0 - \Delta G_{disl}}{kT})$$

(f =~5% Ms can be detected by dilatometer machine)



f : Volume fraction of martensite

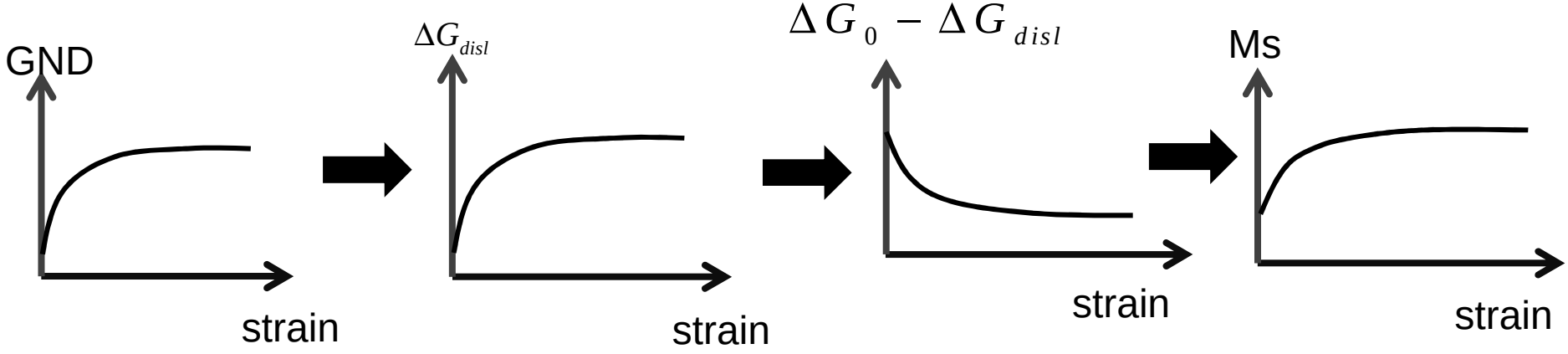
n_0 : number of embryos per unit volume (m^{-3})

V : volume of a martensite lath

ΔG_0 : energy barrier for embryo to grow into martensite lath

ΔG_{disl} : energy provided by dislocations (GND)

exp(): probability of an embryo growing to a matensite lath



It seems that Ms should increase with strain and be constant, but..

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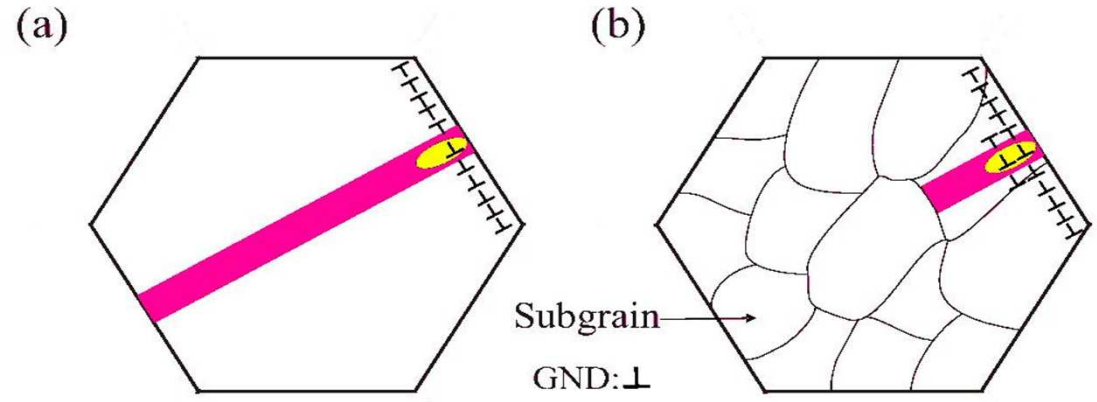
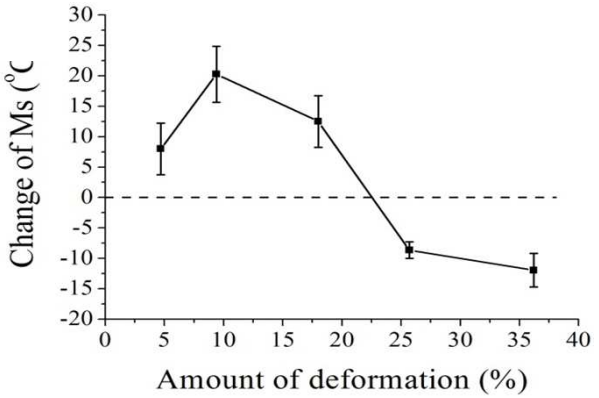
Why Ms decreases with strain?

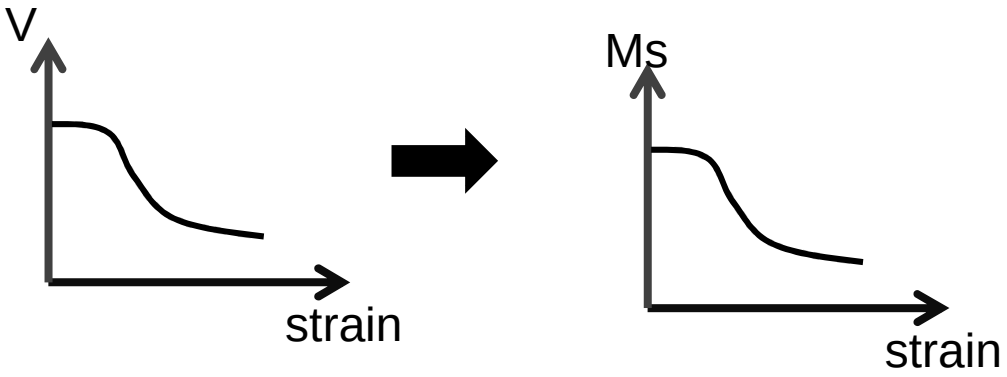


Small strain

Large strain



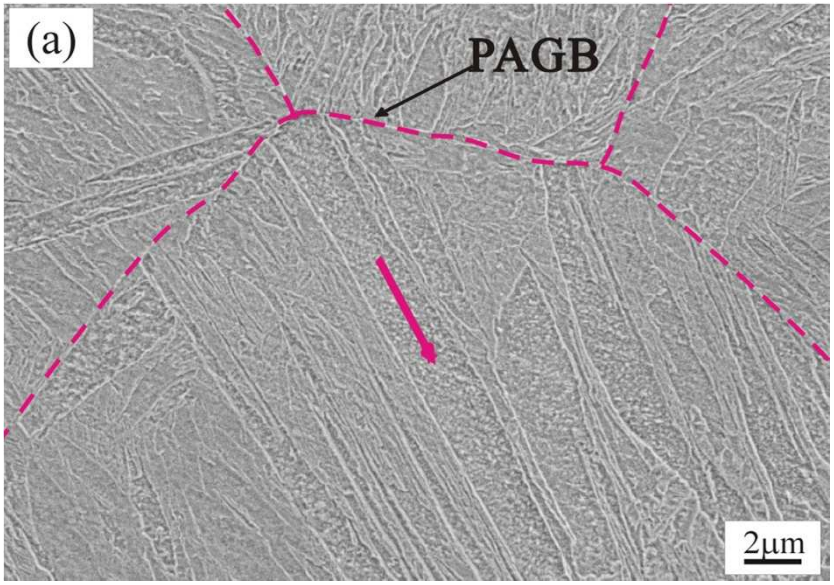
$$f = n_0 V \exp(-\frac{\Delta G_0 - \Delta G_{disl}}{kT})$$

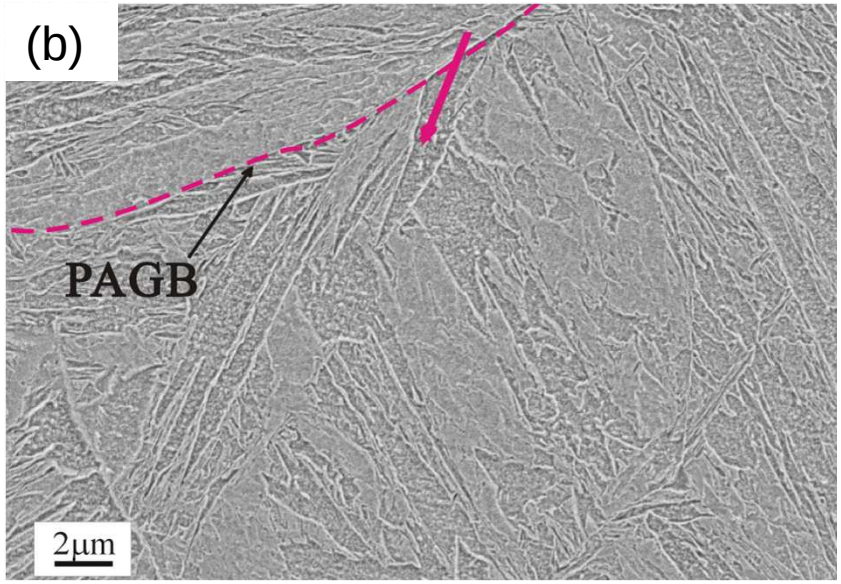


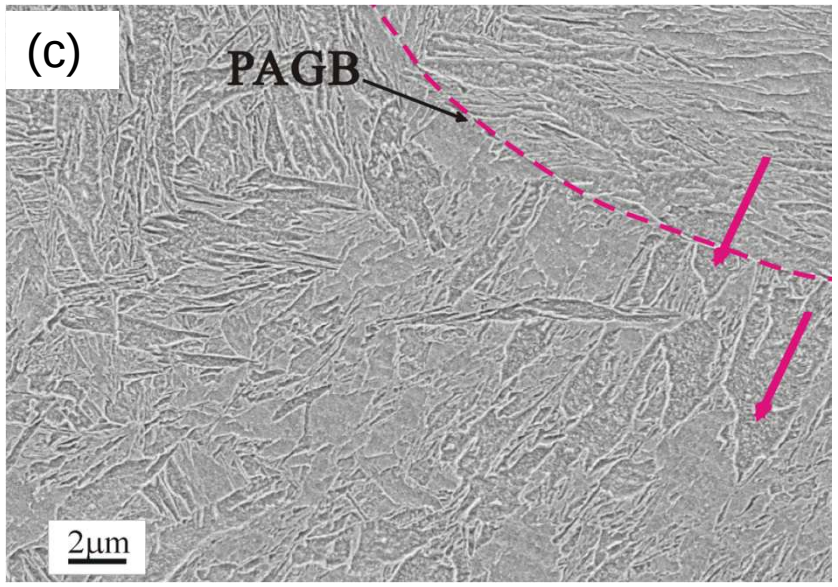
In order to have ~%5 volume fraction, more embryos should be activated, indicating lower energy barrier and therefore lower temperature.

Dislocations in grain interior decrease the Ms.

Martensite size decreases with strains







(a) 4.7%
(b) 18%
(c) 25.7%

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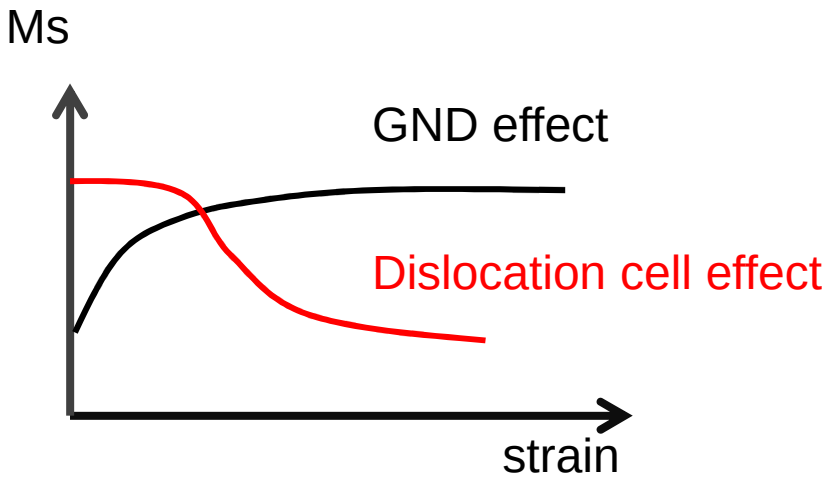
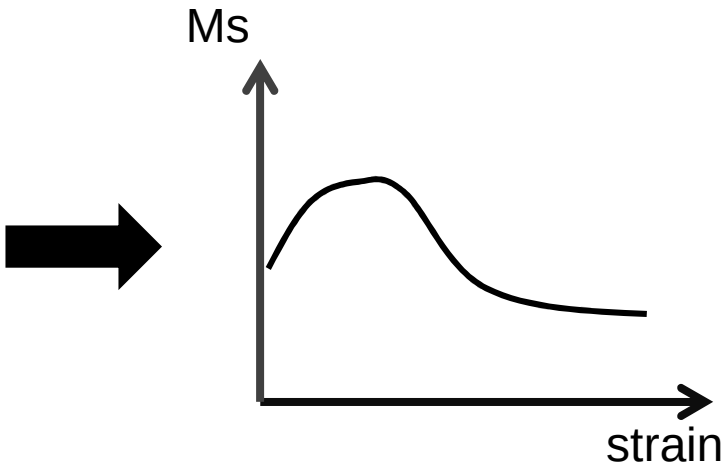
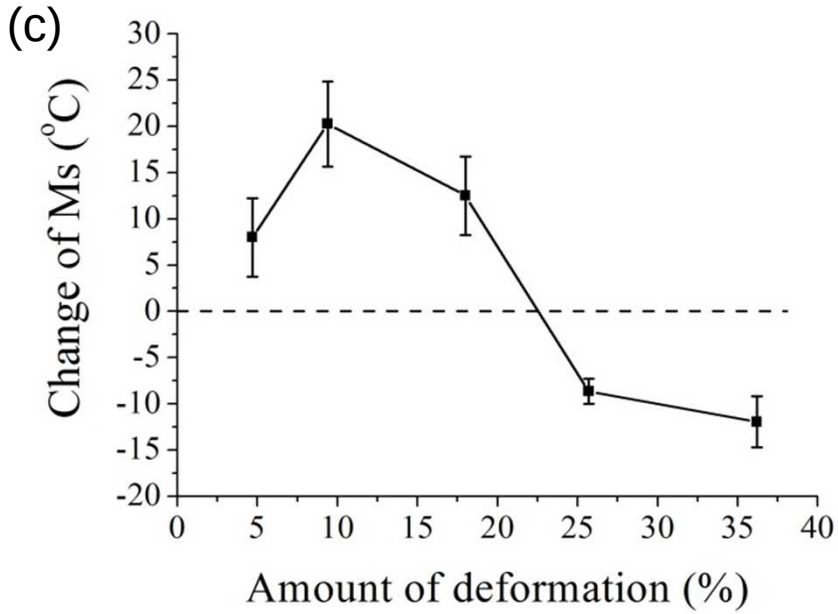
Ms vs strains





Dislocations at austenite grain boundaries increase Ms.

Dislocations in grain interior decrease Ms.



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Conclusions

1. A unified theory based on dislocations can be used to explain both the increase and decrease of Ms with strain.
2. Ms increases with deformation at small strains and decreases with deformation at large strains.
3. Dislocations at grain boundaries are responsible for the increase of Ms.
4. Dislocations in the austenite grain interior are responsible for the decrease of Ms.

Thank you for your attention!