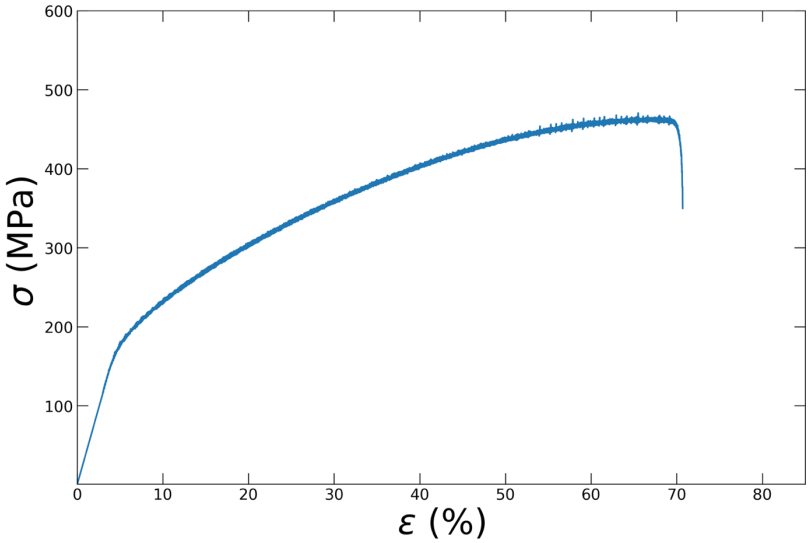
7.1 塑性形变与位错 (单晶)

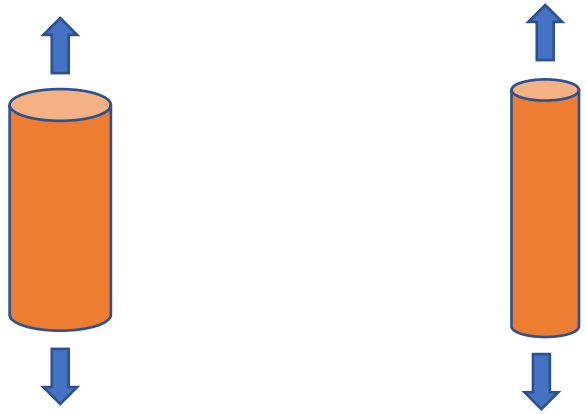
Dongsheng Wen

bubble model
https://www.youtube.com/watch?v=UEB39-jlmdw&t=2s
real examples:
https://kacherlab.gatech.edu/tools-for-teaching/
very nice lecture notes on:
https://www.doitpoms.ac.uk/tlplib/dislocations/index.php
https://ocw.mit.edu/courses/materials-science-and-engineering/3-11-mechanics-of-materials-fall-1999/modules/MIT3_11F99_dn.pdf
direct observation, very nice videos!
Kim, S., Park, J.Y., Park, S. *et al.* Direct observation of dislocation plasticity in high-Mn lightweight steel by *in-situ* TEM. *Sci Rep* **9,** 15171 (2019).
https://doi.org/10.1038/s41598-019-51586-y
https://www.nature.com/articles/s41598-019-51586-y#article-comments
Schematic simulations:
https://ocw.mit.edu/resources/res-3-004-visualizing-materials-science-fall-2017/student-projects-by-year/2017-MIT/visualizing-the-energies-of-screw-dislocations/visualizing-the-energies-of-screw-dislocations/

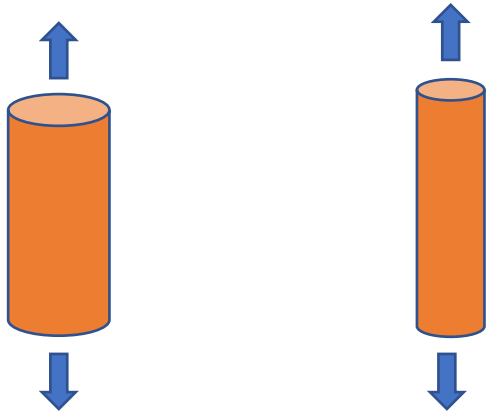
应力-应变曲线

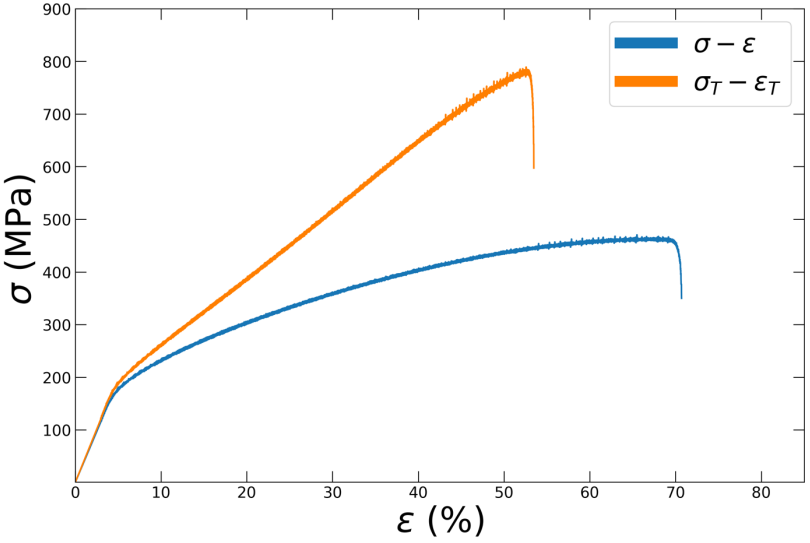
- 工程应力-应变曲线的问题





真应力-真应变曲线



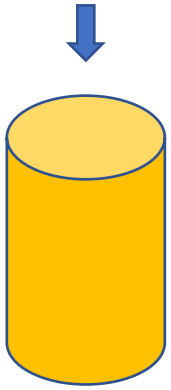

$\sigma - \varepsilon$
$\sigma_T - \varepsilon_T$
σ (MPa)
ε (%)
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80

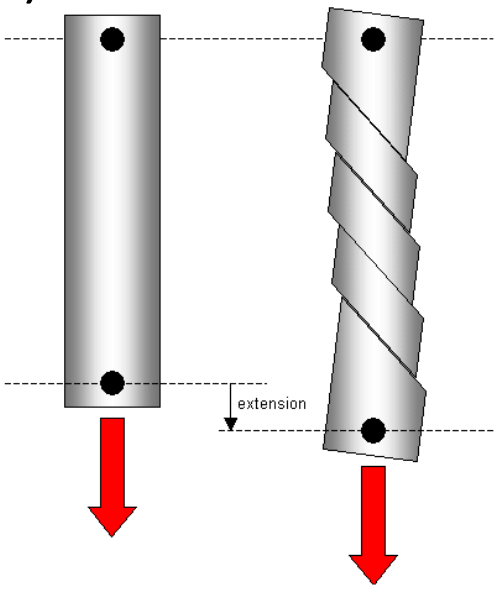
均匀的塑性形变怎么来的？

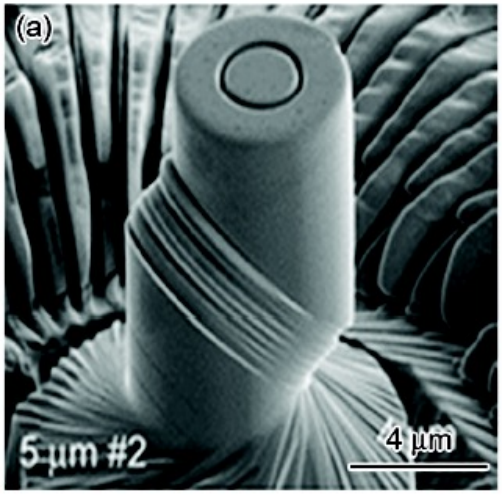
单晶

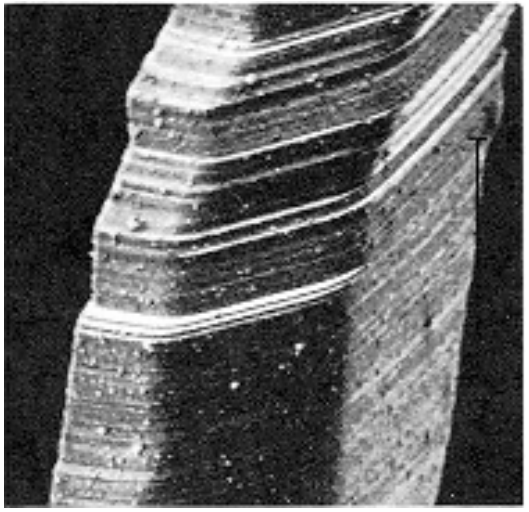
多晶

均匀的塑性形变怎么来的？(单晶)



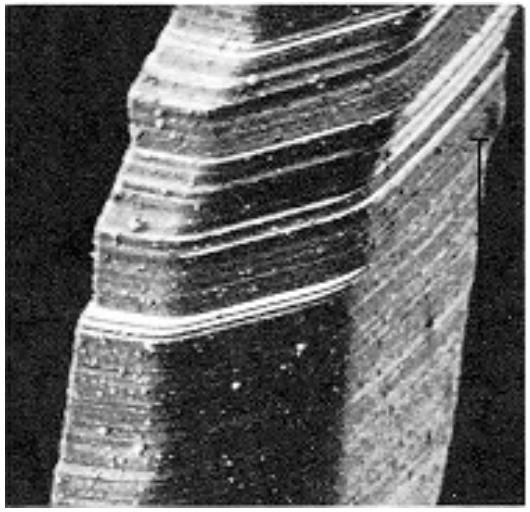


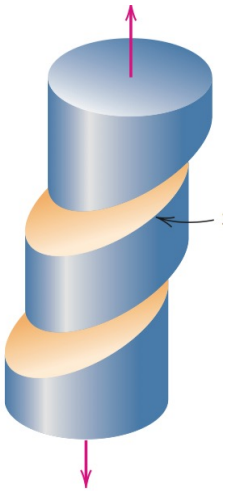


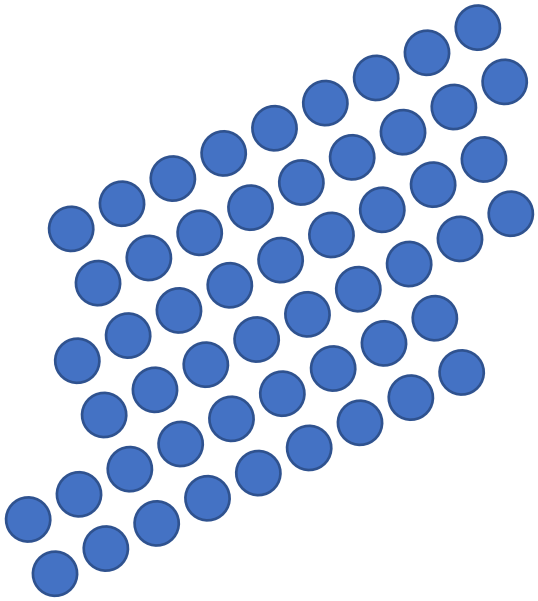


GUO, X., SUN, C., WANG, C., QIAN, L. and LIU, F., 2018. Investigation of Strain Rate Effect by Three-Dimensional Discrete Dislocation Dynamics for fcc Single Crystal During Compression Process. *Acta Metall Sin*, *54*(9), pp.1322-1332.

为啥不沿着施力方向？

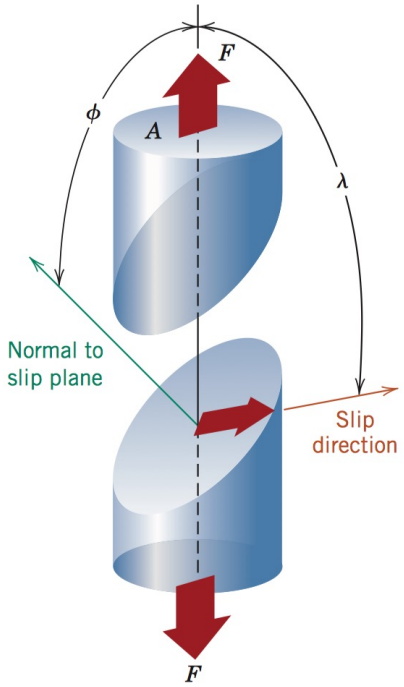




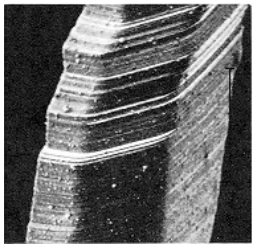


取向因子 (Schmid factor)

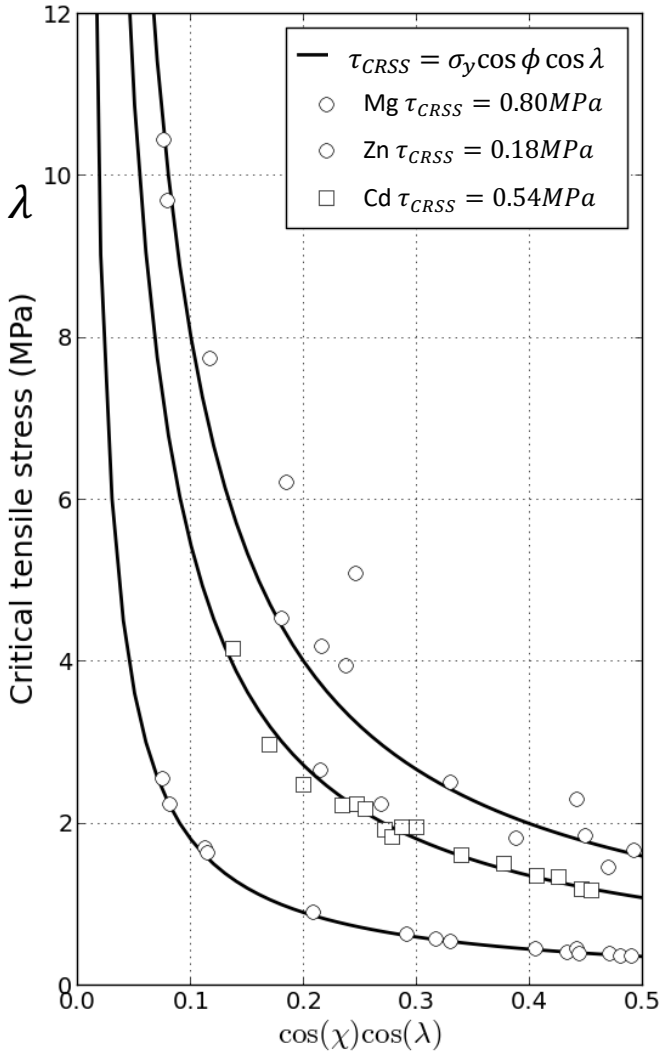
$$\tau = \sigma \cos\phi \cos\lambda$$



产生滑移的时候。。。



$$\tau = \sigma \cos\phi \cos\lambda$$

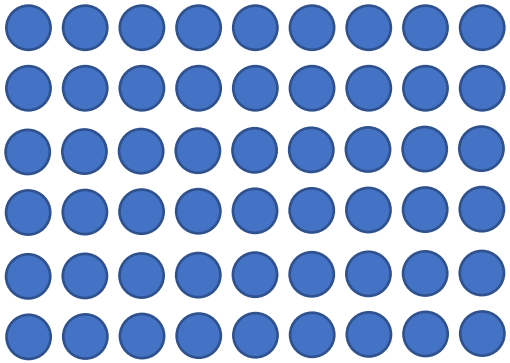


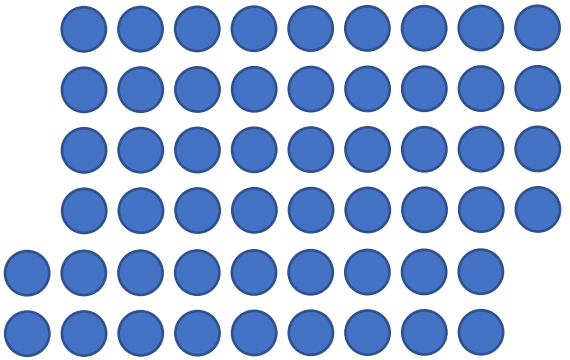
Mg data from [Schmid1950]
Zn data from [Jillson]
Cd data from [Andrade & Roscoe]

SAFRAN

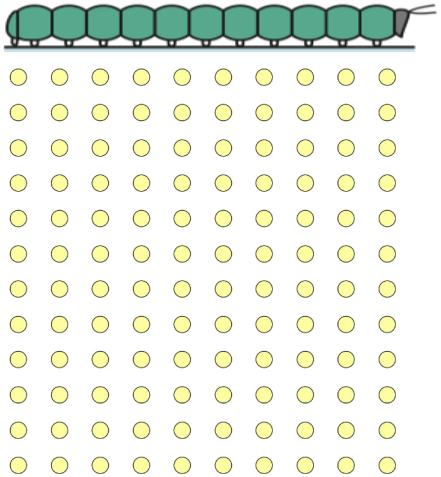
Lionel MARCIN (Safran Tech/M&P), lionel.marcin@safrangroup.com

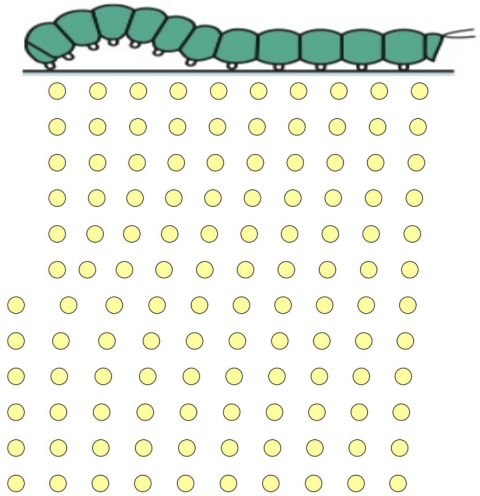
怎么发生滑移？

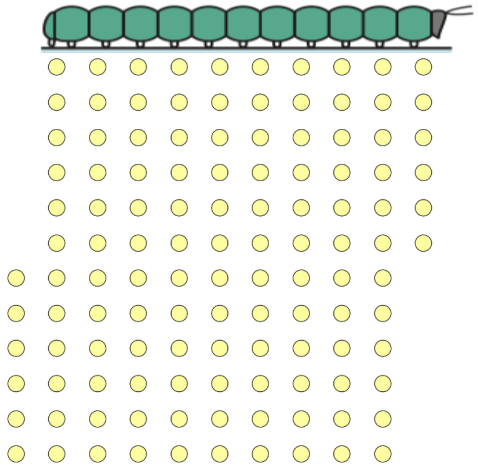


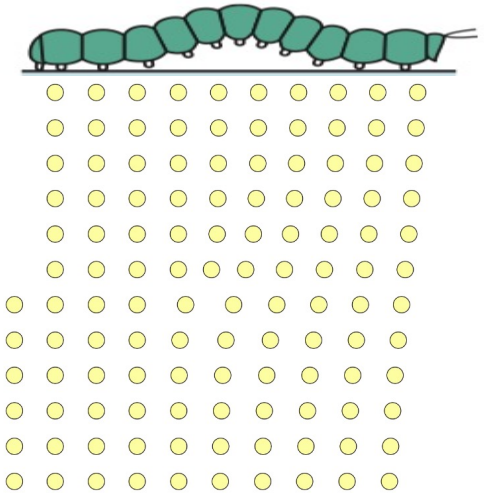


位错 (Dislocation)



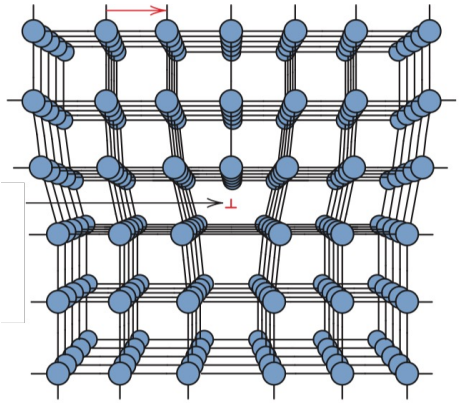


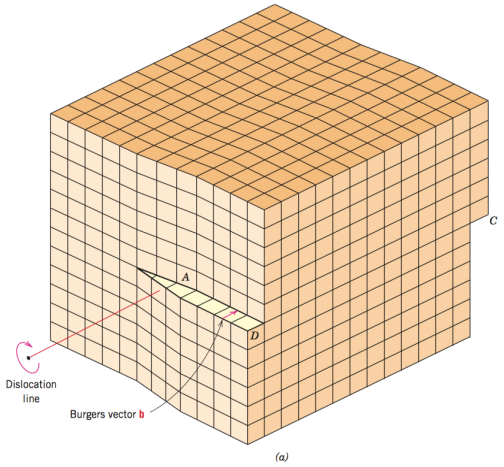




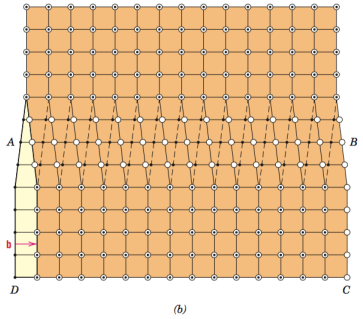
位错 (Dislocation)

- 一维的缺陷。

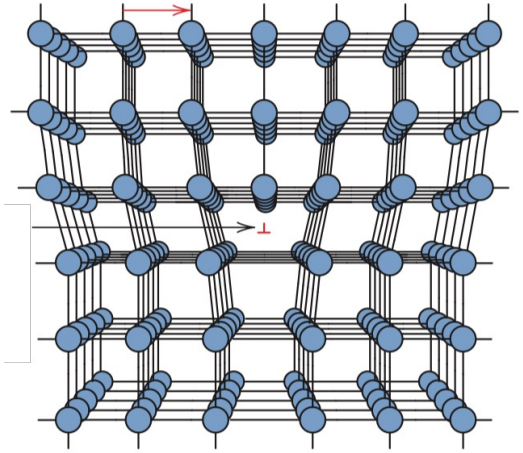




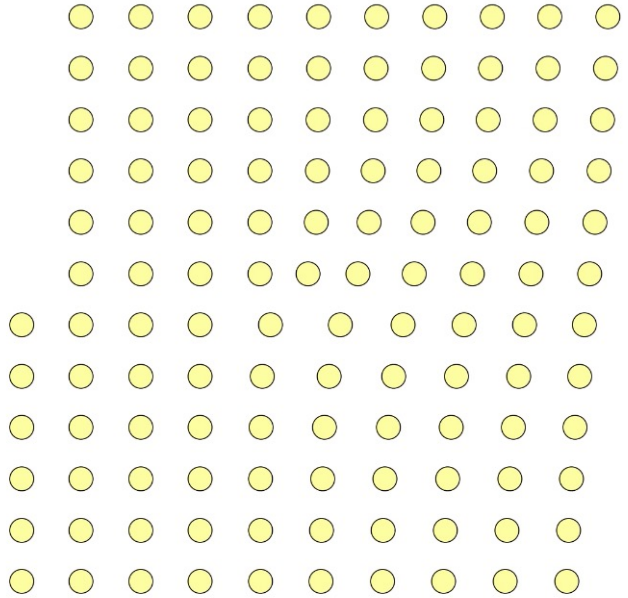
- 我们需要知道哪些位错的信息呢？
  - 类型
  - 晶格畸变
  - 方向



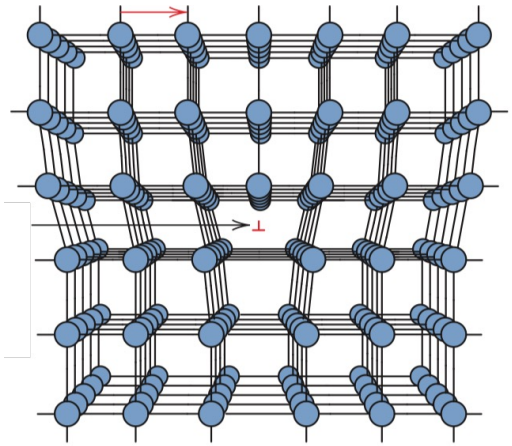
刃位错 (edge dislocation)

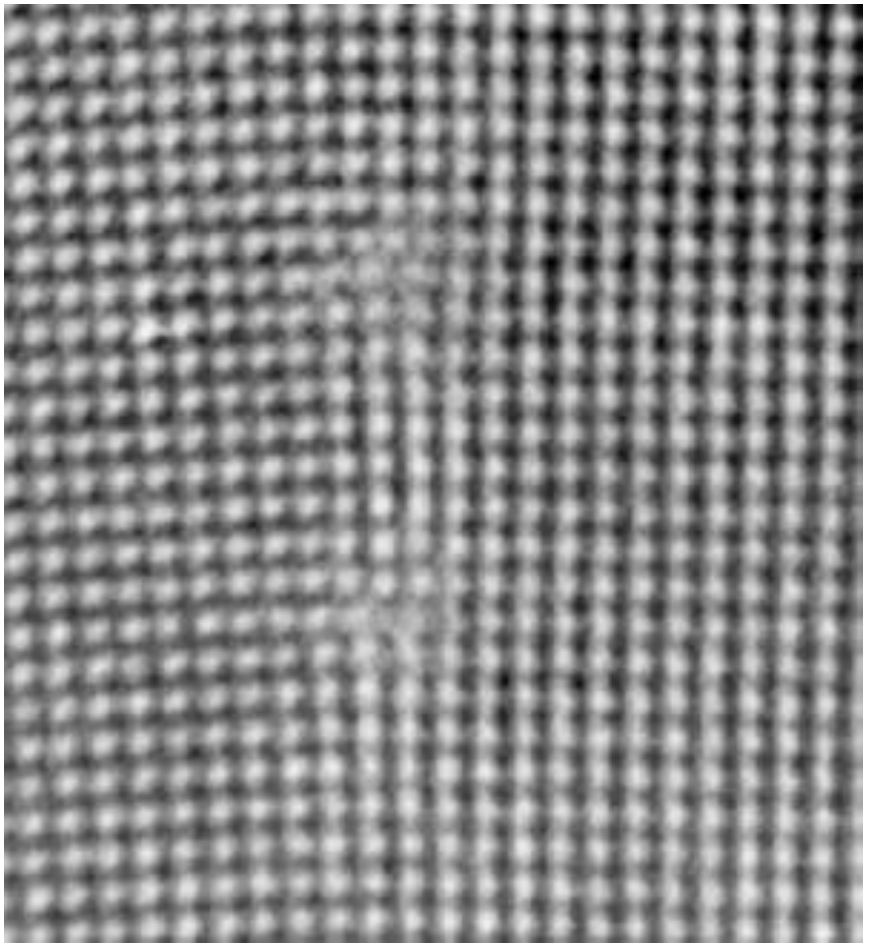


- 伯氏矢量标定
  - 右手法则



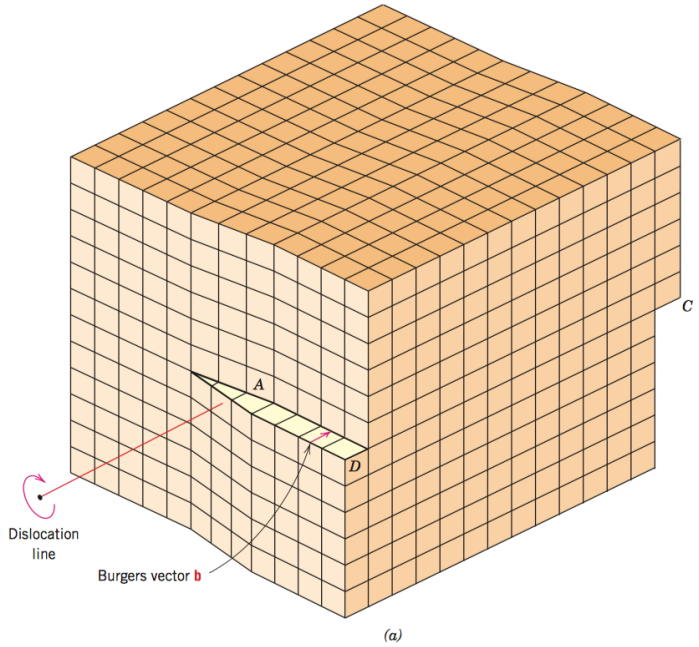
刃位错 (edge dislocation)



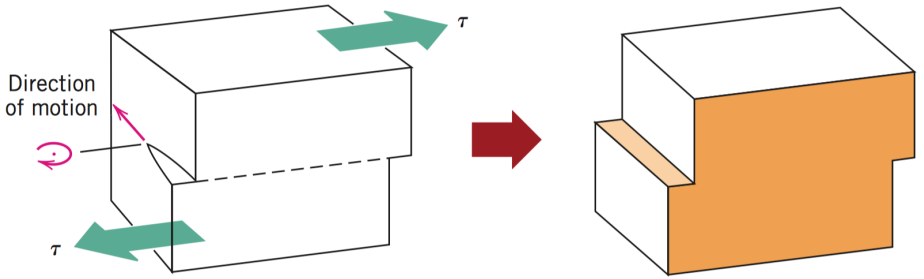


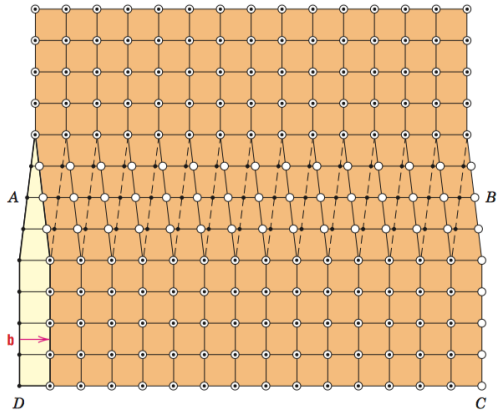
Sigle, W., Sarbu, C., Brunner, D. and Rühle, M., 2006. Dislocations in plastically deformed SrTiO3. *Philosophical Magazine*, *86*(29-31), pp.4809-4821.

螺位错 (screw dislocation)

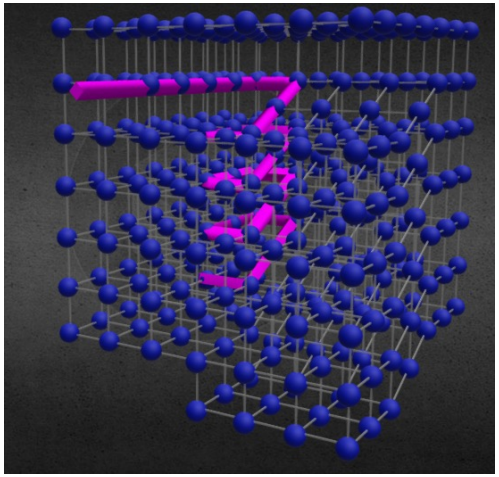


(a)



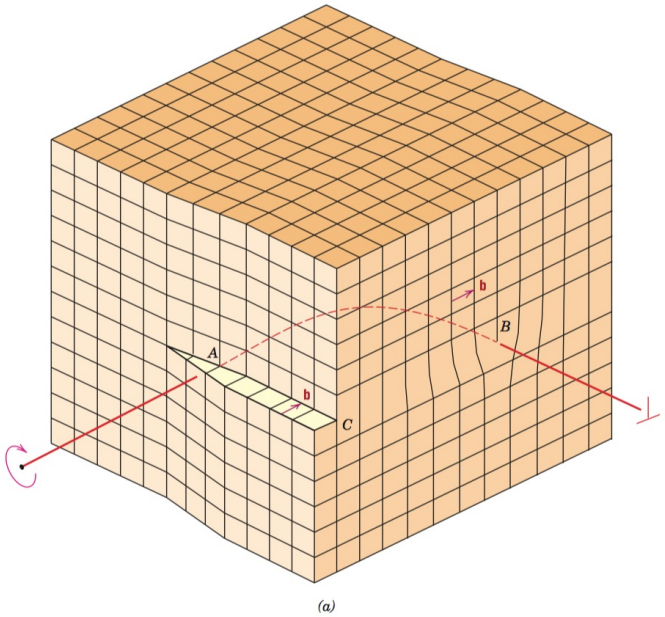


(b)

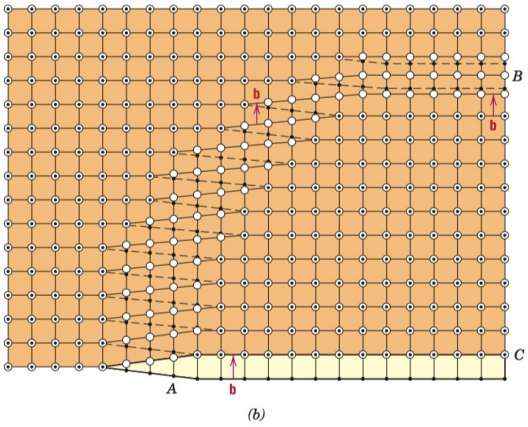


https://sketchfab.com/3d-models/screw-dislocation-c8bae34e30a6489fa5b52a793d05c568

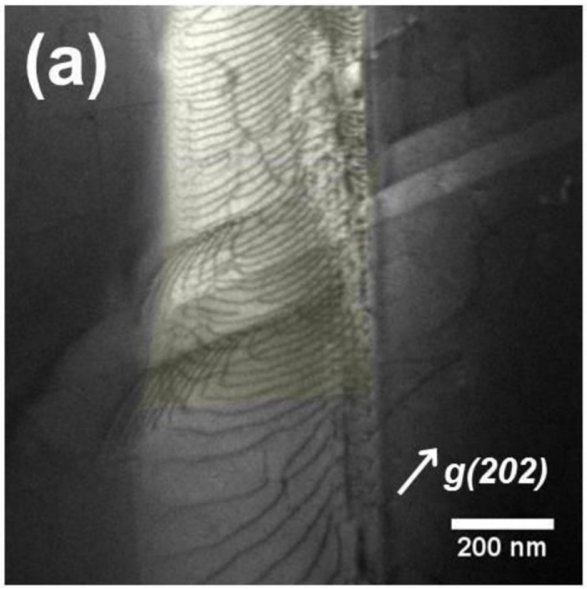
位错一般都是混合的



(a)



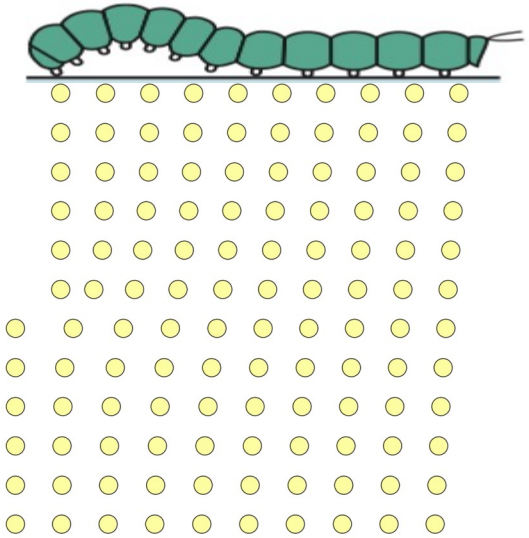
(b)



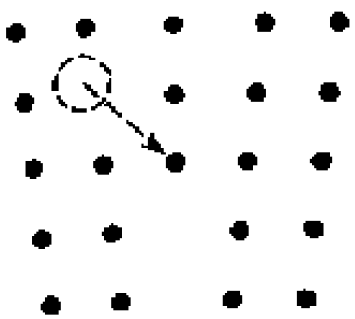
Kim, S., Park, J.Y., Park, S. *et al.* Direct observation of dislocation plasticity in high-Mn lightweight steel by *in-situ* TEM. *Sci Rep* **9,** 15171

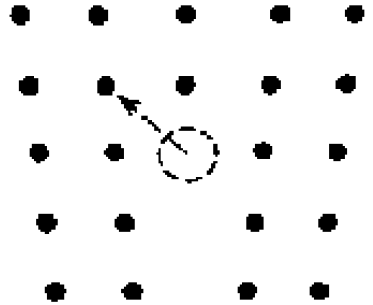
位错的简单移动

- 滑移 (slip)

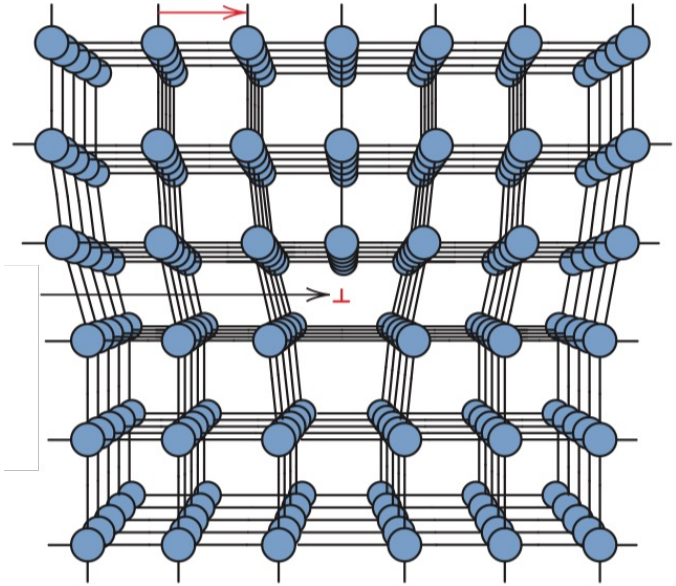


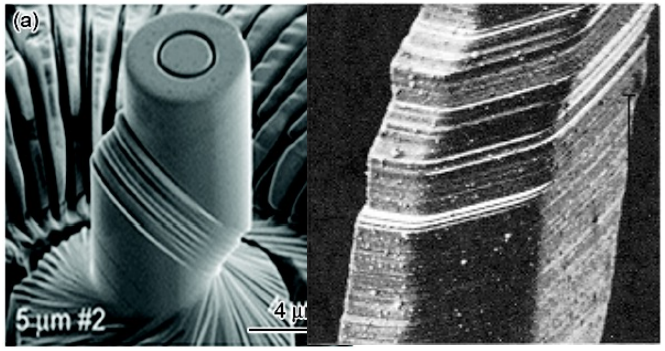
- 攀移 (climb)





哪个面/方向发生了滑移？

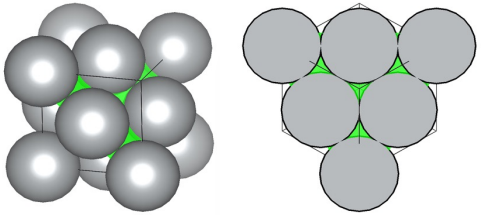




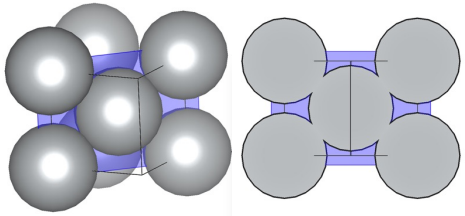
密排面与密排方向

- 密排面 (close-packed planes)

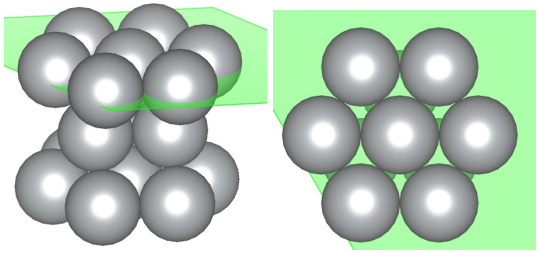
FCC - {111}



BCC – 无
稍微密一点的 {110}

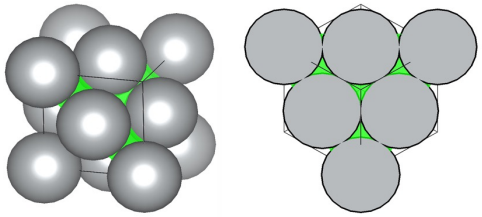


HCP-{0001}

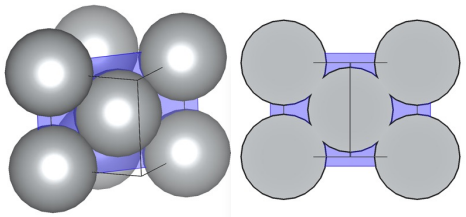


- 密排方向 (close-packed directions)

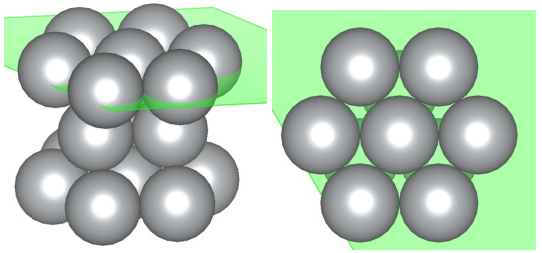
FCC – < $1\bar{1}0$ >



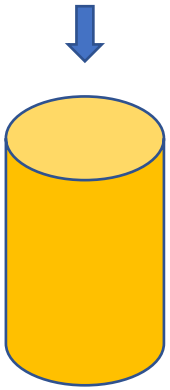
BCC – < $1\bar{1}1$ >



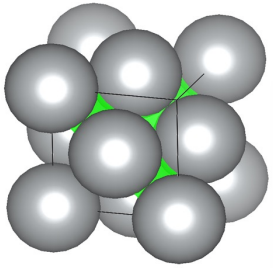
HCP - <$11\bar{2}0$>



均匀的塑性形变怎么来的？(单晶)



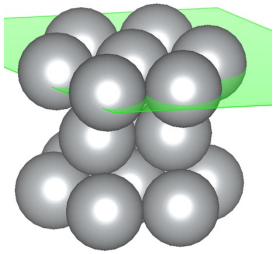
FCC - {111}<110>

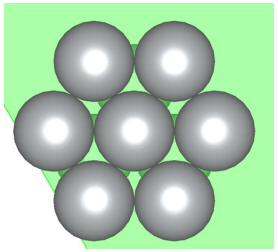


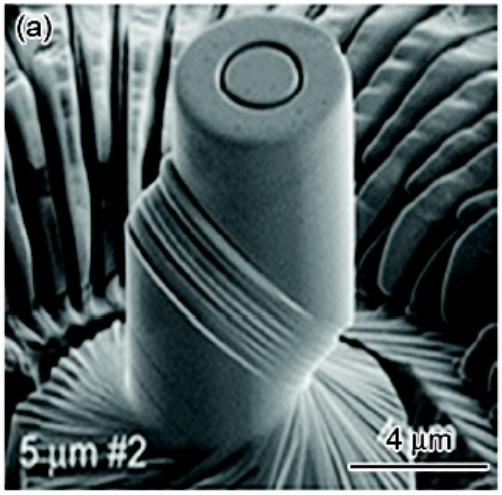
1.为啥不沿着施力方向？

2.怎么发生滑移？

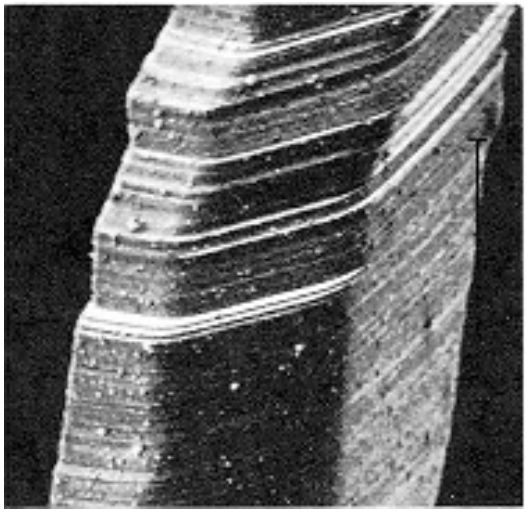
HCP-{0001}<$2\bar{1}\bar{1}0$>







3.哪个面/方向发生了滑移？



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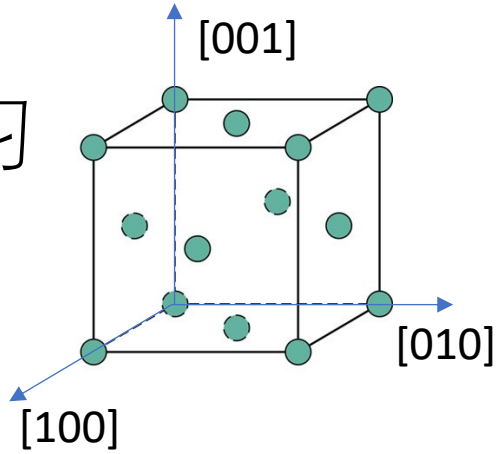
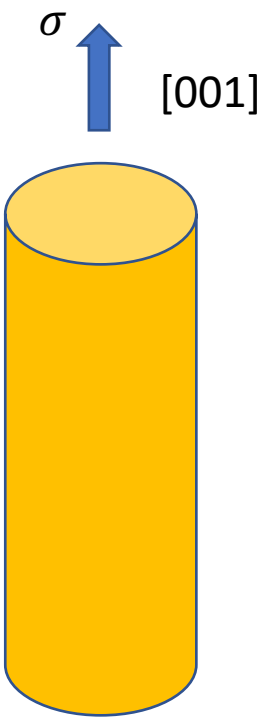
练习



- 一块单晶FCC铜合金拉伸测试，施力方向沿着[001]晶向。观察到当应力到达5MPa时候，滑移面是(111)，滑移方向是$[\bar{1}01]$。求：临界分切应力，τ_{CRSS}

$$\tau = \sigma \cos\phi \cos\lambda$$



7.2 塑性形变与位错 (多晶)

dswen94