TEM Study of Interfaces between Lath Martensite and Austenite in an Fe-20Ni-5.4Mn Alloy

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钢中的界面和性能的关系

材料组织精细调控新趋势—界面控制

相变 = 界面推移，界面与新相形貌密切相关（界面结构各向异性）

- 钢中组织的形貌对性能影响很大：

  铁素体：等轴、针状、贝氏铁素体

  奥氏体：块状、条状

  马氏体：板条状、片状

  碳化物：不同珠光体形貌、ε碳化物、相间沉淀

- 界面作为裂纹源、杂质偏聚区、吸收点（线）缺陷的阱
- 界面是否阻止位错通过取决于界面结构

潜在应用前景举例

贝氏铁素体和马氏体会自发形成择优位向关系和惯习面，及其之间的小角度界面，如果相变开始不久即引入变形，即中断相变进行温加工Q-D-P-X，通过大量变形破坏位向关系可以改变相变产物的形貌为等轴状纳米晶粒，不过新形核的新相仍然存在择优位向关系和形貌。

板条马氏体晶体学形貌的定量解释

板条马氏体是钢中重要强化相，关于马氏体形貌的定量理解仍不圆满，Kelly称之为“被遗忘的孤儿”。

为什么要搞清楚？

为了进一步科学调控。

比如利用变形定量控制变体选择和性能优化

+未知应用

例：搞清楚为什么钢加热特定温度后淬火才能硬化，导致第一张相图（临界点曲线），开辟相图知识体系的发展，指导大量材料设计

可见基础研究的之重要

Outline

Results with conventional TEM

Questions to be answered with in situ TEM

Observations with in situ TEM

Answers to questions

Summary of observations

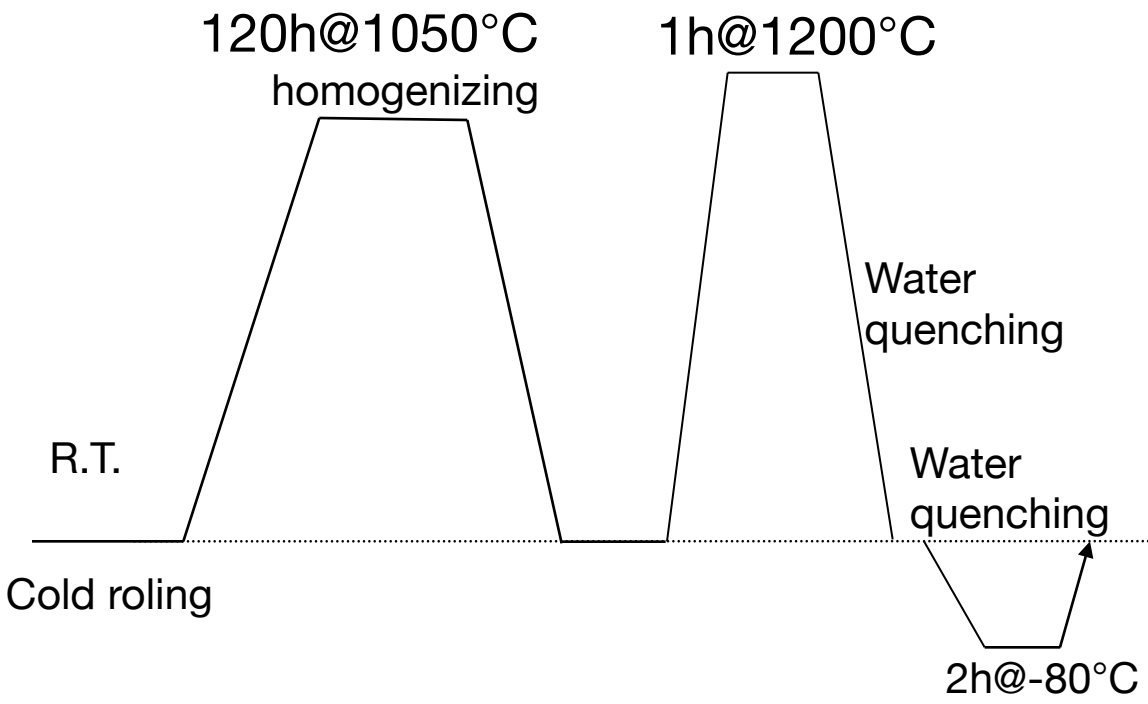
Remaining Questions

Experimental alloy (Fe-20Ni-5.4Mn)

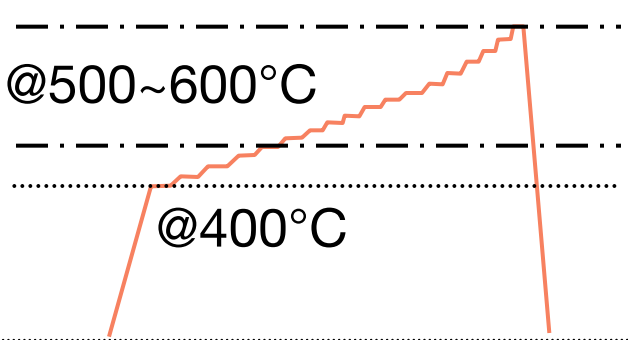
C	Si	Mn	Ni	P	S	Fe
<0.001	<0.01	5.42	20.22	<0.005	0.0015	rest

Kindly provided by Professor Furuhara

Heat-treatment



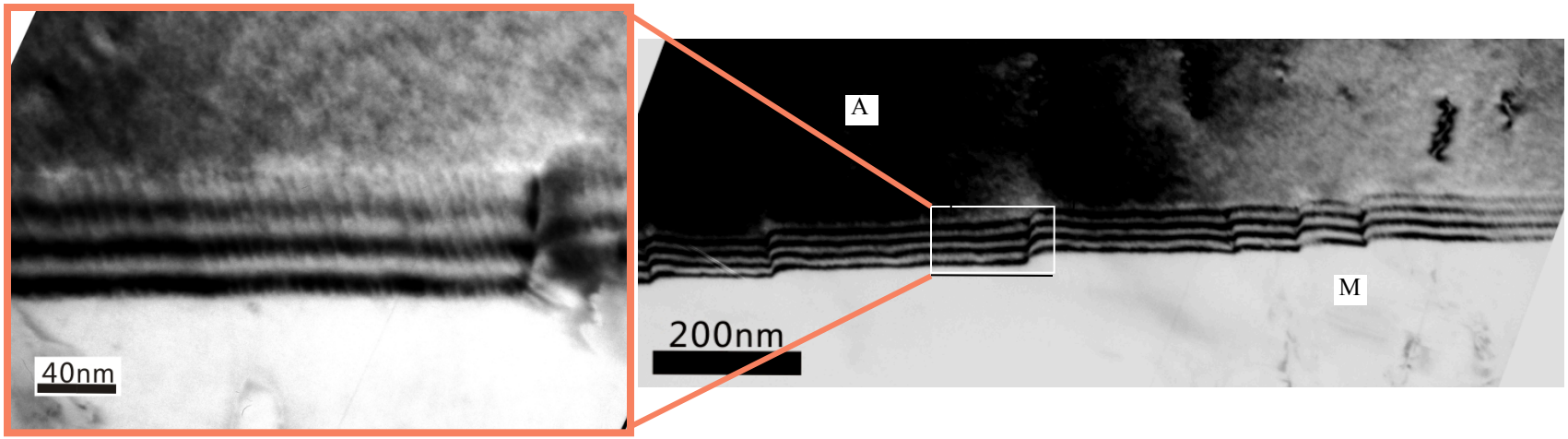
In situ heating in TEM



Results with conventional TEM

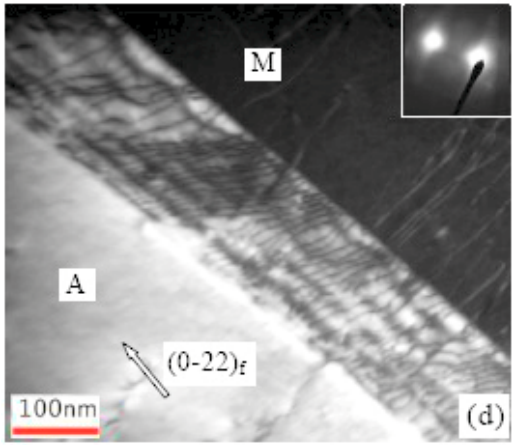
Orientation relationship	$(111)_f$ 1.3° from $(011)_b$ $[10\text{-}1]_f$ 1.6° from [11-1]b **~K-S**
Habit plane orientation	$(0.38\ 0.39\ 0.34)_f$ **~(111)**
Dislocation direction	$[2.78\ \ -0.14\ \ -3.0]_f$**~[100]**
Burgers vector of dislocations	$[10\text{-}1]_f/2$ | $[11\text{-}1]_b/2$
Dislocation spacing	6—15nm

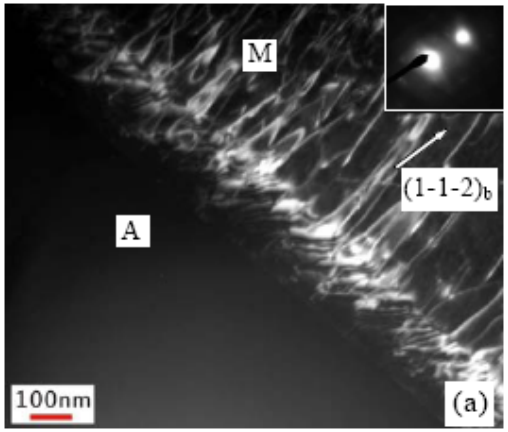
Habit plane contains parallel regular disl. & random steps

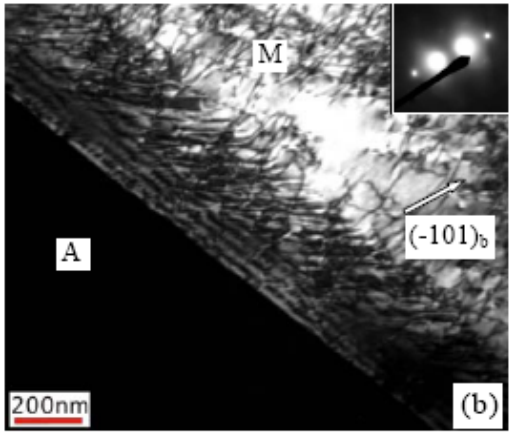


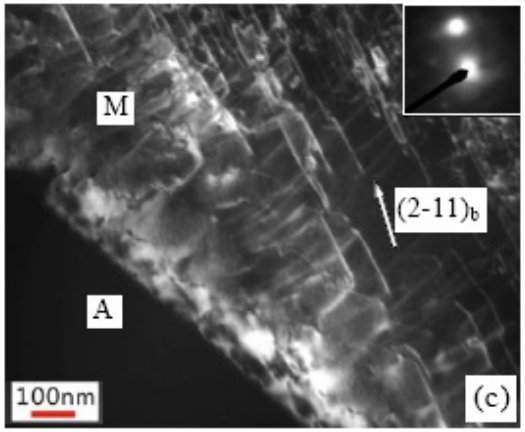
Results with conventional TEM

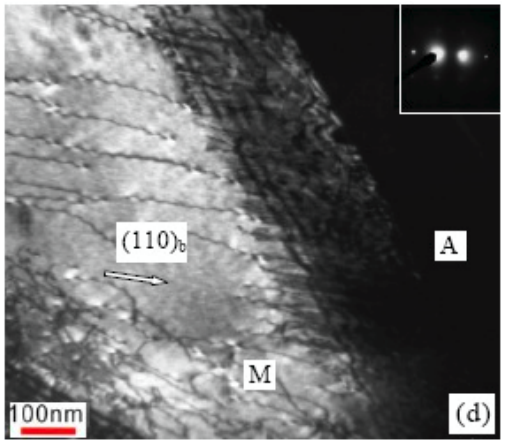
Interfacial dislocations are linked to the dislocations within lath martensite, which are **<111>$_b$/2** (4 sets) near screw dislocations

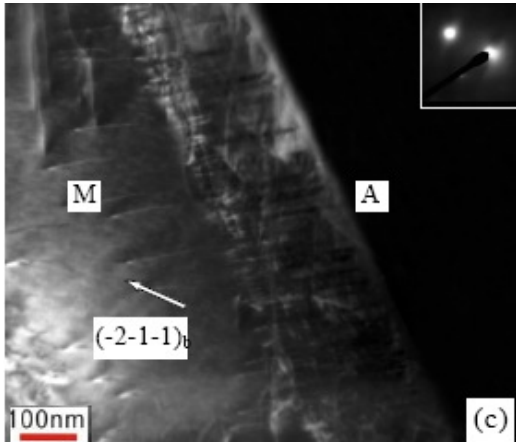












To be answered with in situ TEM

How and when do the inner dislocations generate?

How do various portions of interfaces migrate?

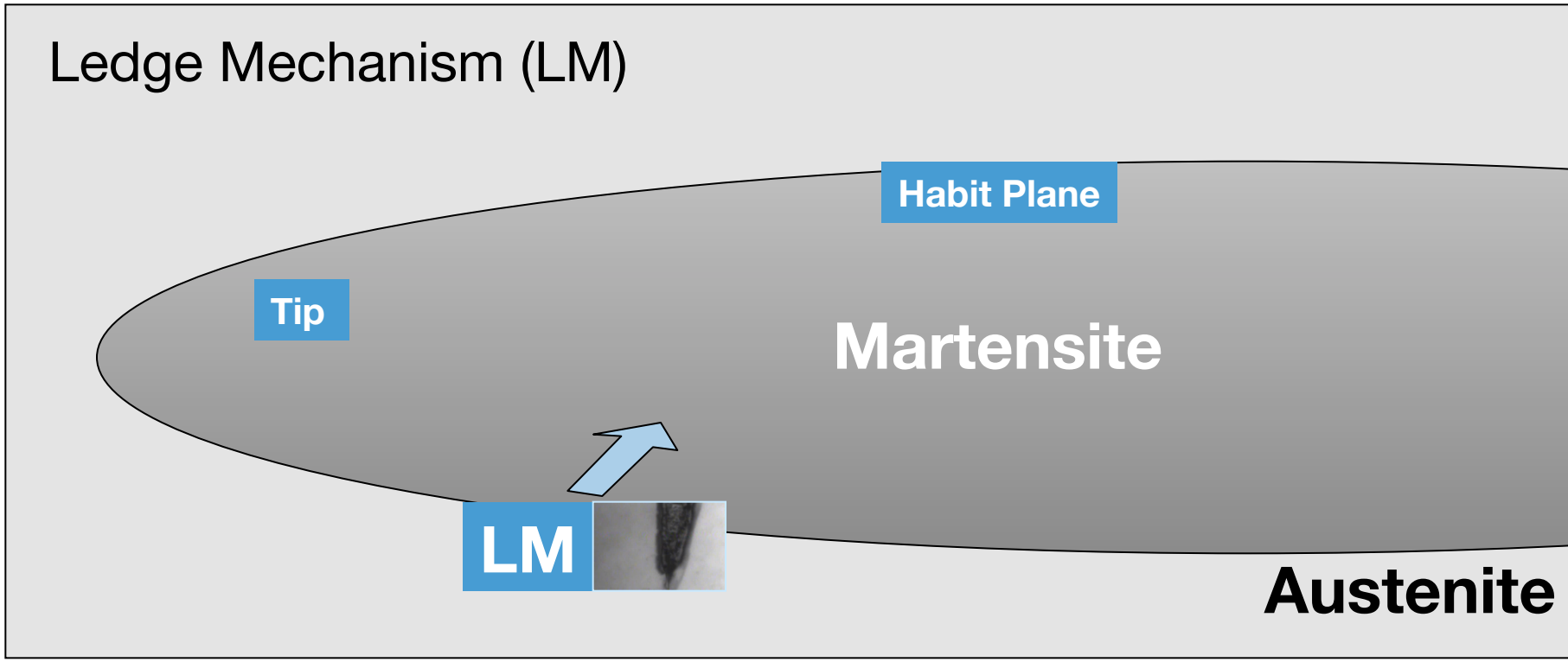
— Is normal motion of the habit plane possible?

— Does observation of steps imply ledge mechanism?

— Are interfacial dislocations are glissile ? (PTMC)

— How are the interfaces dislocations related to the inner dislocations?

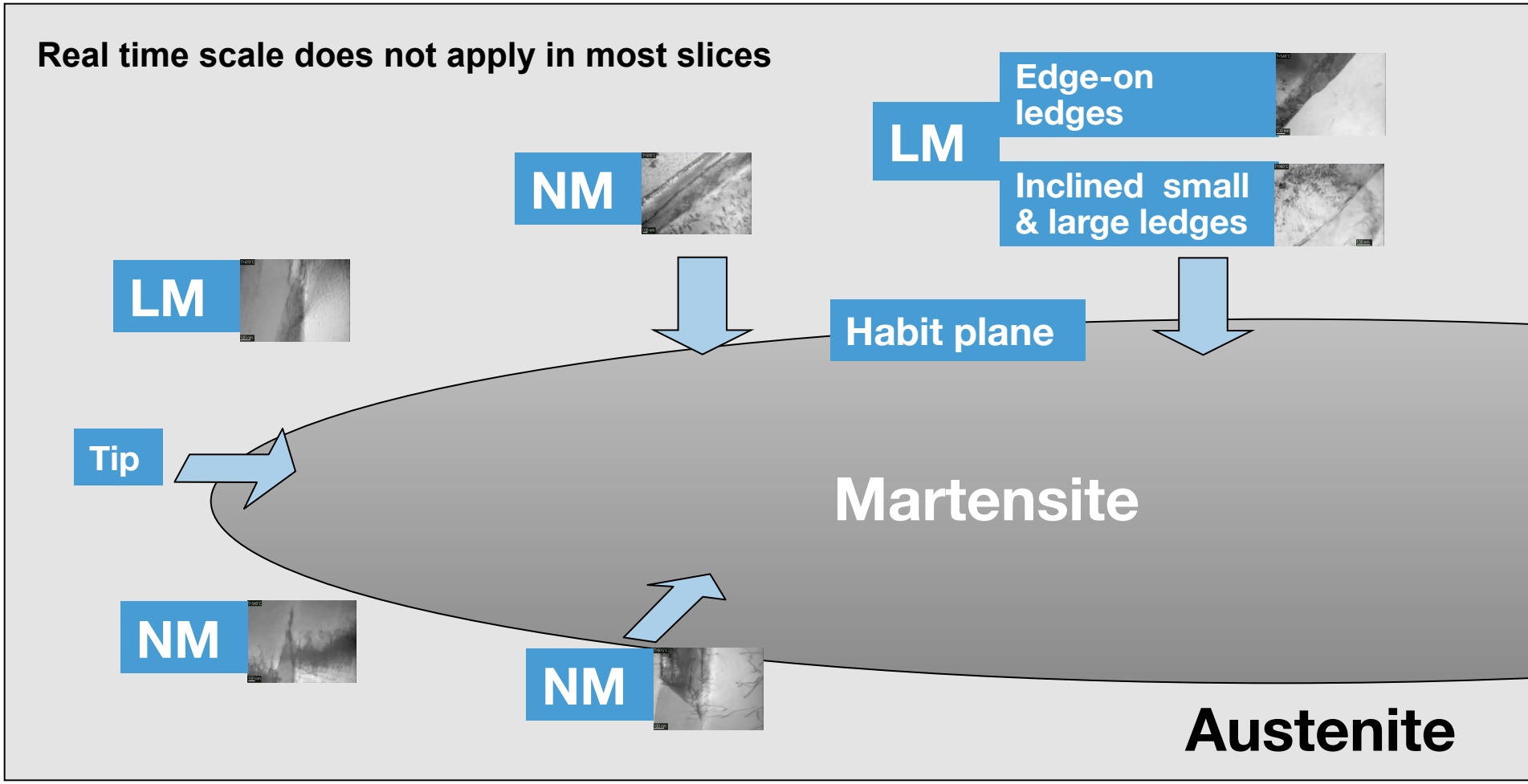
Migration of Interfaces between Martensite & Original Austenite



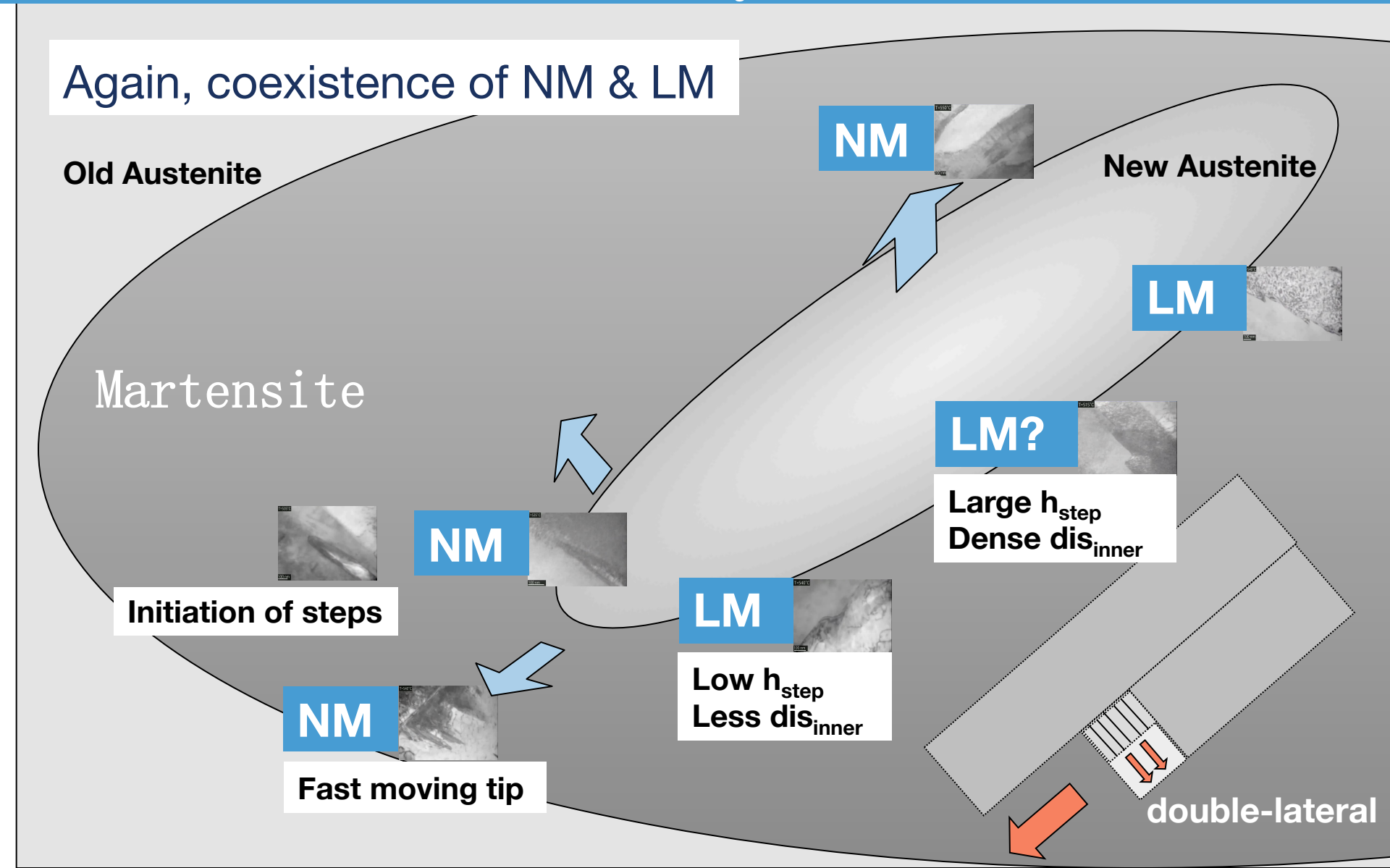
J. Wu, James M. Howe, W.-Z. Zhang, (2011) "An in-situ transmission electron microscopy study of interface growth during martensitic transformation in an Fe-Ni-Mn alloy" *Acta Mater.* **59**, *3297–3303*

Migration of Interfaces between Martensite & Original Austenite

Coexistence of normal motion (NM) & ledge mechanism (LM)



Migration of Interfaces between Martensite & Newly Formed Austenite



Preliminary answers to early questions

How and when do the inner dislocations generate?

They generated as martensite (austenite) is formed

How do various portions of interfaces migrate? NM+LM

- Is normal motion of the habit plane possible? Yes
- Does step observation imply ledge mechanism? Maybe
- Are interfacial dislocations are glissile ? (PTMC) Yes
- How are the interfaces dislocations related to the inner dislocations?

Part of inner dislocation loops becomes the interfacial dislocations

SUMMARY

1. Martensite transforms to austenite upon heating, via various modes:

- via retreating original interfaces of different parts (tips/edges/HP) **or** nucleation and growth of new austenite within martensite
- with Old **and** new HP immobile in some locations, **but** mobile in others
- fast normal motion (martensitic?), **or** slow motion with ledge mechanism (probably depending on local driving force) **or** double-lateral motion with unit of dislocation loops
- New HP can be quite flat in some locations, **or** curve in others

2. Transformation of each mode is closely related to dislocations

- Dense inner dislocations are generated often accompanying **normal motion** of old or new interfaces, but their density seems to reduce fast due to local reactions
- New phase grows with migrate of dislocation network on the interfaces of curved orientations in a **wave-like** fashion
- Front dislocations of dislocation loops **are** the interfacial dislocations, and they can become parallel array in facet (HP?)
- Broad interface (HP?) can migrate with slow **inclined collective motion** of parallel interfacial dislocations with roughly constant spacing, leaving little inner dislocations

Remaining and New Questions

Remaining and New Questions

1. How do the inner dislocations nucleate **?**
2. What are/is the Burgers vectors of inner dislocation loops **?**
3. What are/is the Burgers v. of small isolated ledges/ disconnections**?**
4. What is the structure between the interfacial dislocations **?** Can they be coherent **?**
5. How does the dislocation network glide **?** What is the gliding direction of the parallel dislocations **?**
6. What is the condition for presence of flat HP/ curved HP **?**
7. What is the relationship between boundary motion and morphology of new phase in 3D **?**
8. What is residual strain left after the interface motion **?**
9. What theory can interpret all aspects **?**

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Thank You

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