Ledge Mechanism

To explain the ledge mechanism of growth in systems with coherent or facetted interfaces

Education Level : UG

LOs for prior viewing : Precipitate growth

Course Name: Phase transformations and heat treatment

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(Under guidance of Prof. M P Gururajan )
Learning Objectives

After interacting with this Learning Object, the learner will be able to:
1. Explain the ledge growth mechanism
2. Explain the implication of ledge growth mechanism
Coherent interface: Arises when two phases share an interface plane such that two lattices are continuous across interface.

Incoherent interface: Arises when two phases share an interface plane that has very different atomic configuration in the two phases.

Semicohescent interface: An interface between two phases in which there is partial lattice matching.

A – Low mobility semicoherent interface
B – High mobility incoherent interface
α – Parent phase from which precipitate is growing
B – Precipitate phase
V – Volume of precipitate
Definitions of the components/Keywords:

- $v$ - velocity perpendicular to the facetted interface.
- $h$ - step height.
- $u$ - lateral velocity of the ledge.
- $\lambda$ - ledge width
Master Layout 1: Morphology of precipitate

Step 1: Type of interface decides growth rate

A – Low mobility semicoherent interface
B – High mobility incoherent interface

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### Step 1

<table>
<thead>
<tr>
<th>Description of the activity</th>
<th>Audio narration</th>
<th>Text to be displayed</th>
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</table>
| Draw three concentric rectangles that are curved on either side. Name curved surface as B and planar curve as A. Draw arrow pointing upwards above planar curve and name it as Slow similarly draw horizontal arrow pointing towards right and name it as Fast. | Nuclei is generally bounded by facets that are combination of coherent or semicoherent facets and incoherent interfaces. | A – Low mobility semicoherent interface  
B – High mobility incoherent interface |
Step 2: A critical nucleus in starting phase of growth

Diagram:
- Slow
- Fast
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<td>Draw a rectangle that is curved on either side (left and right). Draw arrow pointing upwards above planar curve and name it as Slow. Similarly draw horizontal arrow pointing towards right and name it as Fast. Keep ratio of height to length of rectangle as 1:3</td>
<td>Note that incoherent interfaces are curved while semicoherent/coherent interface are faceted.</td>
<td></td>
</tr>
</tbody>
</table>
Step 3: Growth in intermediate state

Diagram:
- Slow
- Fast
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<tr>
<td>Increase the height of rectangle by 20% while increasing the length by 100% keeping centre the same. Animation time : 2 seconds</td>
<td>Incoherent interfaces advance at higher rate than coherent interface.</td>
<td></td>
</tr>
</tbody>
</table>
Step 4: Growth completed

Diagram:
- Slow
- Fast
Step 4

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<td>Again increase the height of figure by 20% while increasing the length by 100%. Animation time: 2 seconds</td>
<td>We see that in the direction bounded by incoherent interface precipitate has grown more in comparison to direction bounded by coherent interface. Further, the thickening of the region bounded by the facetted interfaces grows by a mechanism known as Ledge mechanism. Next we will see how ledge mechanism works.</td>
<td></td>
</tr>
</tbody>
</table>
Master Layout 2: A mechanism for thickening

Step 1: Precipitate growing perpendicular to a coherent facetted interface
<table>
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<tbody>
<tr>
<td>Draw a rectangle and divide it in three parts by two horizontal lines, one dotted and one normal. (see slide). Name first from top part as alpha (α) and third as beta (β).</td>
<td>Two phases alpha and beta are trying to form coherent interface. For beta precipitate to thicken, interface must advance as shown with direction of growth perpendicular to interface. Next we will see how growth takes place with Ledge mechanism</td>
<td></td>
</tr>
</tbody>
</table>
Step 2: Ledge mechanism starting
<table>
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<tr>
<td>Draw a rectangle and divide it in two parts by a horizontal step line (see slide). Name upper part as alpha and beta. Animation time : 1 seconds</td>
<td>Consider the formation of a ledge as shown. The terrace is equivalent to the facet plane. However, the step is energetically costly and hence, once formed, will advance at a much faster rate till there is no step left.</td>
<td></td>
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</tbody>
</table>
Step 3: Ledge mechanism at intermediate step
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<tr>
<td>Shift the step in the line towards right at nearly half of length.</td>
<td>Once a ledge is formed it will try to complete parallel to plane rather than forming a new ledge.</td>
<td></td>
</tr>
<tr>
<td>Animation time : 2 seconds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step 4: Advance complete for a ledge

\[ \alpha \]

\[ \beta \]
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<tr>
<td>Draw a rectangle and divide it in three parts by two horizontal lines, one normal and one dotted. (see slide). Name first from top part as alpha ($\alpha$) and third as beta ($\beta$). Animation time: 3 seconds</td>
<td>A ledge formed has completed its growth and hence, at the end, there is no step on the facetted surface, but the precipitate has thickened perpendicular to the facetted plane. Now, another new ledge will be formed and this process will be repeated. Dashed line shows interface position at previous step.</td>
<td></td>
</tr>
</tbody>
</table>
Master Layout 3: Ledge mechanism in action

Step 1: Relation between horizontal and vertical velocity

\[ v = \frac{uh}{\lambda} \]

Text to be displayed:

\( v \) - velocity perpendicular to the facetted interface.

\( h \) - step height.

\( u \) - lateral velocity of the ledge.

\( \lambda \) - ledge width

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<td>Draw a step like line with three steps. Label various variables as shown. Draw vertical and horizontal arrows and name them as ( v ) and ( u ) respectively.</td>
<td>It is known that interface advance rate in horizontal and vertical direction are related as ( V ) is equal to ( u ) ( h ) divided by ( \lambda ). Here ( v ) is the velocity perpendicular to the faceted interface. ( H ) is the step height. ( U ) is the lateral velocity of the ledge. And, ( \lambda ) is the ledge width.</td>
<td>Text to be displayed is shown slide under green heading. Display the text below the figure and display the equation on right side of figure.</td>
</tr>
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</table>
Questions

1. Coherent interfaces are curved interface. True or false?

2. Incoherent interface advance at higher rate than coherent interface. True or False?

3. Ledge thickening rate is proportional to which of the following parameters?
   a) $h$
   b) $u$
   c) $\lambda$

4. Lateral velocity is inversely proportional to which of the following mechanism?
   a) $h$
   b) $\lambda$
   c) $v$
1. False. 
In coherent interfaces require crystals match perfectly at the interface plane which restricts interface to be curved.

2. True. 
Incoherent interfaces does not demand proper alignment of atoms at the interface resulting in higher growth rate.

3. $h, u$
Follows from formula $v = \frac{uh}{\lambda}$

4. $h$
Follows from formula $u = \frac{vh}{\lambda}$
Links for further reading

Reference websites:
1. neon.mems.cmu.edu/rollett/.../302.L3.ppt.growth.25Oct02.ppt

3. Books:

Research papers:
Summary

1. Incoherent interface have faster growth rate than coherent one

2. Coherent interfaces are faceted while incoherent interfaces are curved one