Texture and Anisotropy: Applications

Dr.-Ing. 郭 瑞 昭
1. Deformation Textures in Metals
2. Annealing Textures in Metals
3. Applications of textures
Commercial purity aluminium (AA1xxx)

Application:
The pure aluminum foil is found its application in electrolytic capacitors. The surface area of capacitors can be increased through an etching process. Narrow channels along <100> directions into foil, i.e. cube texture are desired.

Composition of AA1050:
Commercial pure aluminum contains iron and silicon more than 1% wt.

<table>
<thead>
<tr>
<th>Nominal compositions of aluminium alloys for can bodies.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Si%</strong></td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>AA3004</td>
</tr>
<tr>
<td>AA3104</td>
</tr>
</tbody>
</table>
Commercial purity aluminium (AA1xxx)

Effect of Fe:
Small amounts of iron changes the annealing texture from pure cube to a retained rolling texture.

Effect of Fe and Si:
Si and Fe lead to the formation of a-Al-Fe-Si phase in the form of plates or rods up to 10 mm. PSN at the Al-Fe-Si particles leads to a random texture and with weakening rolling (R) texture.

Effect of T and strain:
An increase in temperature or a decrease in strain rate reduced the relative drop in cube \{001\}<100> and the relative increase in rolling texture components of Cu \{112\}<111> and S \{231\}<346> at the higher strain.
Commercial purity aluminum (AA1xxx)
### Al-Mg-Si Automotive Sheet (AA6xxx)

#### Table 15.3
Processing routes for AA6xxx automotive sheet, showing the effect on the final texture, of an intermediate anneal before cold rolling.

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Breakdown hot rolling</strong></td>
<td>25–40 mm plate (transfer gauge) Recrystallized to 200 μm grains Strong cube texture</td>
</tr>
<tr>
<td><strong>Tandem mill hot rolling</strong></td>
<td>3–6 mm strip (hot band) Hot-deformed microstructure Rolling texture</td>
</tr>
<tr>
<td><strong>Coiling</strong></td>
<td>Partly recrystallized microstructure Fine Mg$_2$Si precipitation</td>
</tr>
<tr>
<td><strong>Intermediate anneal</strong></td>
<td>Fully recrystallized Precipitates coarsen Cube texture</td>
</tr>
<tr>
<td><strong>Cold rolling</strong></td>
<td>0.8–1.22 mm sheet Deformed microstructure</td>
</tr>
<tr>
<td><strong>Solution treatment</strong></td>
<td>Recrystallized to ~20–30 μm grains Precipitate dissolution</td>
</tr>
<tr>
<td><strong>Forming</strong></td>
<td>Age-hardening during paint-bake</td>
</tr>
<tr>
<td><strong>No intermediate anneal</strong></td>
<td>Partly recrystallized Fine Mg$_2$Si precipitates Rolling + Cube texture</td>
</tr>
<tr>
<td><strong>Rolling texture</strong></td>
<td>Rolling texture</td>
</tr>
<tr>
<td><strong>Weak cube texture</strong></td>
<td>Strong cube texture</td>
</tr>
</tbody>
</table>

In addition to the parameters discussed above, there are other means of controlling the final texture, which are not discussed here, including the alloy composition, the exit temperature of tandem rolling and the amount of the cold rolling reduction.
Al-Mg-Si automotive sheet (AA6xxx)
Aluminium beverage cans (AA3xxx)

Figure 2. The current market share by application sectors.\textsuperscript{4,10}
Aluminium beverage cans (AA3xxx)

Aluminium beverage cans are fabricated from two parts:

- can body (generally made from 3104 sheet)
- can end (typically made using 5182 due to its higher strength)

Good sheet formability is required for the body making process: blanking, cupping and finally drawing and ironing the side-walls.

Anisotropy in the mechanical behaviour of the sheet must be minimised to limit the formation of so-called 'ears' on the deep drawn cup.
Aluminium beverage cans (AA3xxx)
Cupping

Fig. 1. Deep-drawing.
Fig. 7. Drawing and wall-ironing.
Flanging

Fig. 11. Necking and flanging systems.
Fig. 15. Steel end for beverage cans.
Development of microstructure and texture

As-cast microstructure:
Features of the cast ingot are intermetallic phases \((\text{FeMn})\text{Al}_6, \text{Mg}_2\text{Si}\), eutectic microsegregations and grain with 100 \(\mu\text{m}\).

Homogenisation:
Objectives of homogenisation are the elimination of microsegregations, transformation of \(\beta-(\text{FeMn})\text{Al}_6\), and \(\text{Mg}_2\text{Si}\) in dispersoids.
- Microsegregations (removed during heating)
- \(\beta-(\text{FeMn})\text{Al}_6\), in \(\alpha-\text{Al15(FeMn)3Si2}\) (desired due to hardness)
- \(\text{Mg}_2\text{Si}\) (dissolves and helps the formation of \(\alpha-\text{Al15(FeMn)3Si2}\))
Development of microstructure and texture

Hot rolling and recrystallization:
   A strong cube texture is required after RX. The RX texture is dominated by cube component (preserved in hot rolled microstructure) and random component (particle stimulated nucleation /PSN of RX).

   A higher rolling temperature promotes the cube texture and restricts the random texture.
Development of microstructure and texture

Cold rolling:

The requirement for deep drawing of can bodies is good formability and low earing.

After cold rolling the strength of the cube texture is reduced and cold-rolling texture is developed (Brass, Copper and S). The +-45 earing can be minimized if the cube texture is maximal.

<table>
<thead>
<tr>
<th>Texture</th>
<th>Name</th>
<th>Earing</th>
</tr>
</thead>
<tbody>
<tr>
<td>{100} &lt;001&gt;</td>
<td>Cube</td>
<td>4-fold 0/90° etc.</td>
</tr>
<tr>
<td>{110} &lt;001&gt;</td>
<td>Goss</td>
<td>2-fold 0/180°</td>
</tr>
<tr>
<td>{110} &lt;112&gt;</td>
<td>Brass</td>
<td>4-fold 45° etc.</td>
</tr>
<tr>
<td>{112} &lt;111&gt;</td>
<td>Copper</td>
<td>4-fold 45° etc.</td>
</tr>
<tr>
<td>{123} &lt;412&gt;</td>
<td>S (~R)</td>
<td>4-fold 45° etc.</td>
</tr>
</tbody>
</table>
Impact on Materials

2007 World Installed Production of Grain Oriented Silicon Steel

Total = 2.1 Million (MT)

* Data Courtesy of Sumitomo Corporation
Requirements of Silicon Steel sheets

Requirements:
1. Easy magnetisation
   composition/ high Silicon $\rightarrow$ brittle and not cold rolling
   concentration levels of carbon, sulfur, oxygen and nitrogen must be kept low
   orientation/ $<100>$ direction
   purity

2. Low hysteresis loss
   as the same 1

3. Low eddy current loss
   grain size, $\downarrow$
   sheet thickness, $\downarrow$
   stress $\downarrow$
Requirements of Silicon Steel sheets

Requirements in the Armco process:
1. The nucleation of \{110\}<001> grains
2. These grains must be able to grow
3. Grains of other orientation should not grow

\{110\}<001> orientation first appears during the initial hot rolling as a friction-induced shear texture at and near the surface.

Normal rolling texture consists of \{112\}<110> and \{111\}<110>
The basis of the Goss process is to heat the silicon iron strip to around 1200°C, to induce the secondary recrystallisation of large grains with [001](1 10) texture, which were predominant because the presence of manganese sulphide (MnS) suppresses the growth of other grains.
Silicon Steel sheets

Requirements in the Armco process:
1. Provision for the nucleation of $\{110\}<001>$ grains

2. These grains must be able to grow

3. Grains of other orientation must not grow
Silicon Steel sheets

During hot rolling, small MnS particles are precipitated as the steel cools and, at the same time, some crystals with the Goss texture are formed along with many other orientations.

- The desired \{110\}\(<001>\) orientation appears during the initial hot rolling as a friction-induced shear texture at and near the surface.

- During cold rolling \{112\}\(<110>\) and \{111\}\(<110>\) texture are formed. Therefore, two “light” cold rolling stages are applied.

- Goss grains survive at the centers of transition bands

- Some Goss grains appear in the annealing texture after decarburising anneal, they are larger than those of the other orientations

- They grow by abnormal grain growth during the final texture anneal
Silicon Steel sheets

These MnS particles are resistant to rapid coarsening and, by preventing normal grain growth, keep the matrix grain size small during high temperature annealing.

The possibility of undesirable orientations by surface nucleation process is eliminated by addition of sulphur to the MgO coating.
Silicon Steel sheets

After the cold rolling, nuclei with the Goss texture recrystallise during the decarburisation anneal. (1\textsuperscript{st} recrystallization)

The grain size, at this stage, is around 0.02 mm diameter, and this increases in the Goss-oriented grains at over 800°C, during the high-temperature anneal when the MnS (inhibitor) retards the growth of other grains.

During this secondary recrystallisation process, the Goss grains each consume $10^6-10^7$ primary grains and grow through the thickness of the sheet to diameters of 10 mm or more. All grains do not have the ideal Goss orientation, but most are within 6° of the ideal [101] (110), this is the best that can be achieved with MnS as a grain growth inhibitor. (2\textsuperscript{nd} recysallization)