Symmetry among diffusional products in austenite

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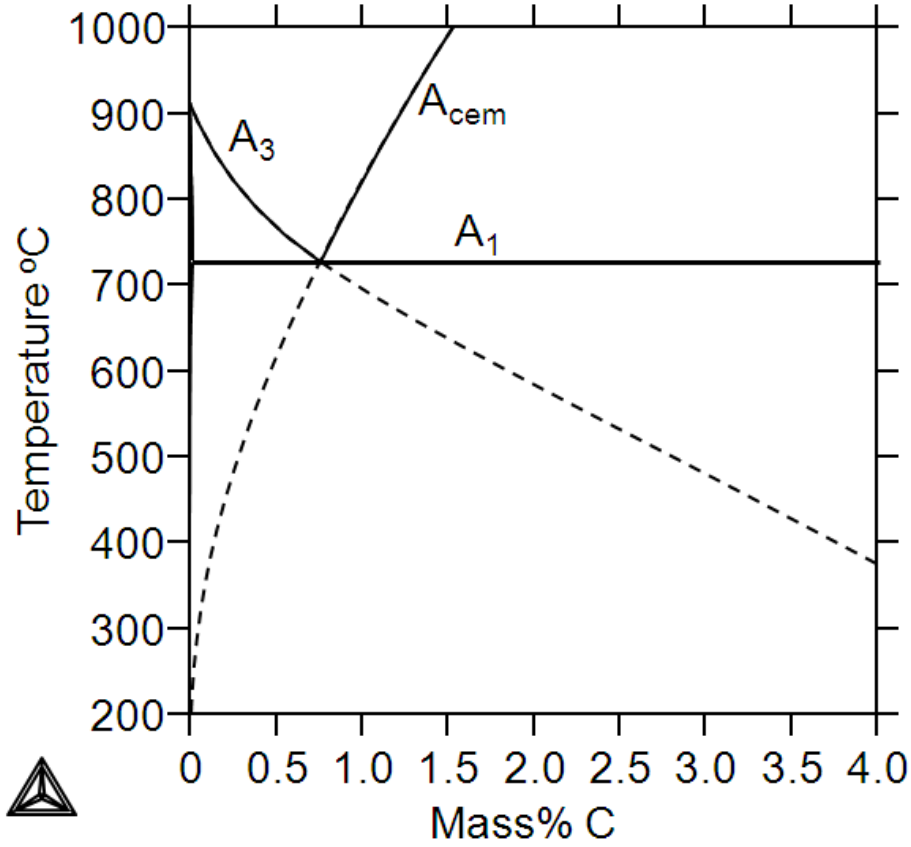
Bainite – Inverse bainite

In 1957 Mats Hillert introduced the name inverse bainite when discussing the symmetry in the Fe-C system.

Bainite – eutectoid microstructure of ferrite and cementite with **ferrite as leading phase** in the main growth direction.

Inverse Bainite – eutectoid microstructure of ferrite and cementite with **cementite as leading phase** in the main growth direction.

Asymmetry in the Fe-C system



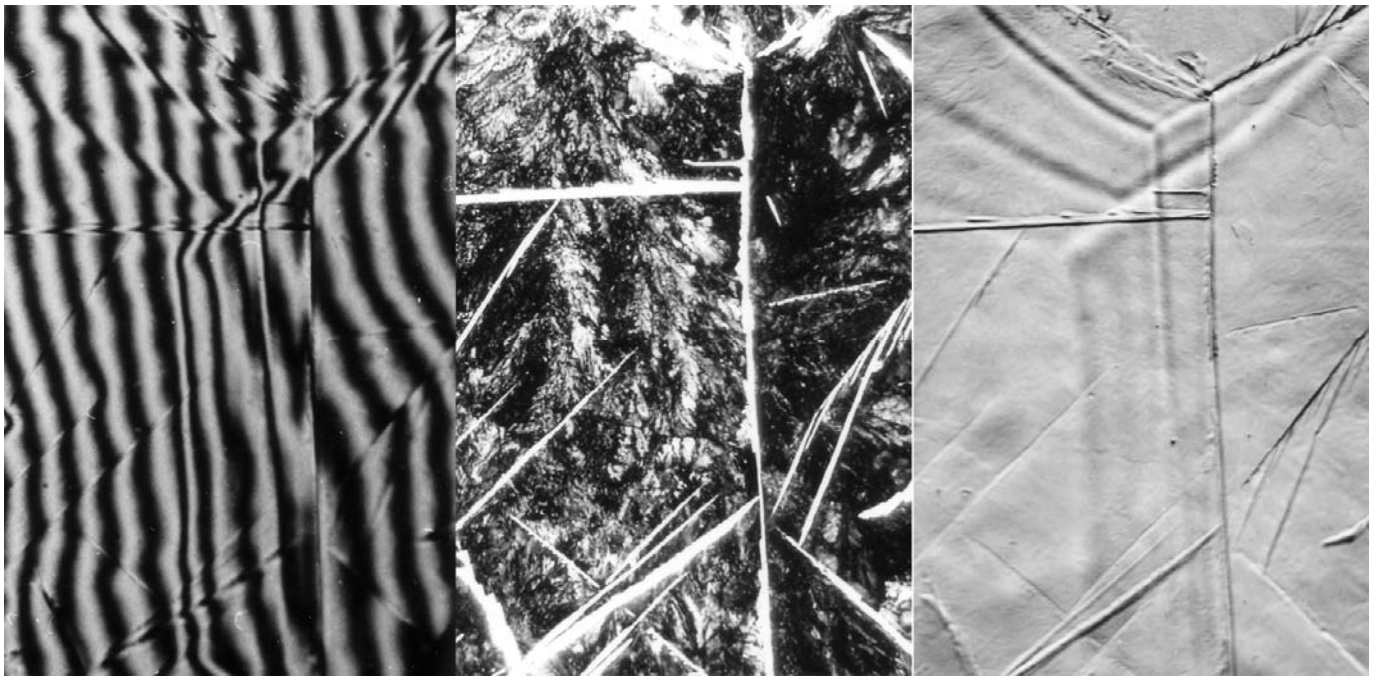
Bainite Pearlite Inverse bainite

Inspiration to the present work

- Greninger and Troiano, 1940, Spiky pearlite
- Hultgren, 1951, Smooth pearlite
- Nilan, 1967, Columnar bainite

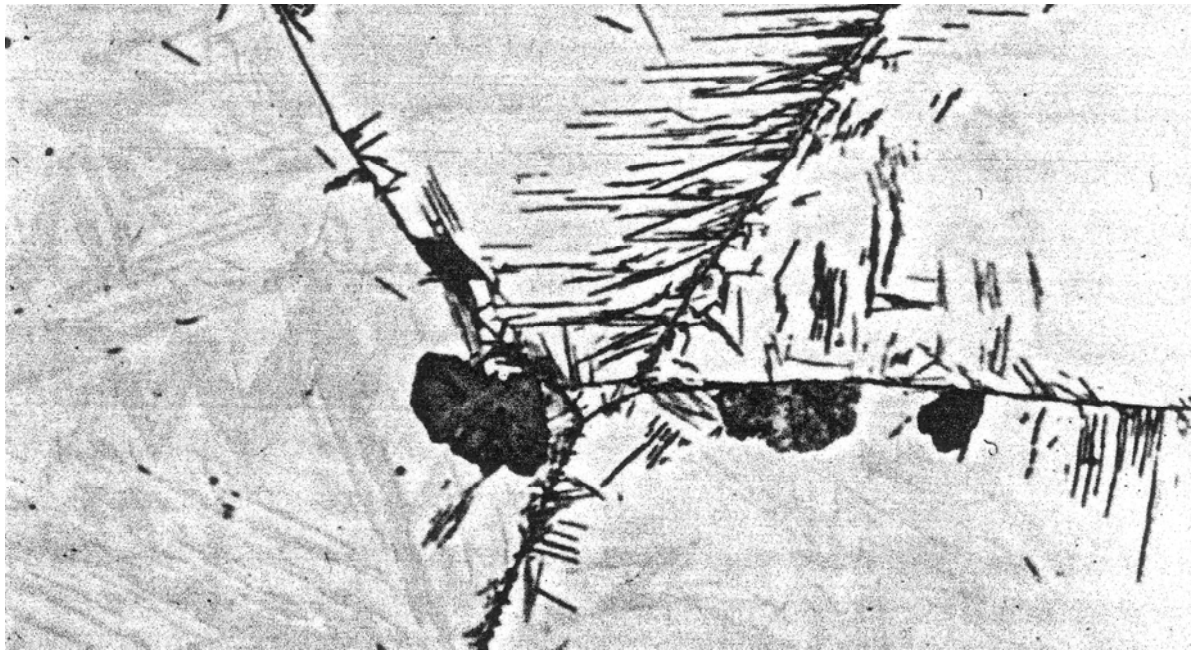
- Modin and Modin,0.86, 1.2 and 1.65%C, 1955 and 1958
- Spanos et al, 1990, study on 0.95%C and 1.12%C with 2%Mn

Surface relief from Widmanstätten cementite



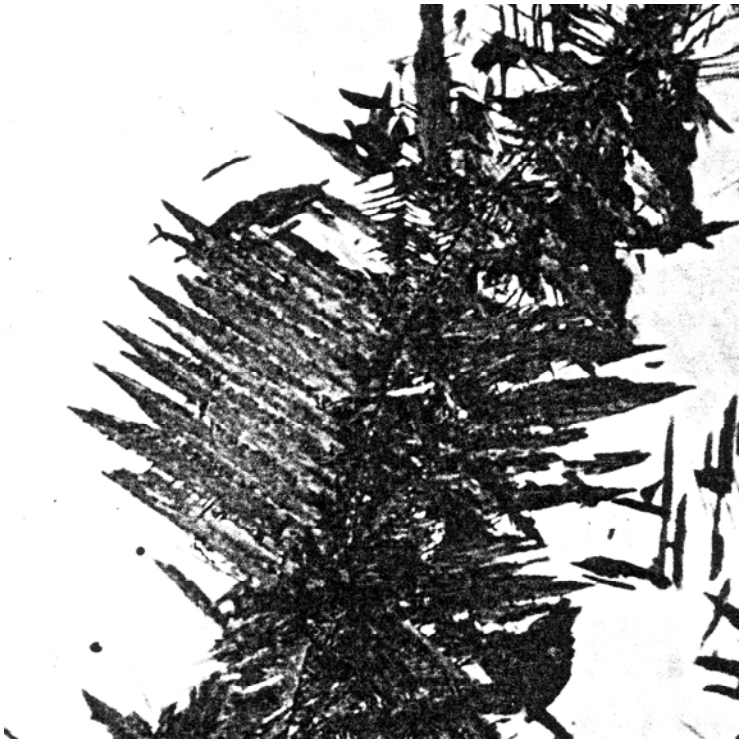
300 s at 650 C Speich 1961

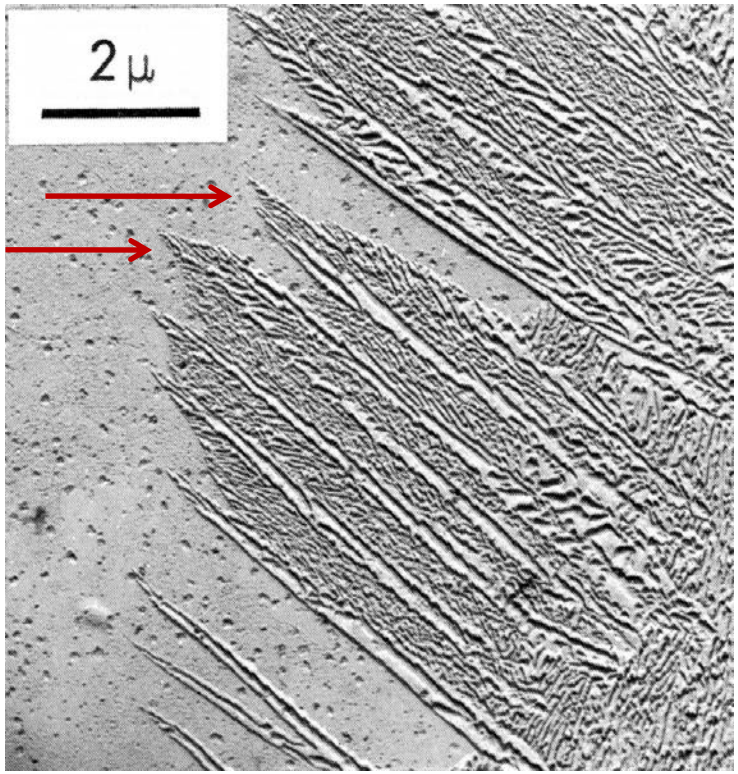
Pearlite and Widmanstätten cementite



1.65%C, 550 C, Modin and Modin

Inverse bainite and Widmanstätten cementite

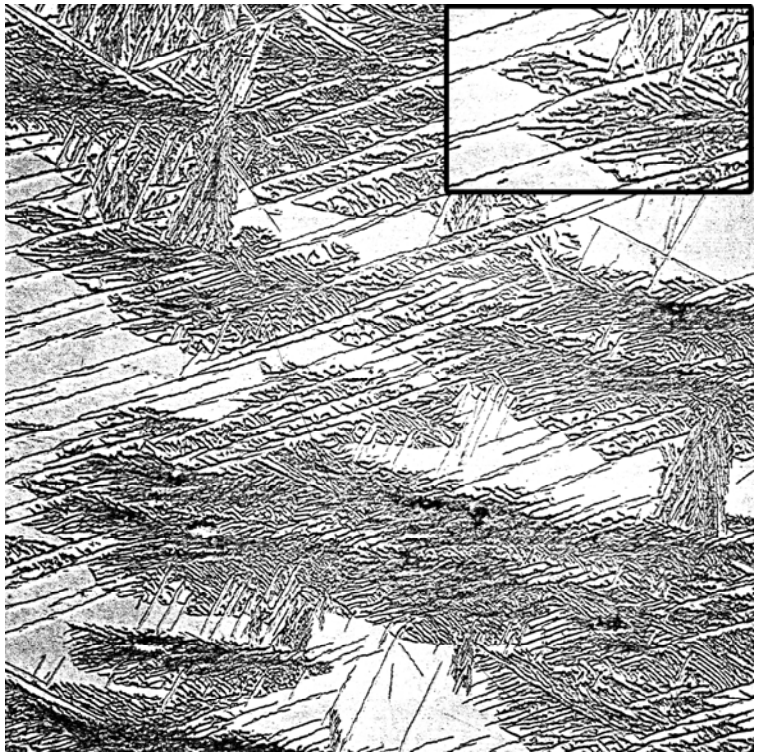




1.65%C, 25 s at 500 C, 700x, Modin and Modin

1.34%C, 1 s at 550 C, 12000x Kinsman and Aaronson

Ordinary inverse bainite between primary Widmanstätten cementite



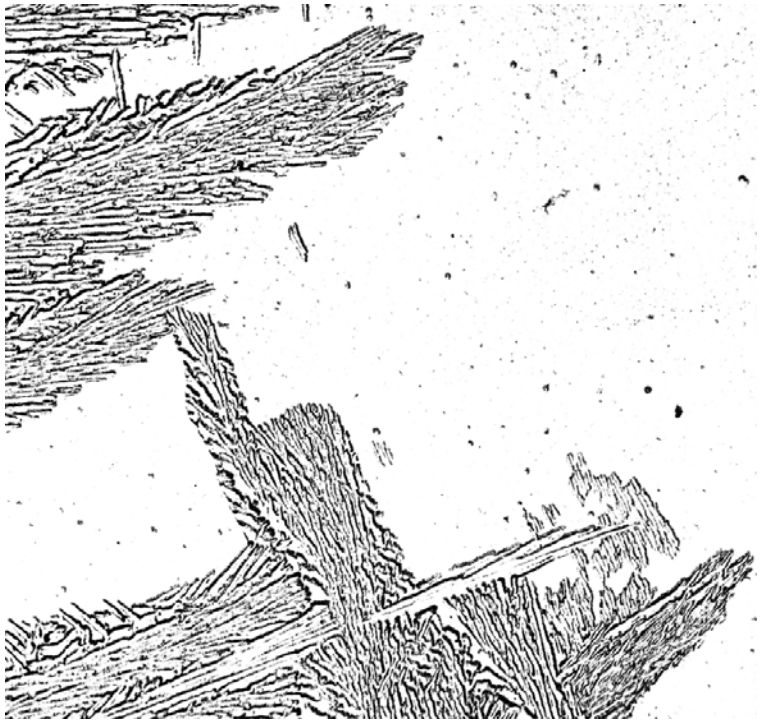
1.65%C, 25 s at 500 C, 3000x + 5500x, Modin and Modin

Inverse bainite

Spiky nodules

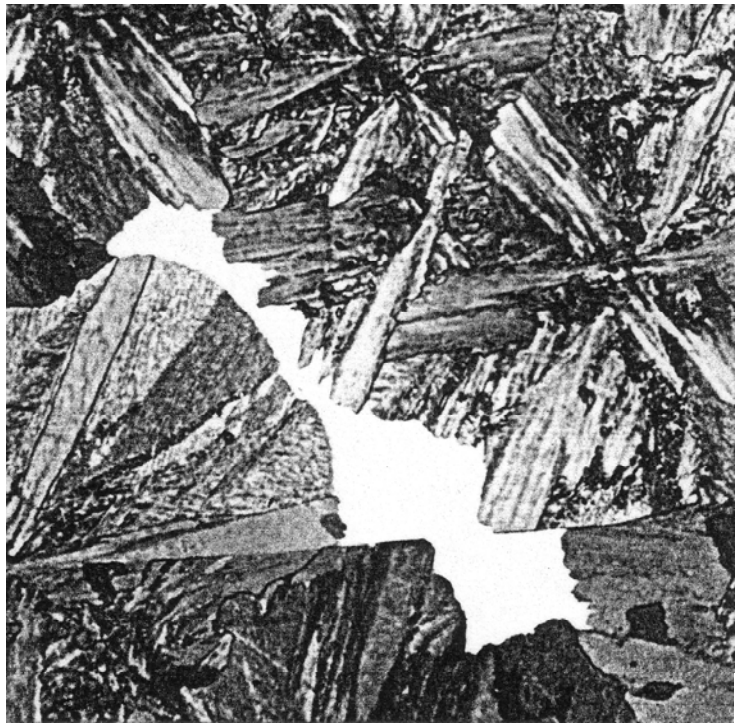
1.65%C, 60 s at 450 C, 600x, Modin and Modin

Fan-like (columnar)

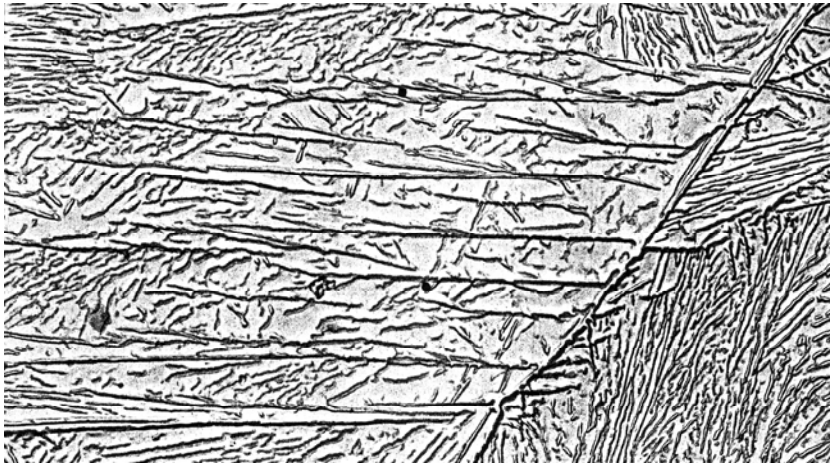


1.65%C, 60 s at 450 C, 9000x, Modin and Modin

Fan-like/columnar inverse bainite



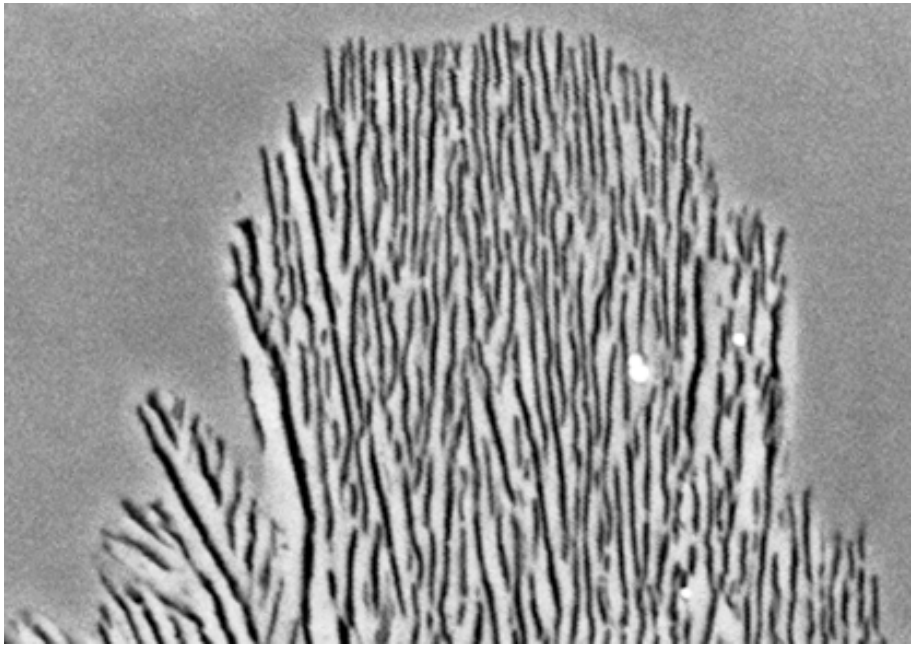
650x

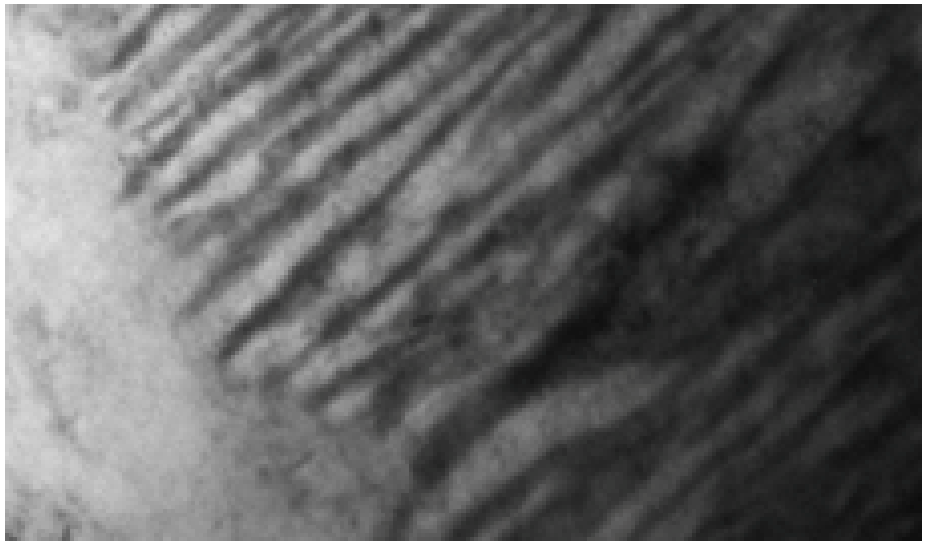


4000x

1.65%C, 240 s at 400 C, Modin and Modin

Fan-like/Columnar inverse bainite



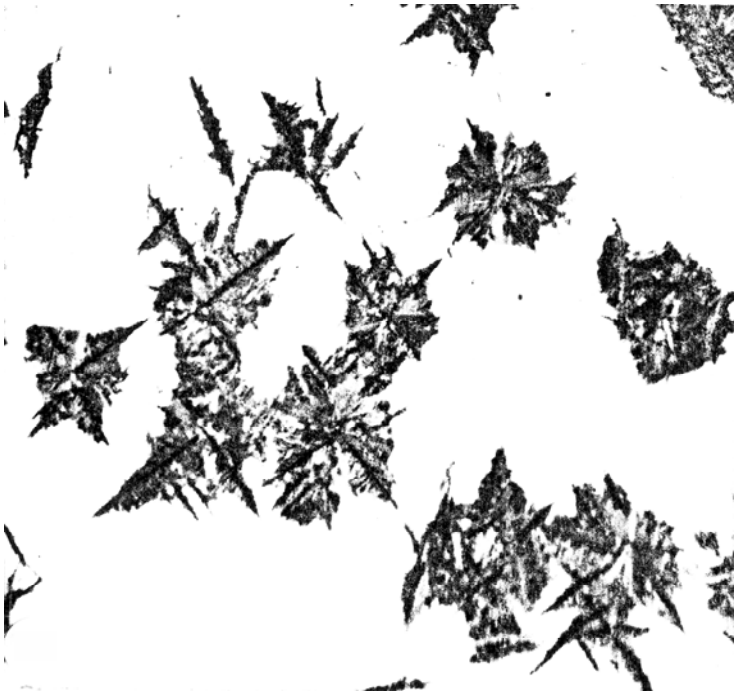


24000x

1.65%C, 360 s at 350 C, Carbide etching

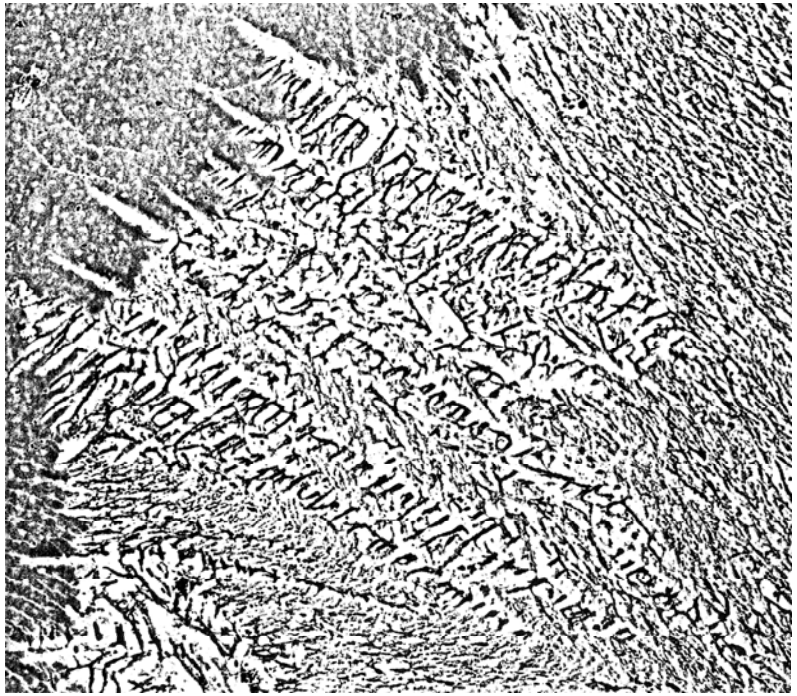
Competition between ferrite and cementite

Spiky eutectoid



550x

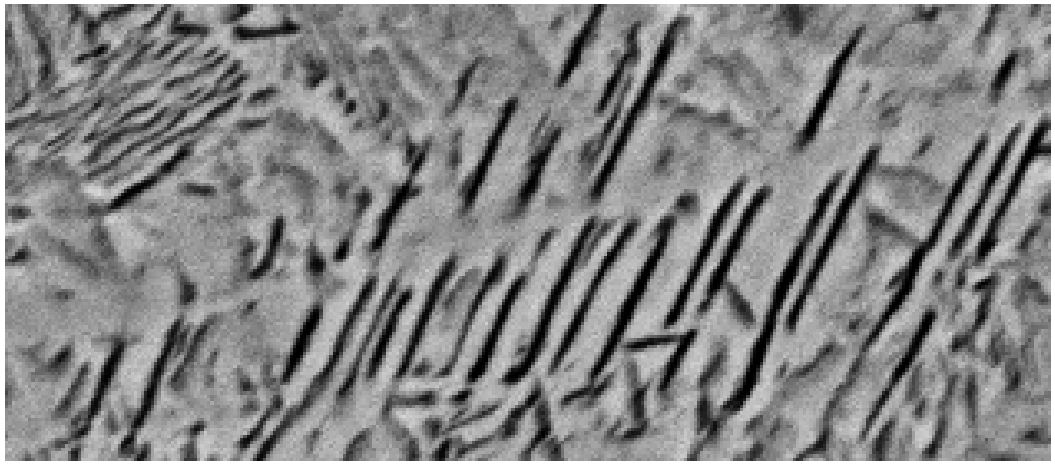
Fan-like eutectoid



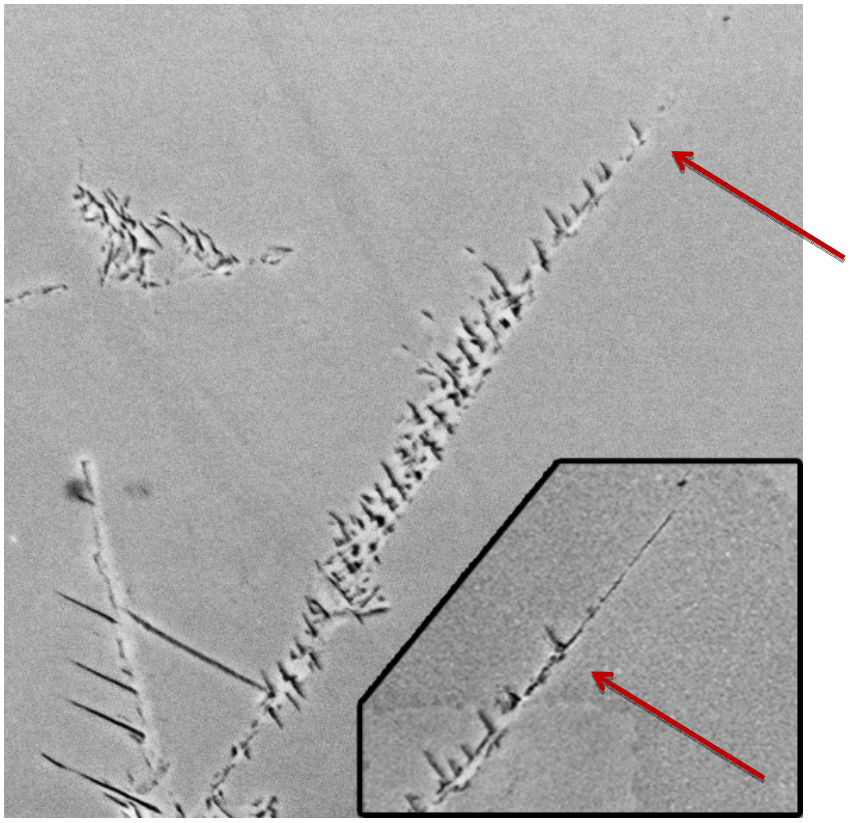
7000x

1.65 %C, 2 h 300 C, Modin and Modin

Central plate of ferrite

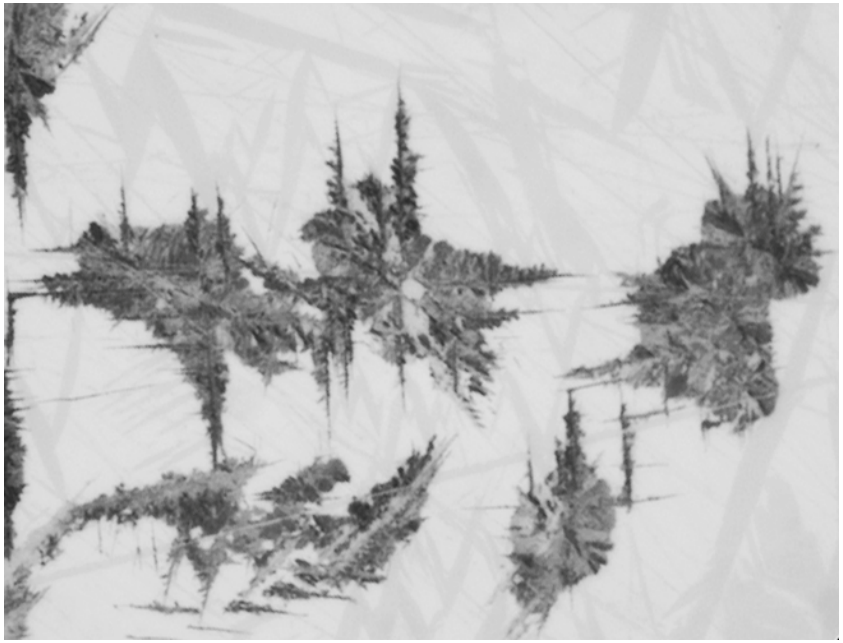


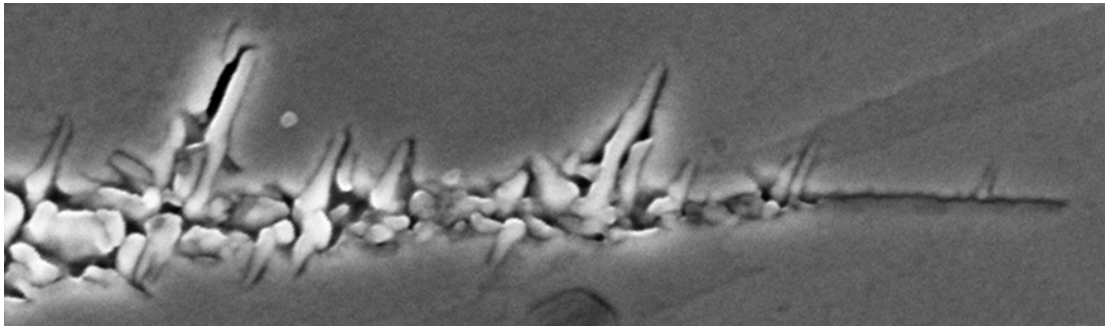
1 h 300 C, 22000x, Carbide etching



1 h 300 C, 12000x, carbide etching + nital in the insert

Competition between ferrite and cementite

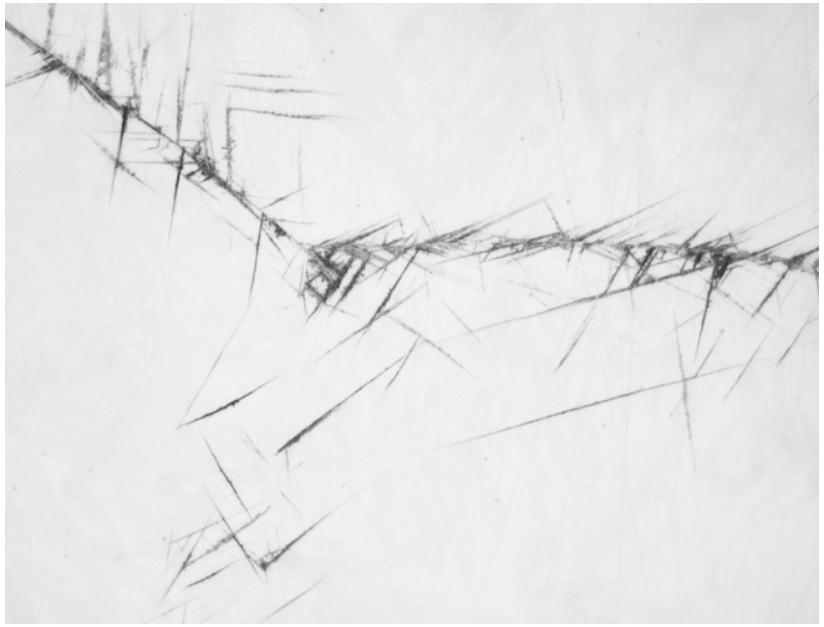




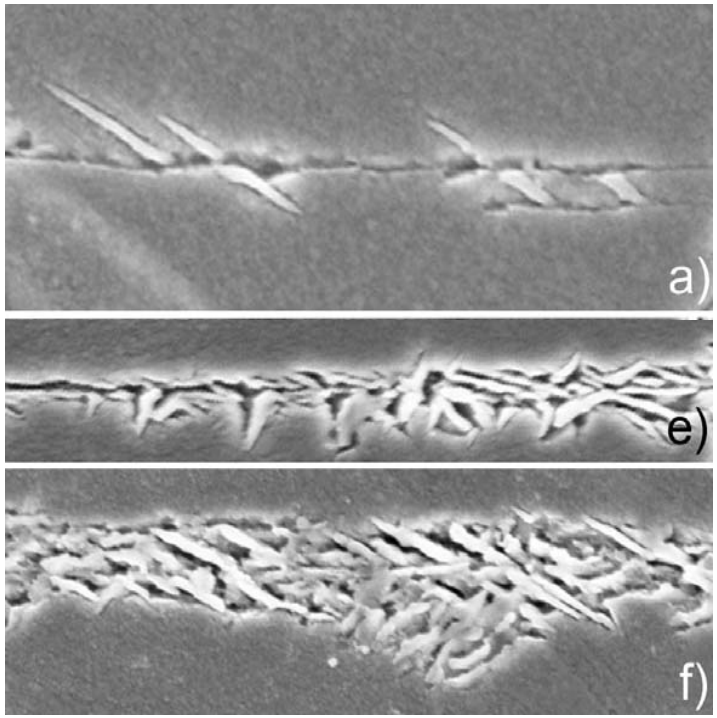
900x 26000x

1.67 %C, 2 h 275 C, nital etching

Irregular lower bainite



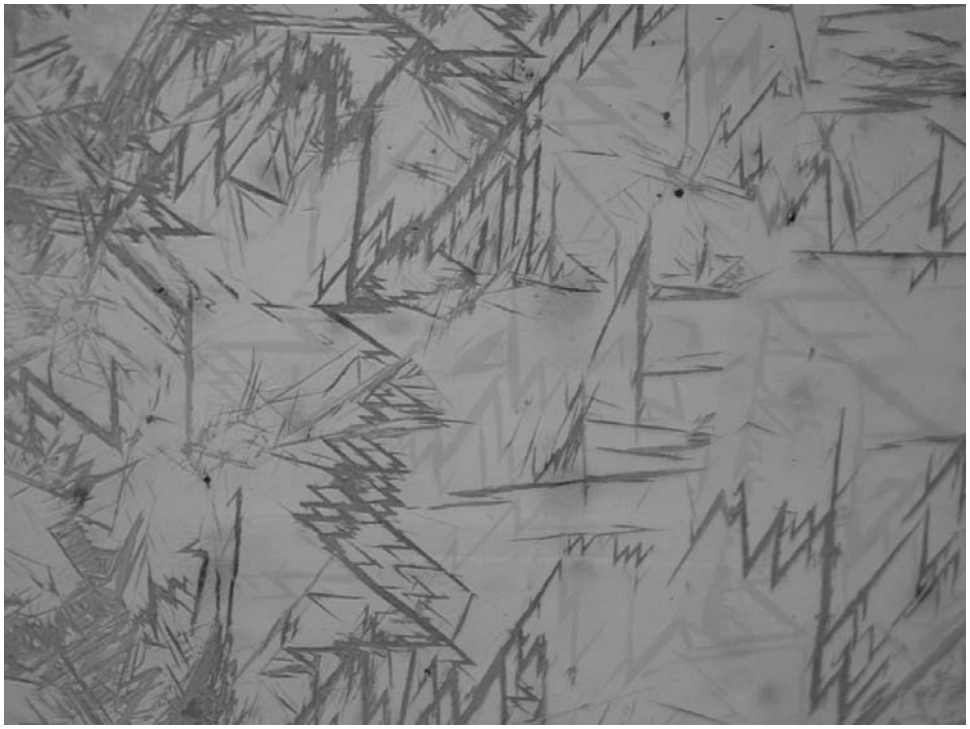
900x

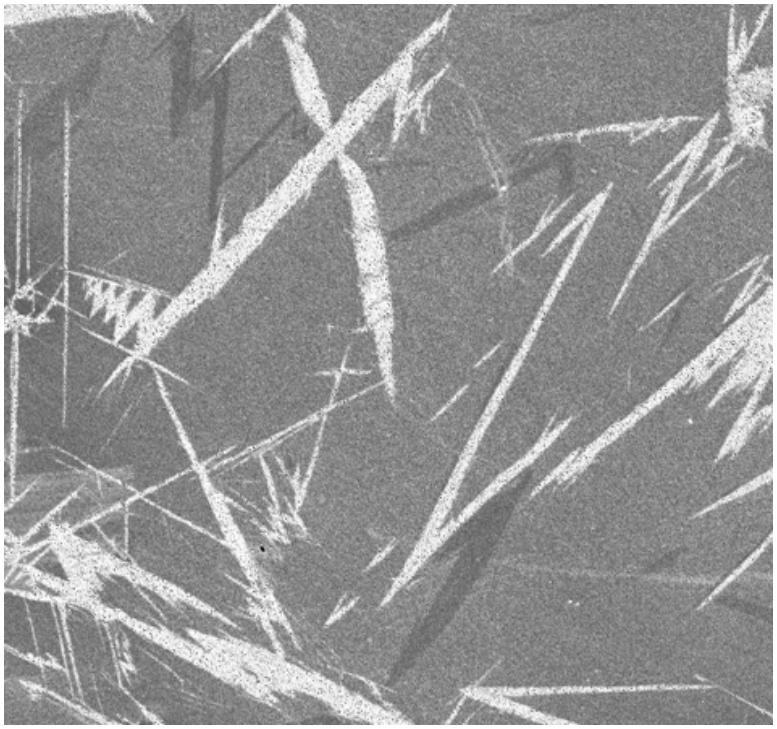


a,e:22000x
f:34000x

1.67 %C, 4 h 250 C

Zig Zag pattern



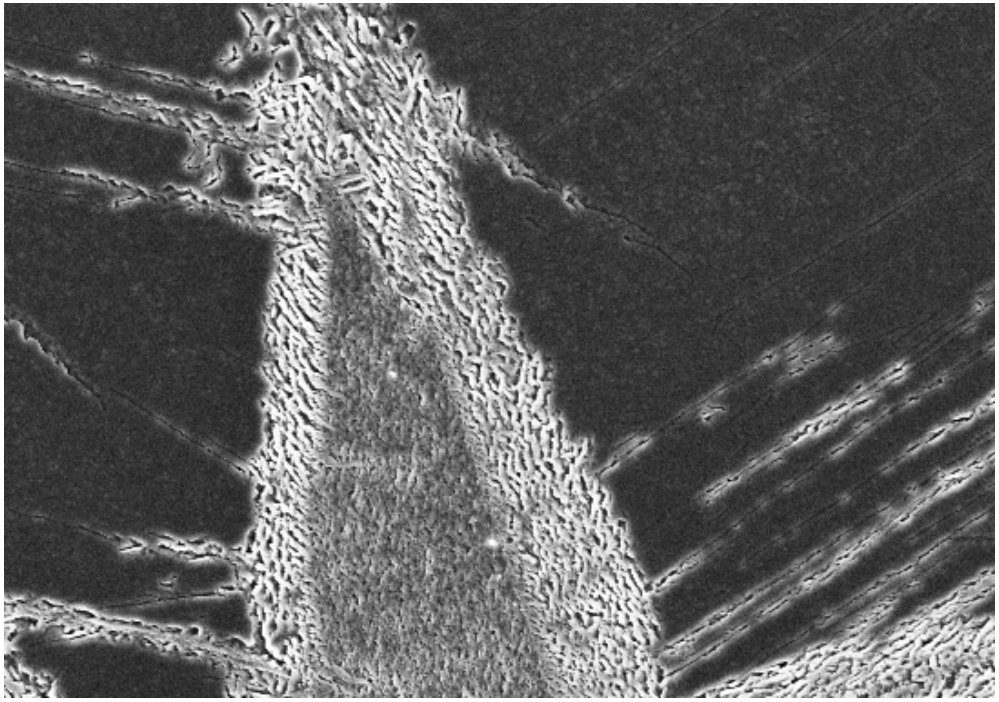


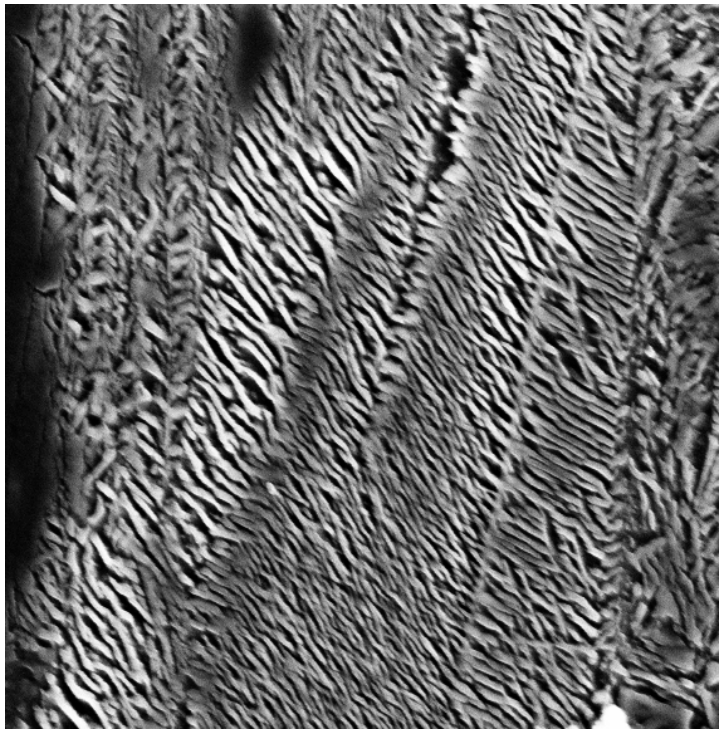
400x 1200x

1.67 %C, 96 h 200 C

Lower bainite

Lamellar and irregular lower bainite



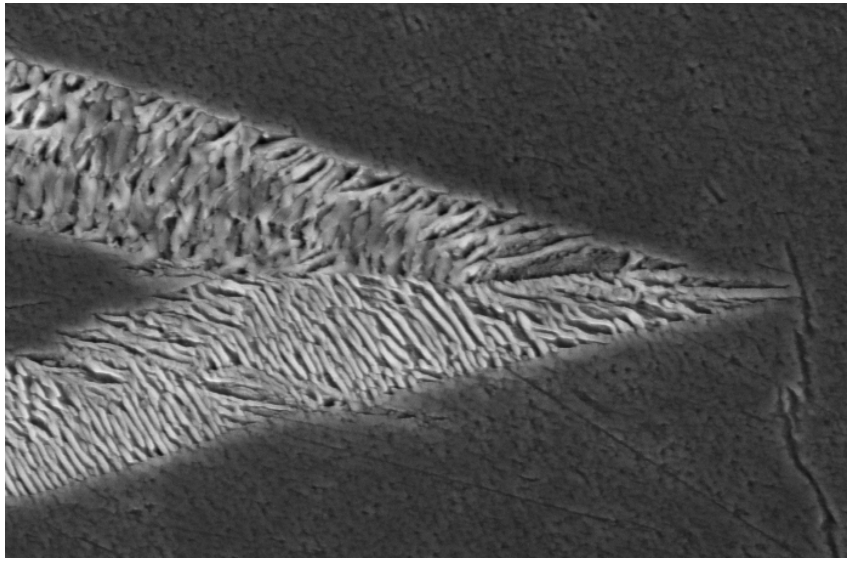


6000X

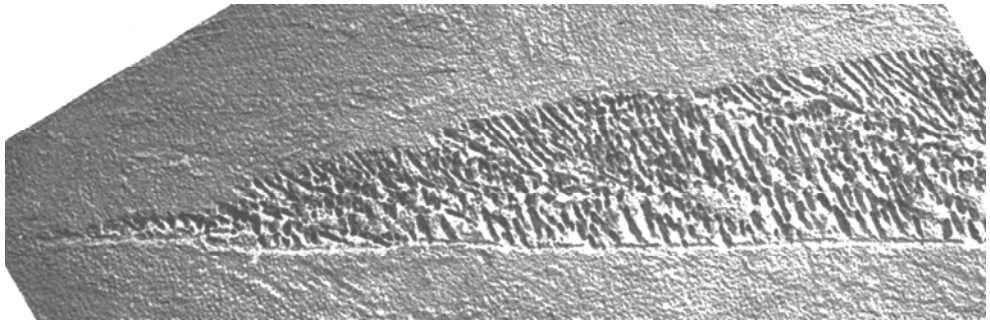
21000X

1.67 %C, quenching + 75 h 200 C

Lower bainit

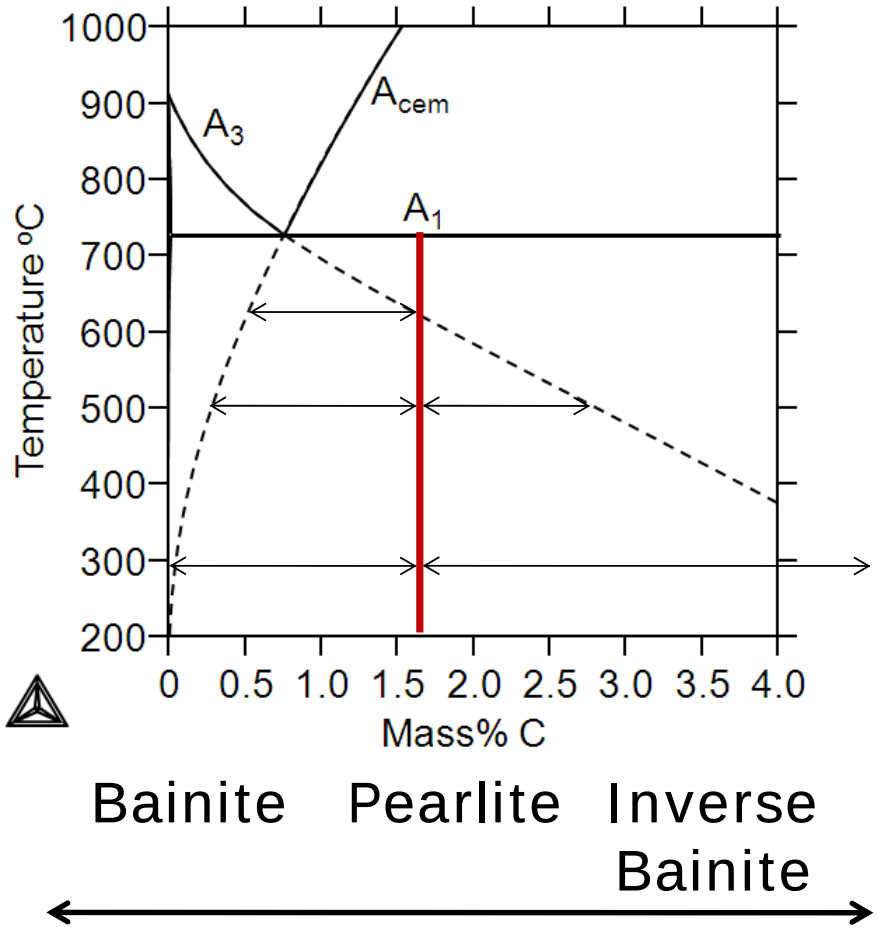


1.67 %C, 96 h 200 C, 16000X



0.69 %C, 345 C, 10000X, Oblak and Hehemann, 1967

Symmetry in austenite transformation products



High carbon:

Spiky - cementite leading phase

Spherical

Spiky - ferrite leading phase

Summary

- Widmanstätten cementite gives a surface relief just as Widmanstätten ferrite- Proposed that they form by the same mechanism.
- Symmetry with carbon:
  - Bainite - ferrite leading phase
  - Pearlite - no leading phase
  - Inverse bainite – cementite leading phase
- Symmetry with temperature:
  - Spiky- cementite leading phase
  - Fan-like /Spherical
  - Spiky – ferrite leading phase/ cem have a crystallographic relation with austenite
  - Ordinary lower bainite