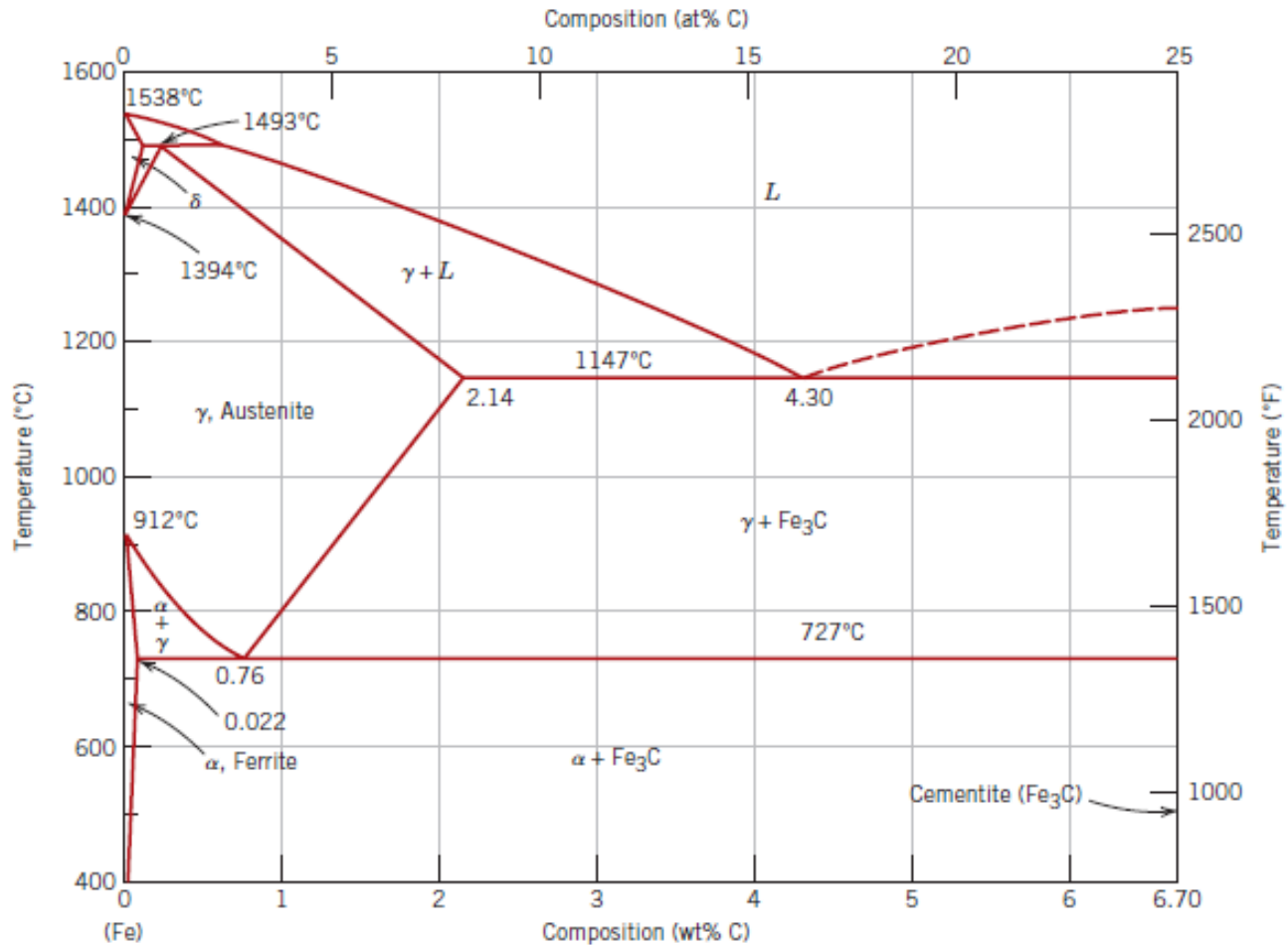


07

CIÊNCIA E ENGENHARIA DOS MATERIAIS

Engenharia de Produção / Engenharia Mecânica
Prof. Luis Fernando Maffeis Martins

Diagramas eutetóides



Reação eutetóide

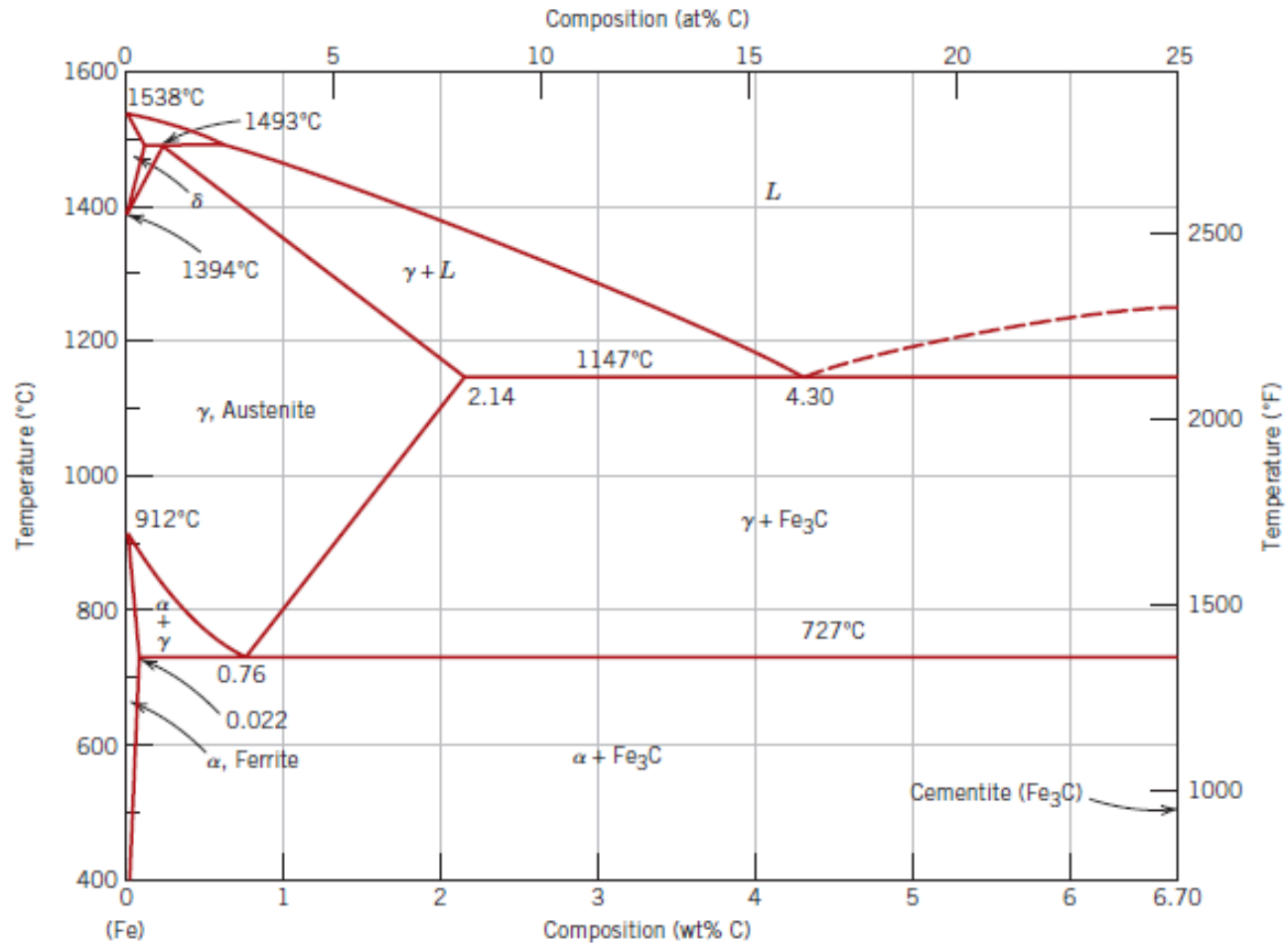
- Uma fase sólida, durante o resfriamento, se transforma em duas fases sólidas diferentes



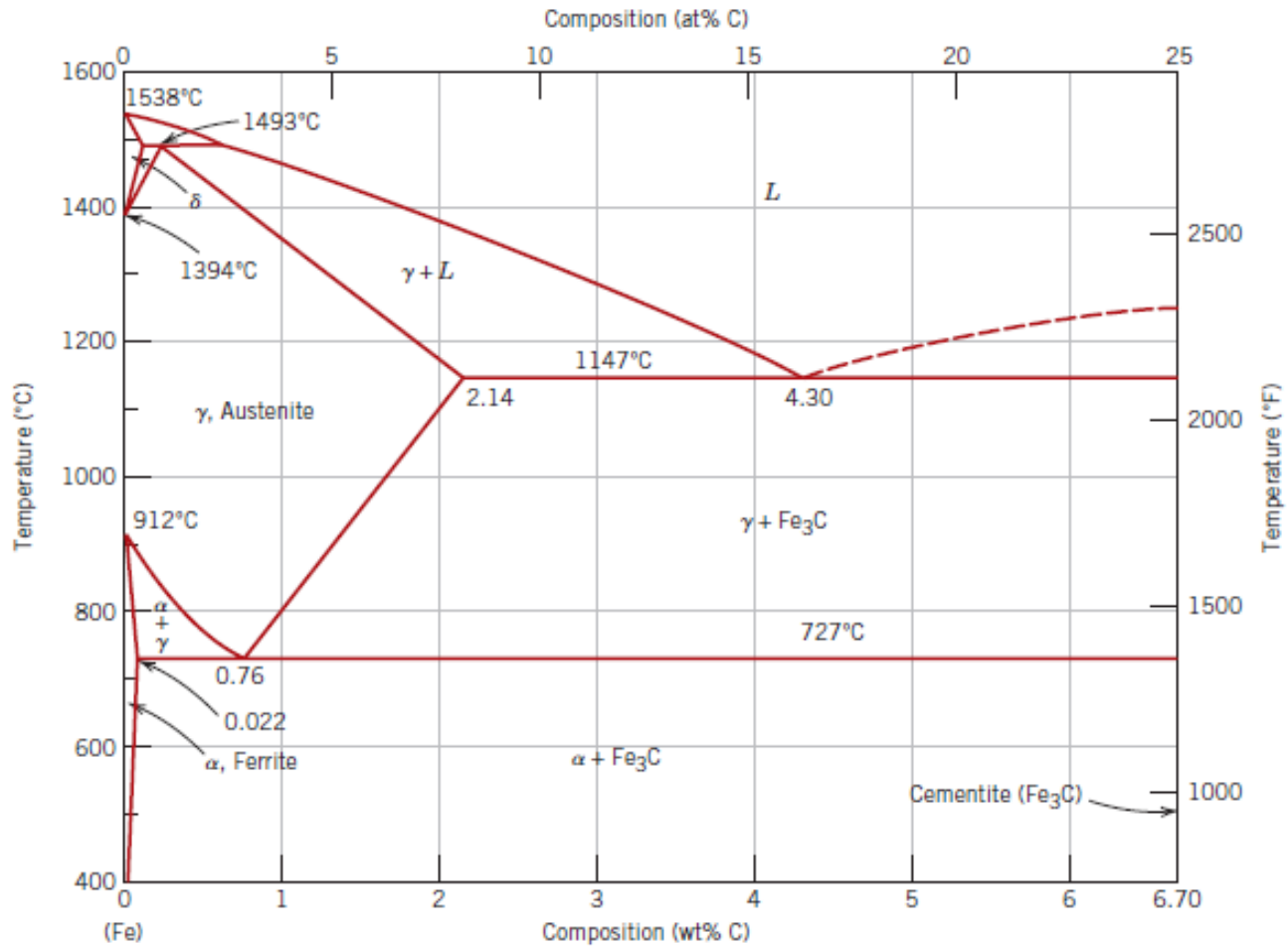
- A temperatura em que a reação eutetóide ocorre é denominada temperatura eutetóide.
- Durante o aquecimento, à temperatura eutetóide, as duas fases sólidas se transformam em uma única fase sólida diferente



Diagramas eutetóides



Diagramas Fe-Fe₃C



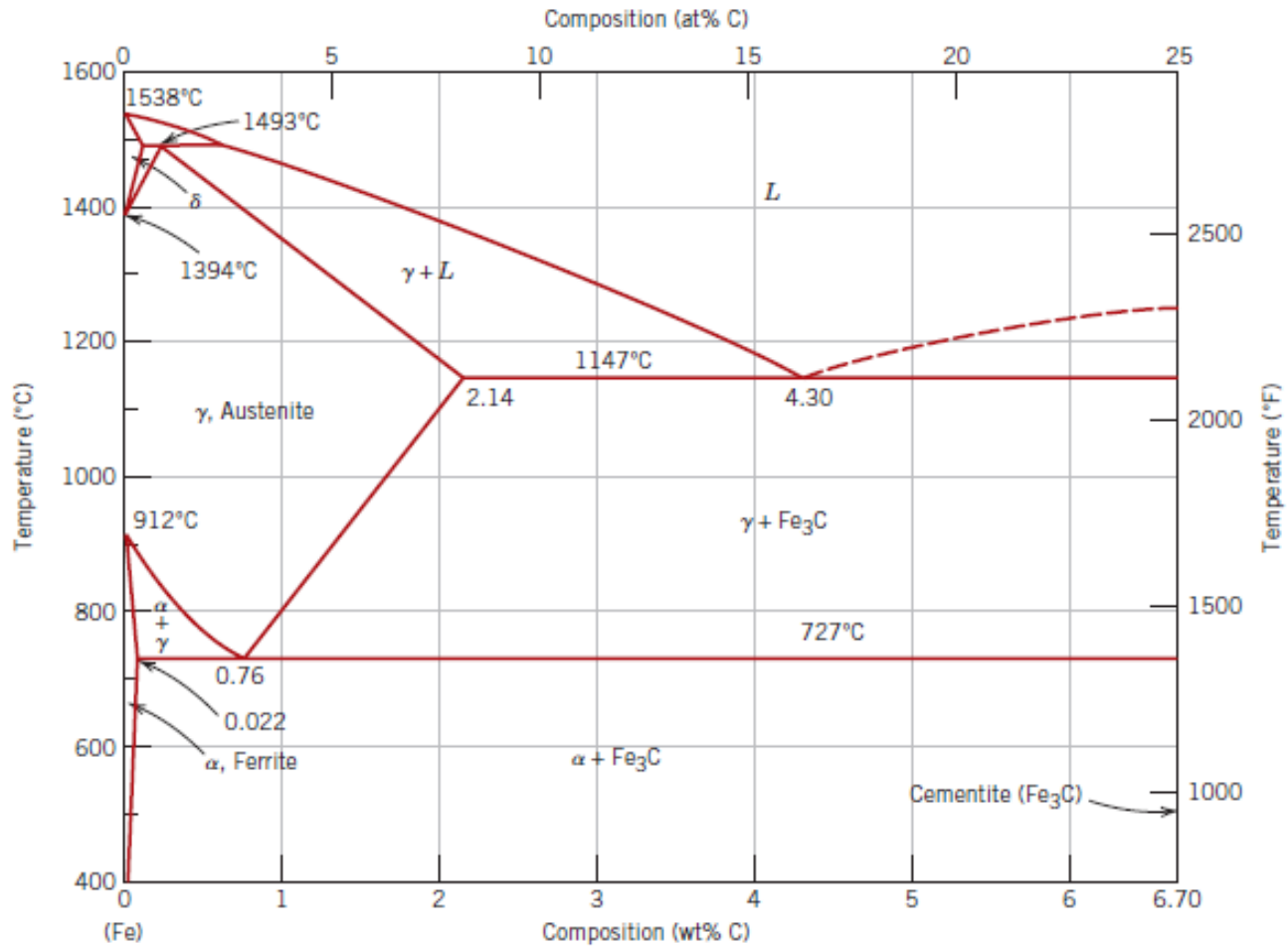
Ferro

- O ferro apresenta, durante o aquecimento, duas mudanças em sua estrutura cristalina antes de fundir:
 - $T < 912 \text{ } ^\circ\text{C}$ -- cúbica de corpo centrado (CCC)
 - $T = 912 \text{ } ^\circ\text{C}$ -- CCC \rightarrow cúbica de faces centradas (CFC)
 - $T = 1394 \text{ } ^\circ\text{C}$ -- CFC \rightarrow CCC
 - $T = 1538 \text{ } ^\circ\text{C}$ -- CCC \rightarrow líquido

Ferro

- $T < 912 \text{ } ^\circ\text{C}$ = ferrita - α - CCC
- $912 < T < 1394^\circ\text{C}$ = austenita - γ - CFC
- $1394 < T < 1538 \text{ } ^\circ\text{C}$ = ferrita δ - CCC
- $T > 1538 \text{ } ^\circ\text{C}$ = líquido

Diagramas Fe-Fe₃C



Sistema Fe-Fe₃C

- Reação eutetóide:

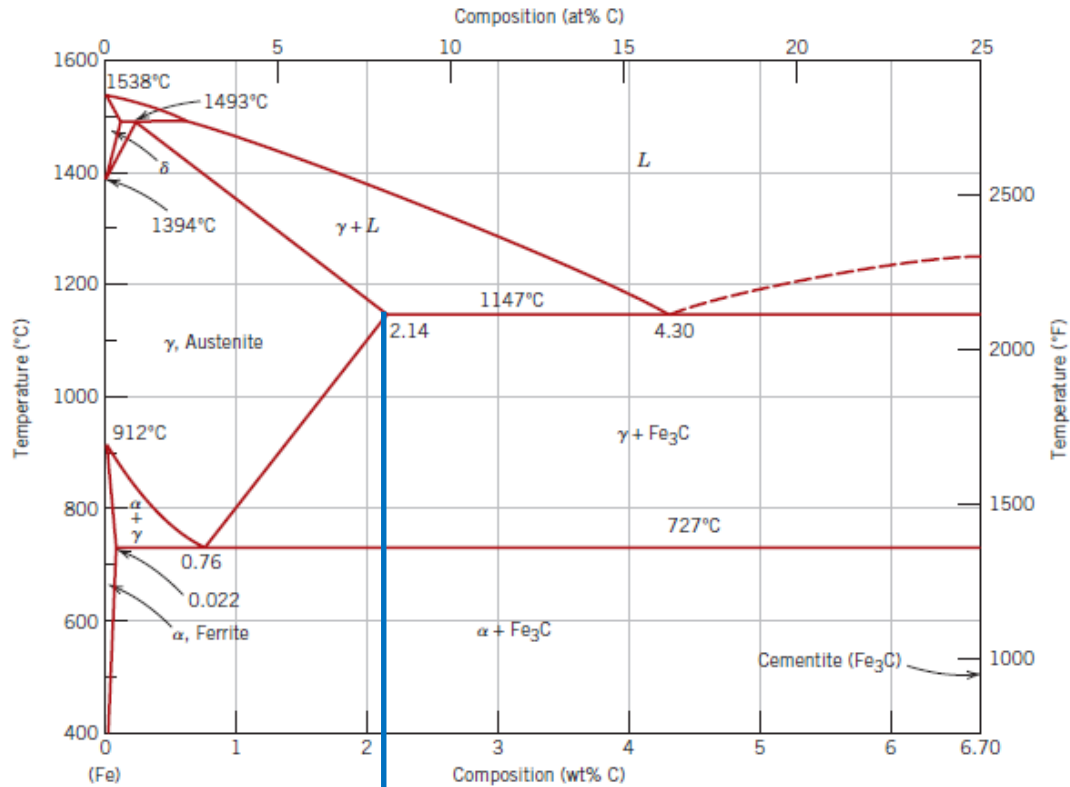


γ = austenita

α = ferrita

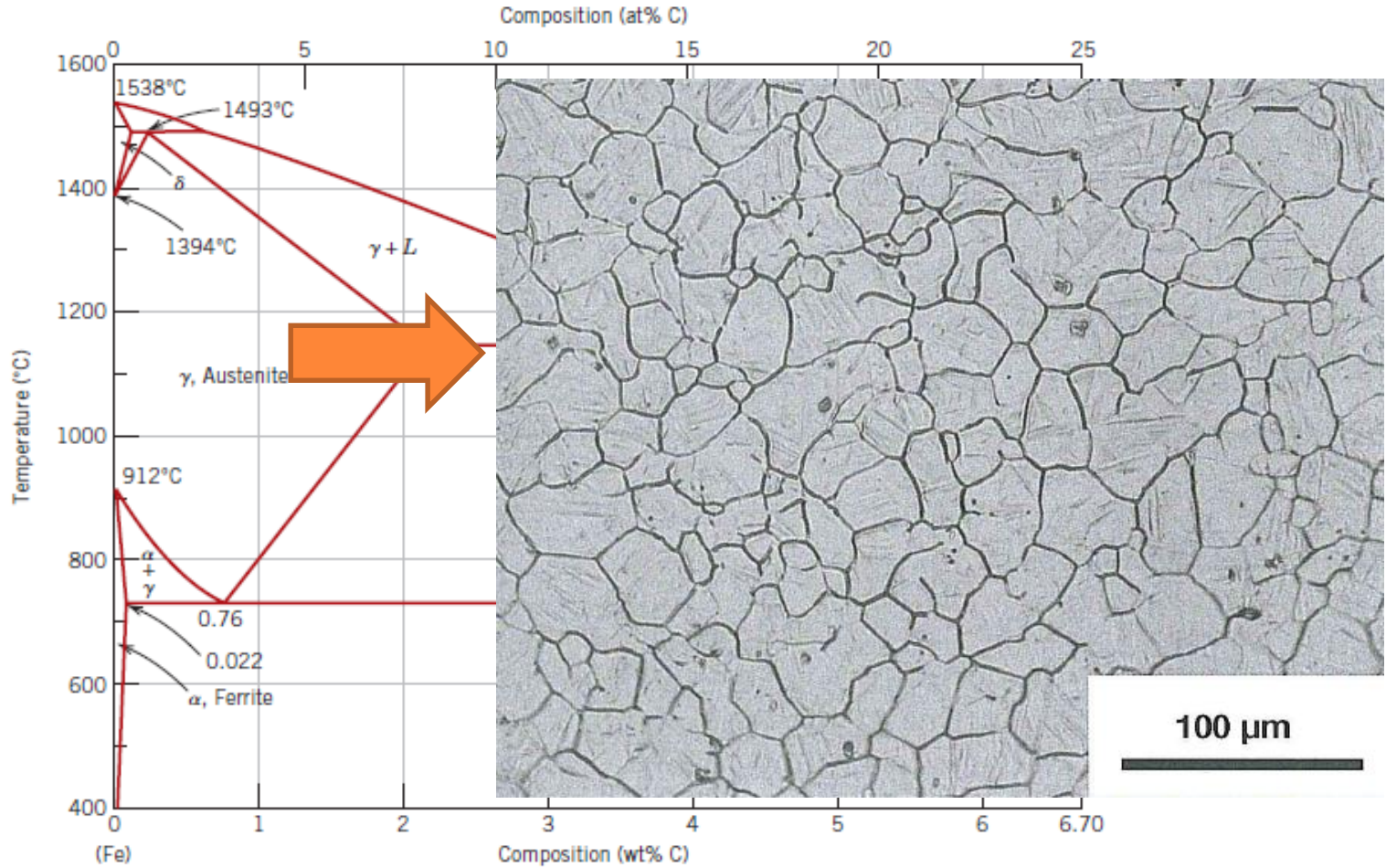
Fe₃C = cementita

Diagramas Fe-Fe₃C

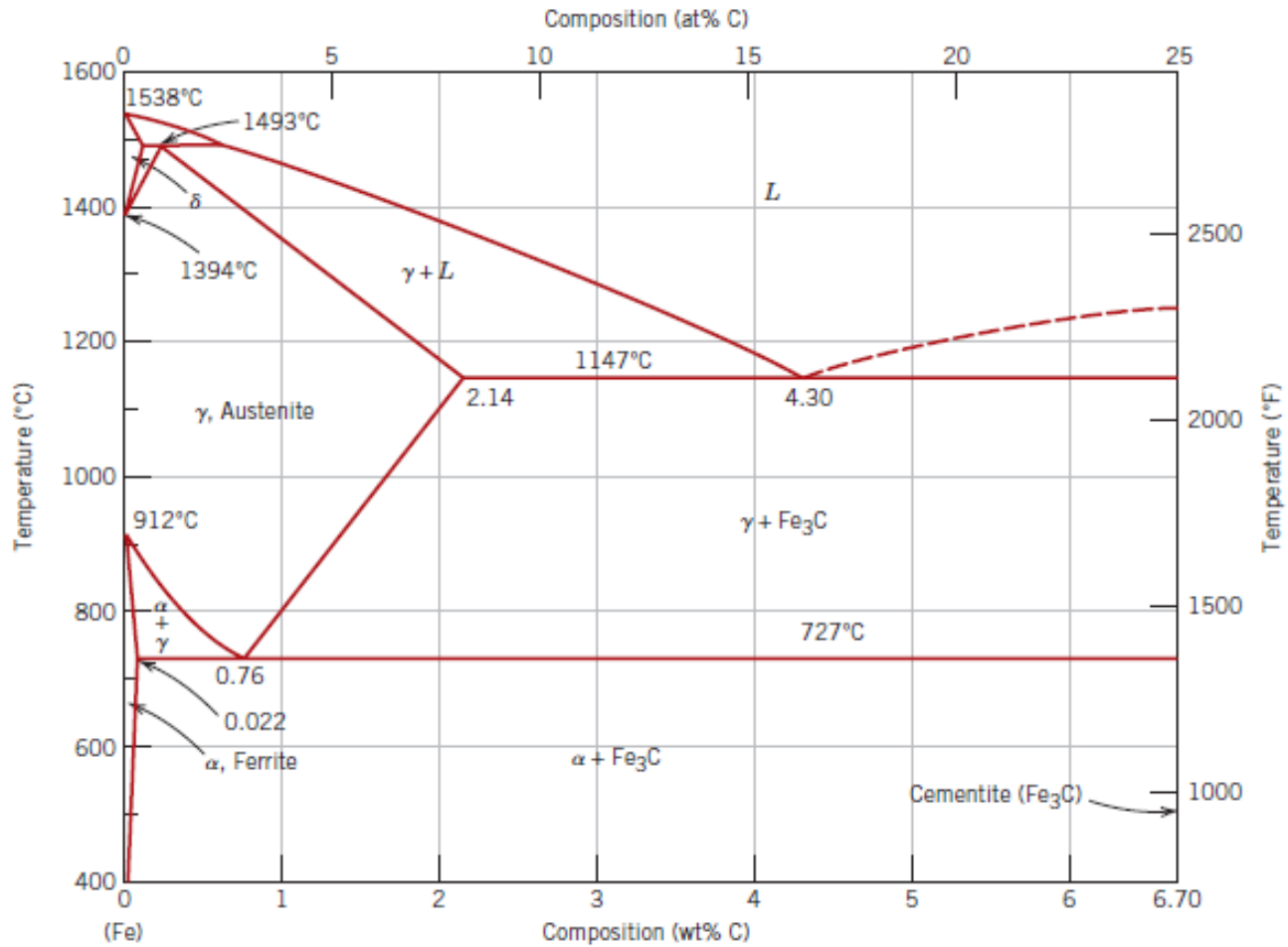


Aços ← → Ferros Fundidos

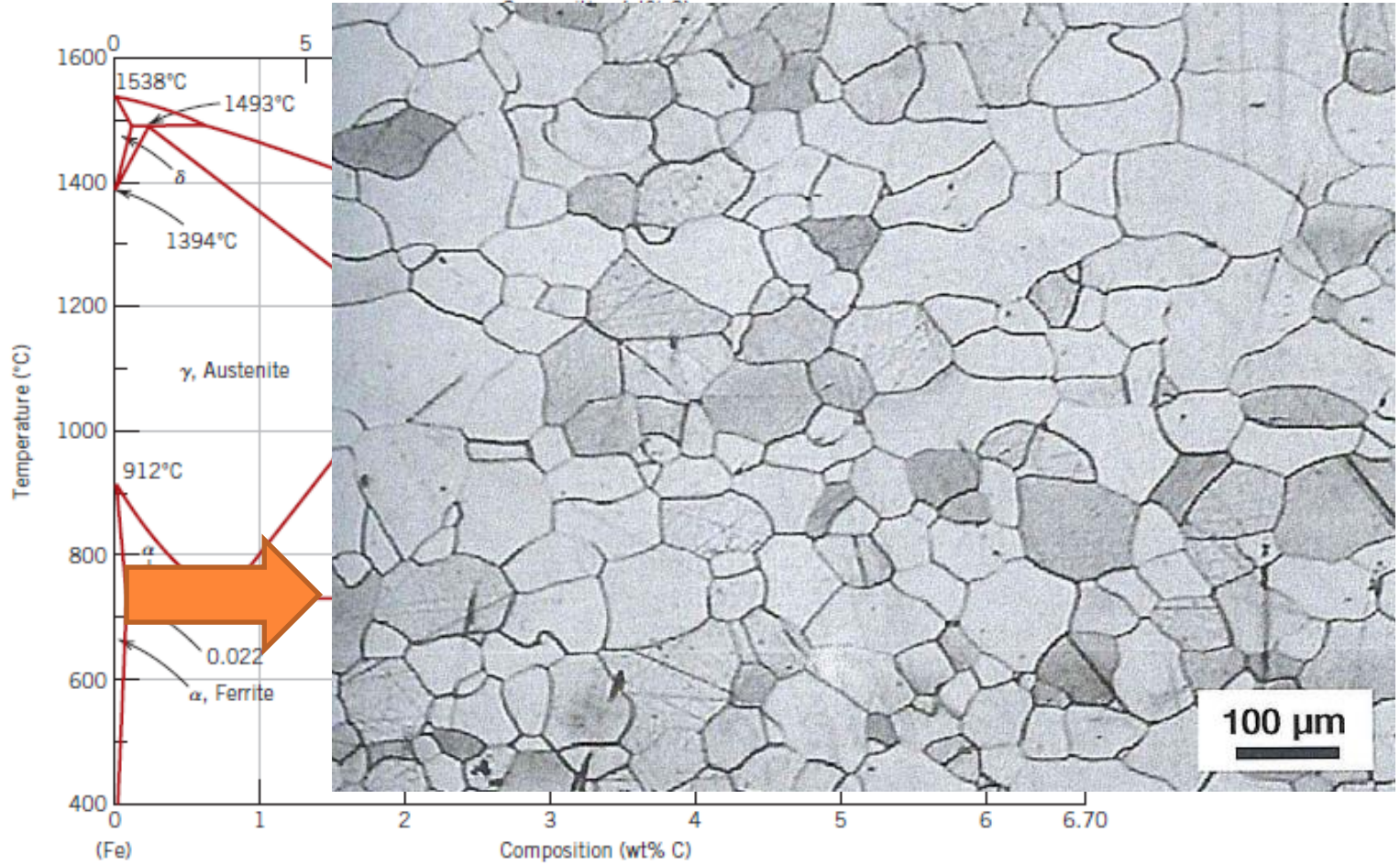
austenita γ



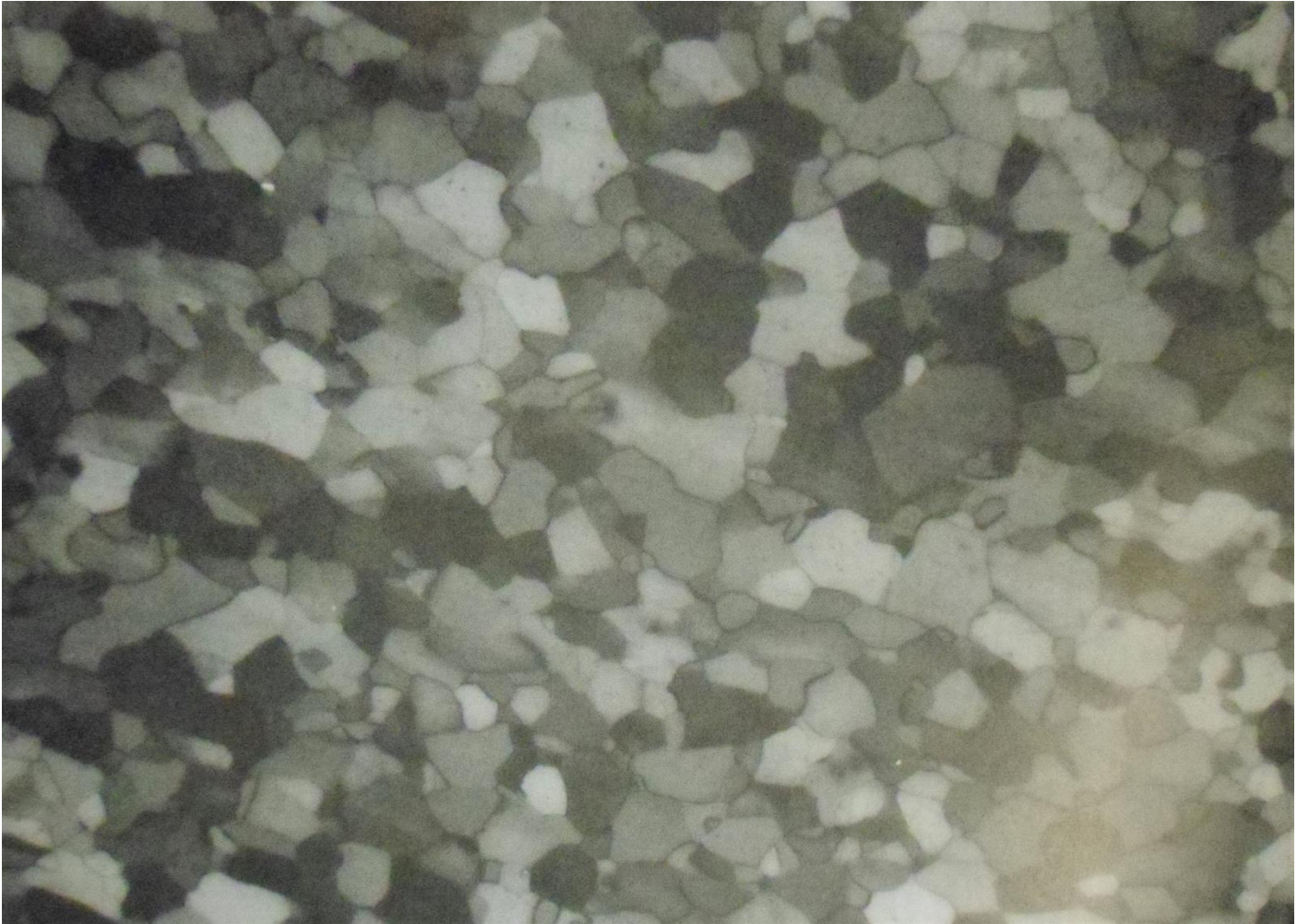
Diagramas Fe-Fe₃C



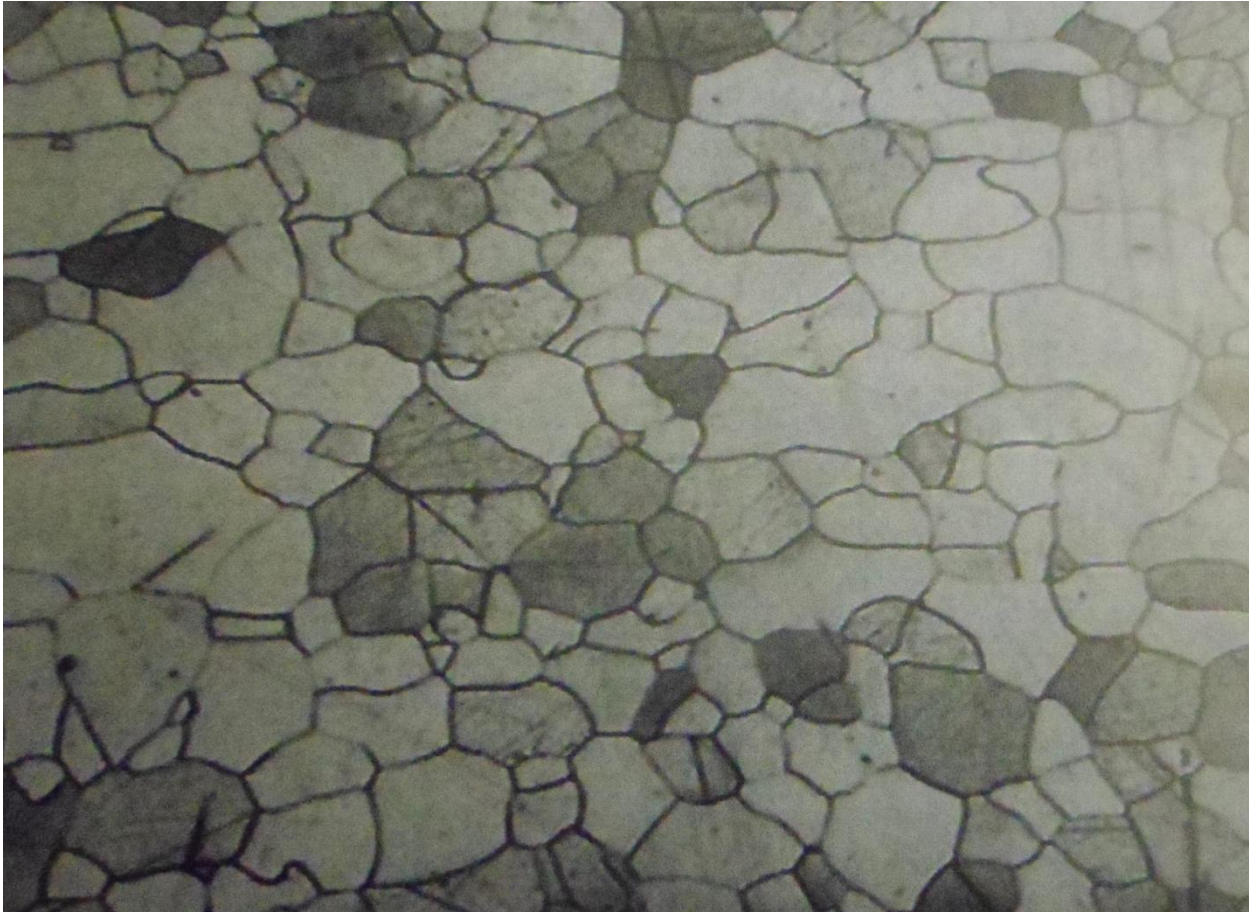
ferrita α



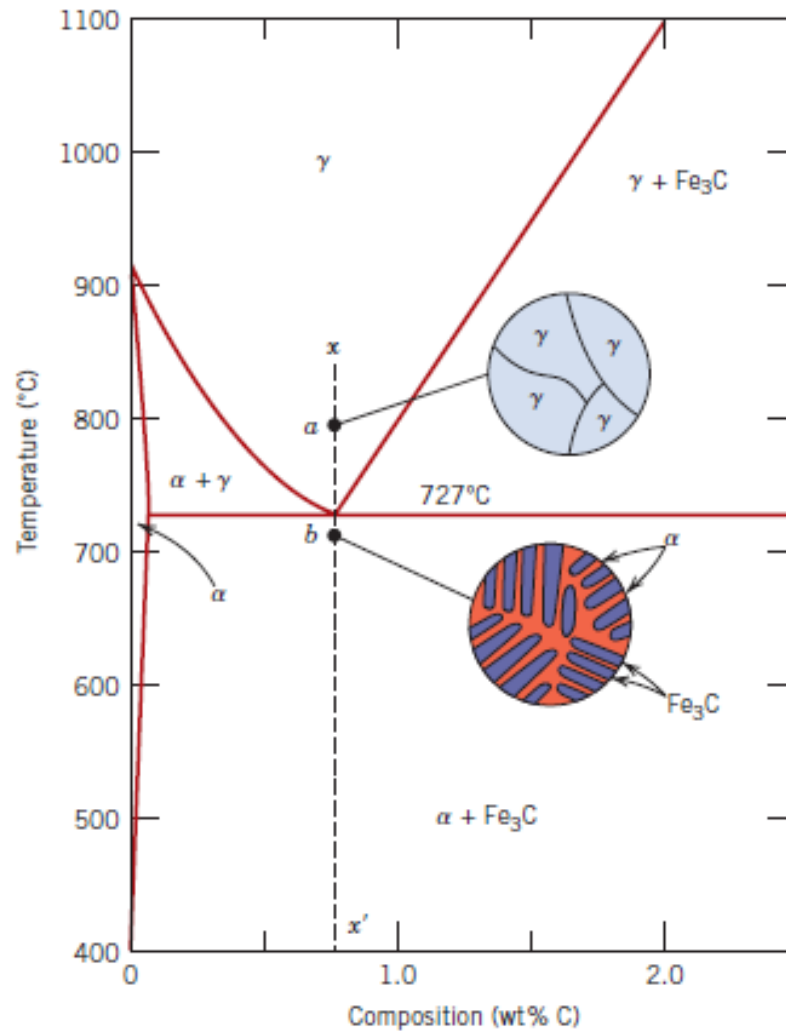
ferrita α



ferrita α



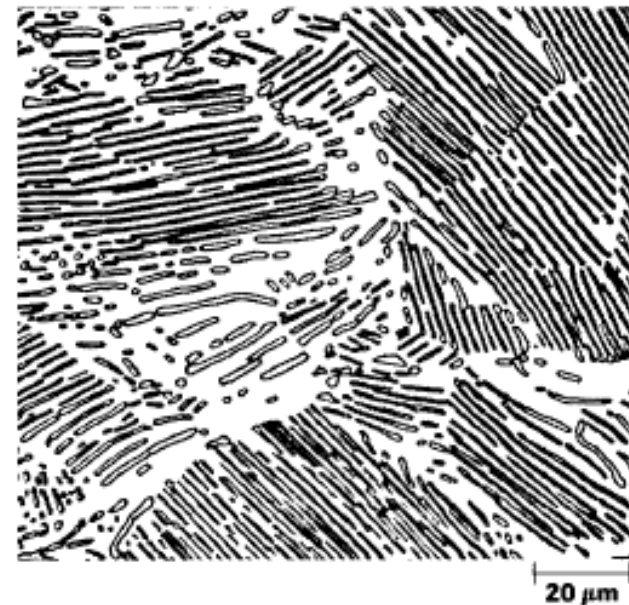
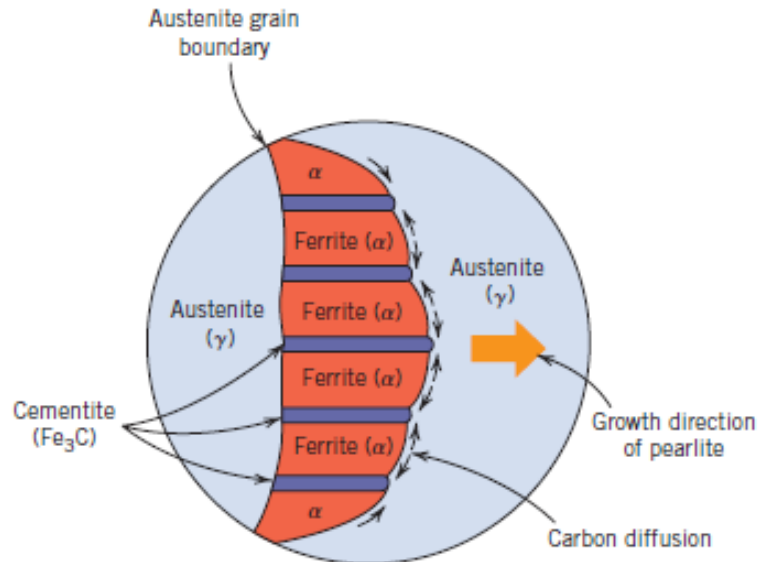
Microestrutura



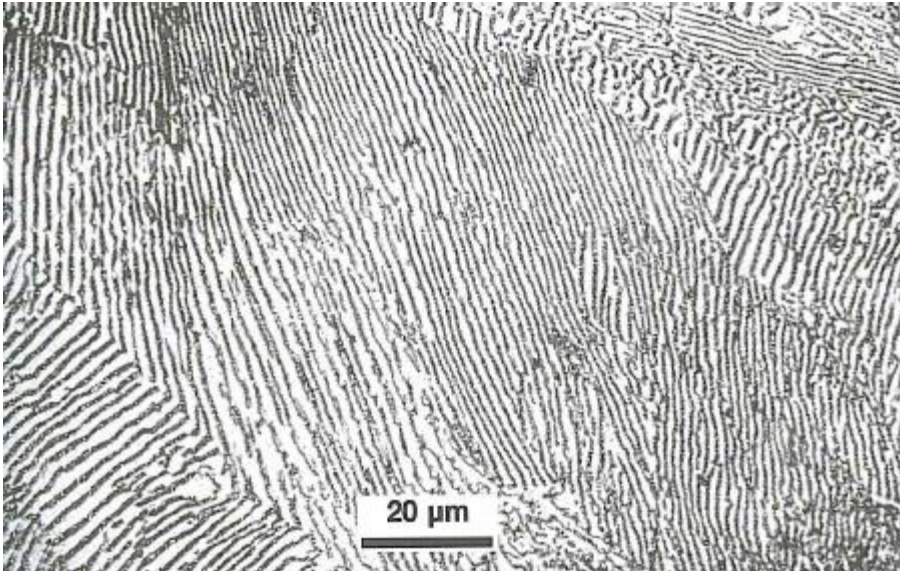
Aço eutetóide
%C = 0,76

Microestrutura

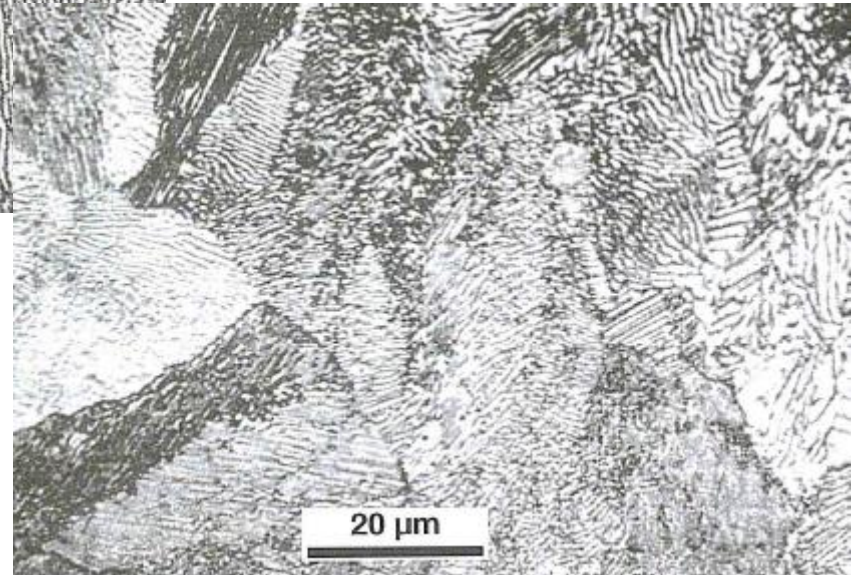
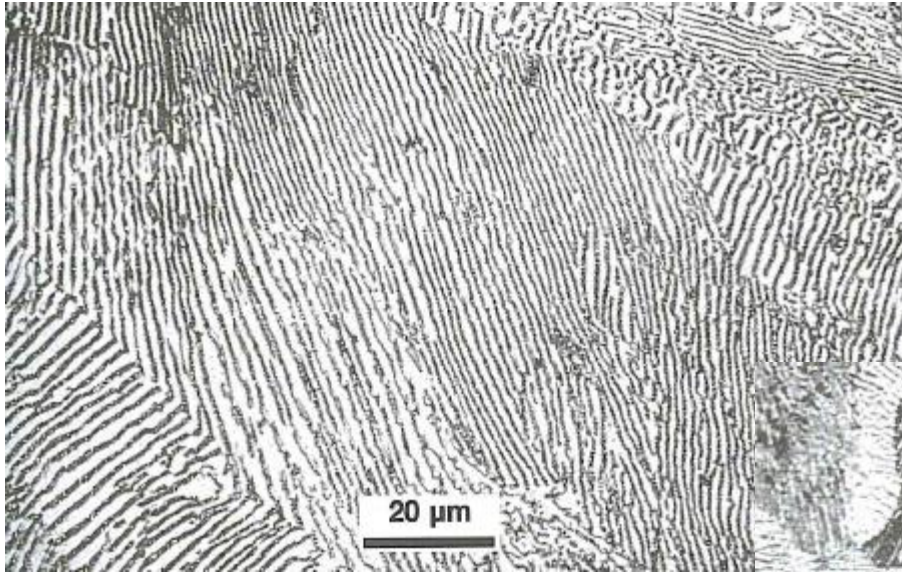
$\alpha + \text{Fe}_3\text{C}$ com forma lamelar (perlita)



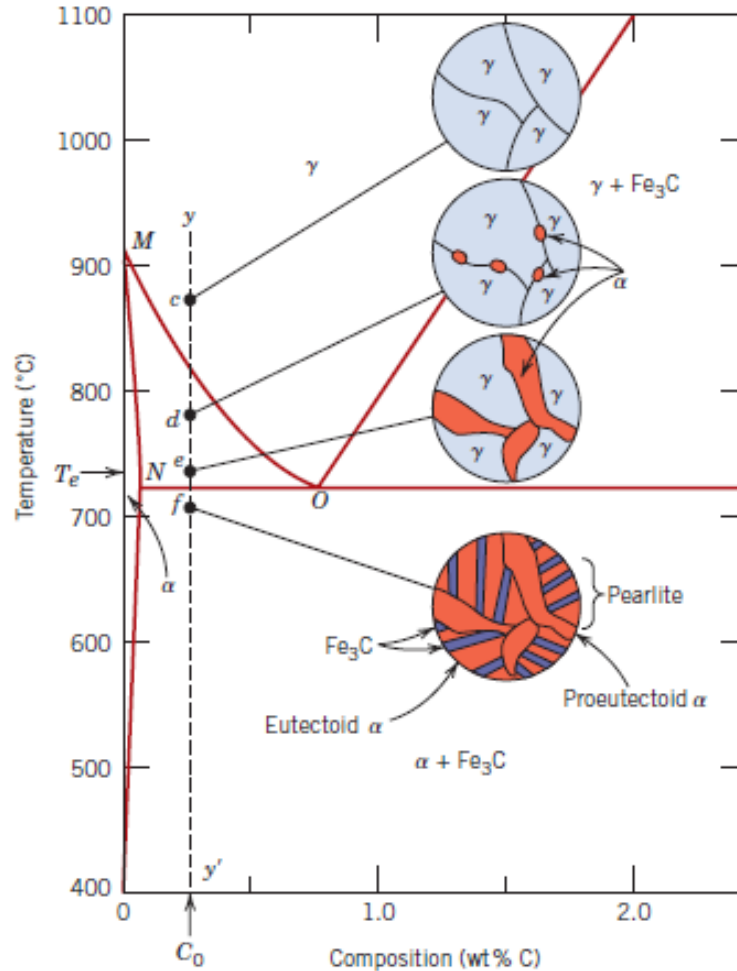
Perlita



Perlita



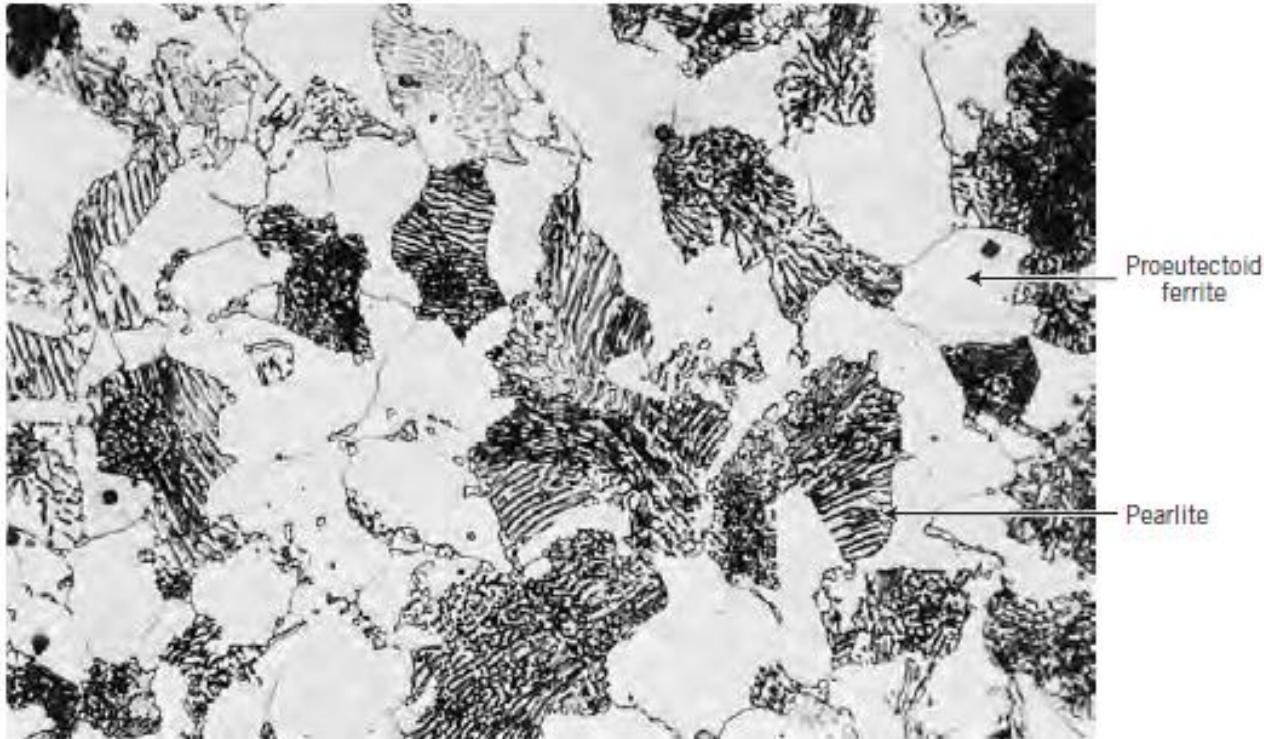
Microestrutura



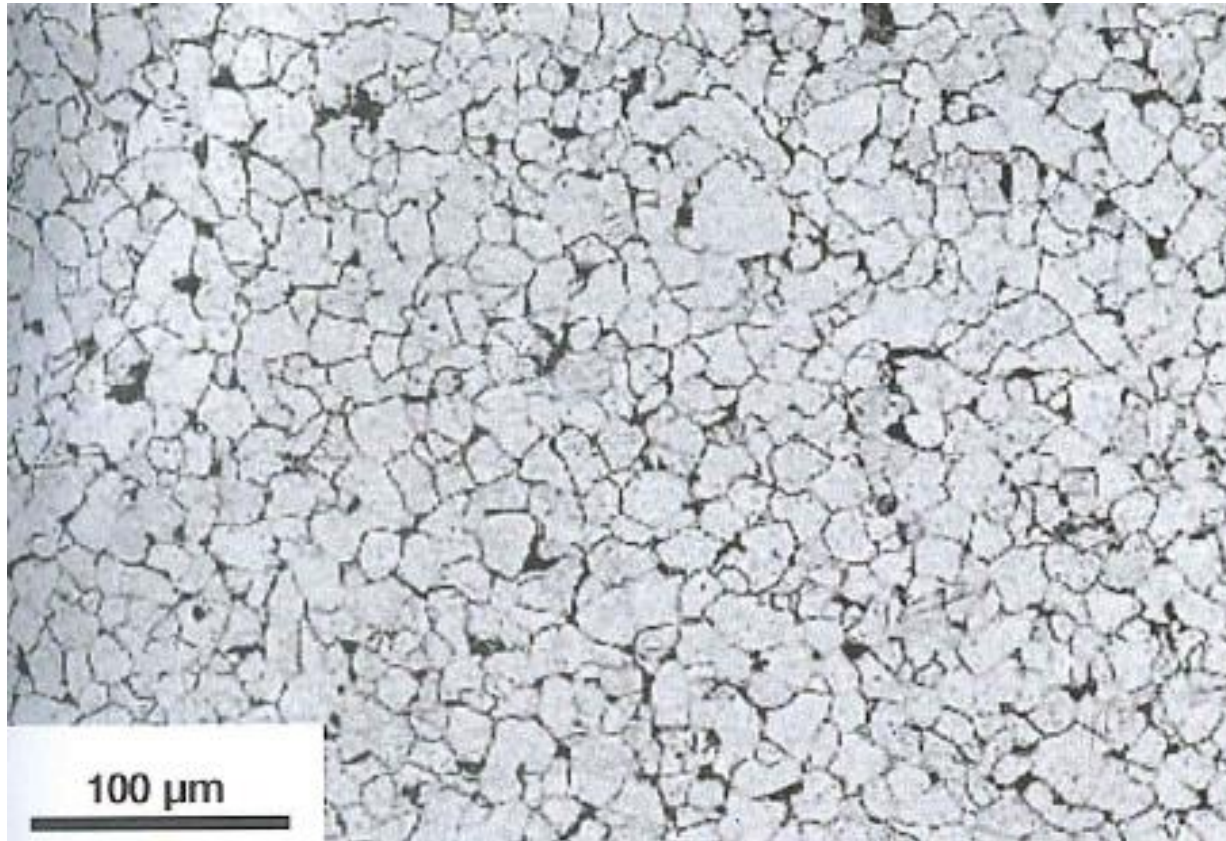
Aço hipoeutetóide
 $\%C < 0,76$

Microestrutura

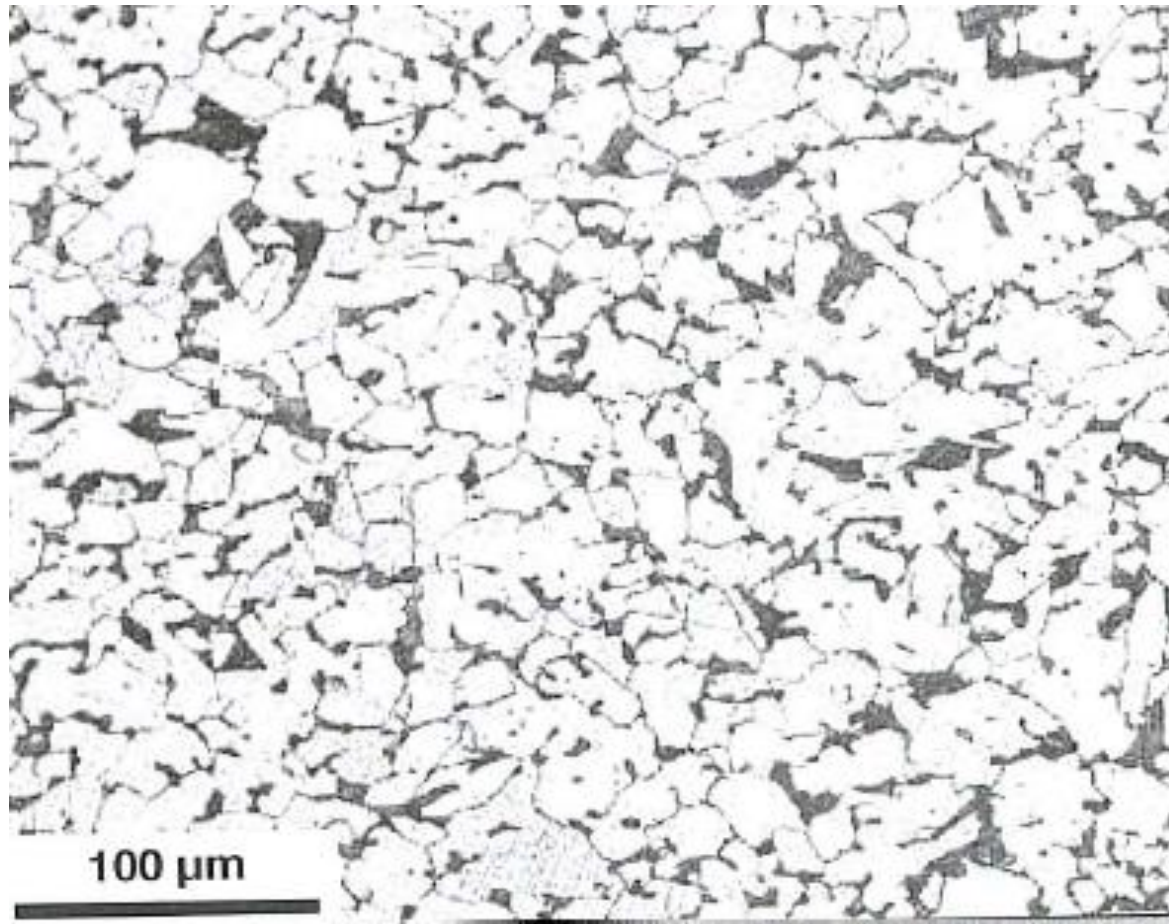
Aço hipoeutetóide
 $\%C < 0,76$



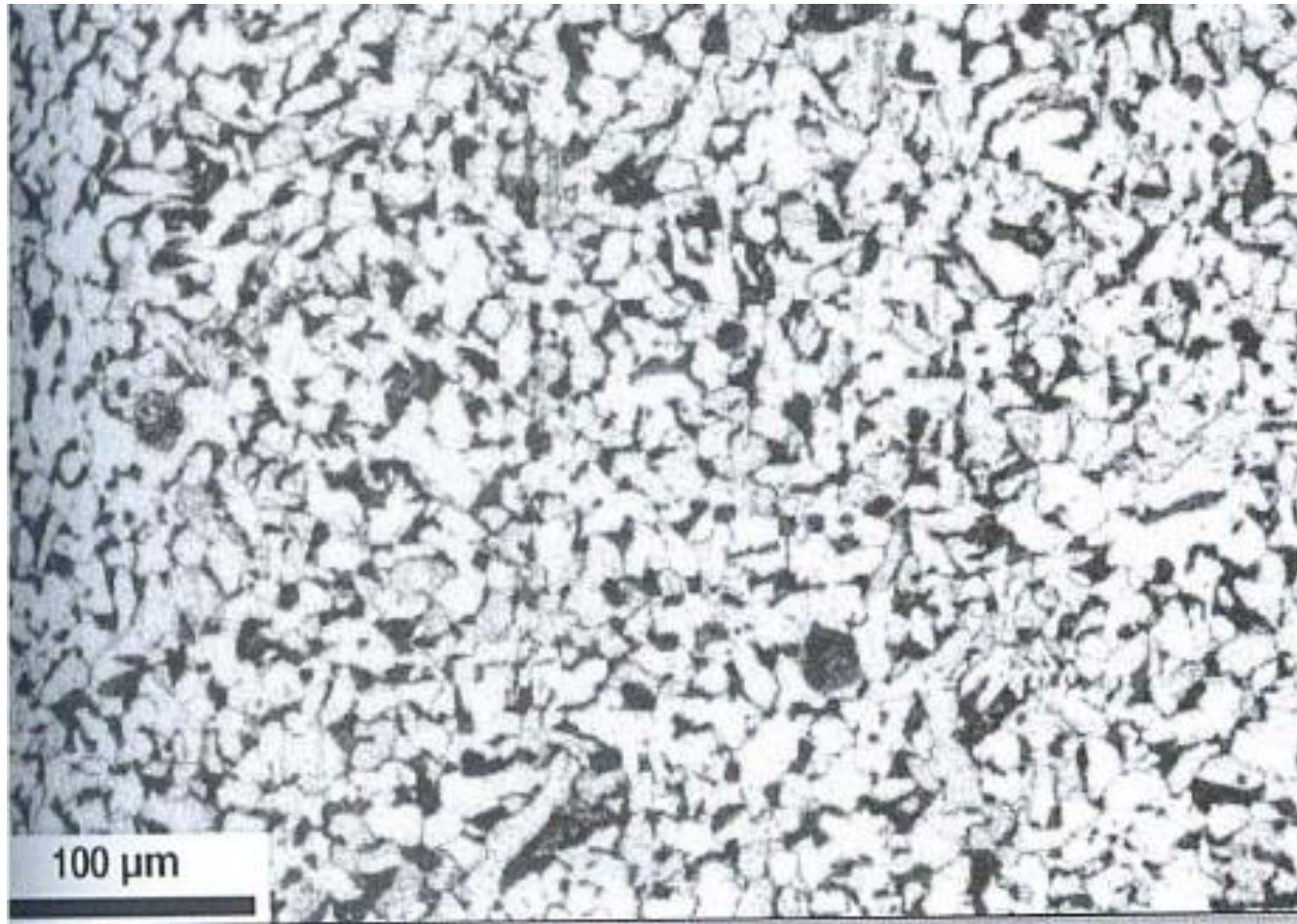
SAE 1006 – ferrita + perlita



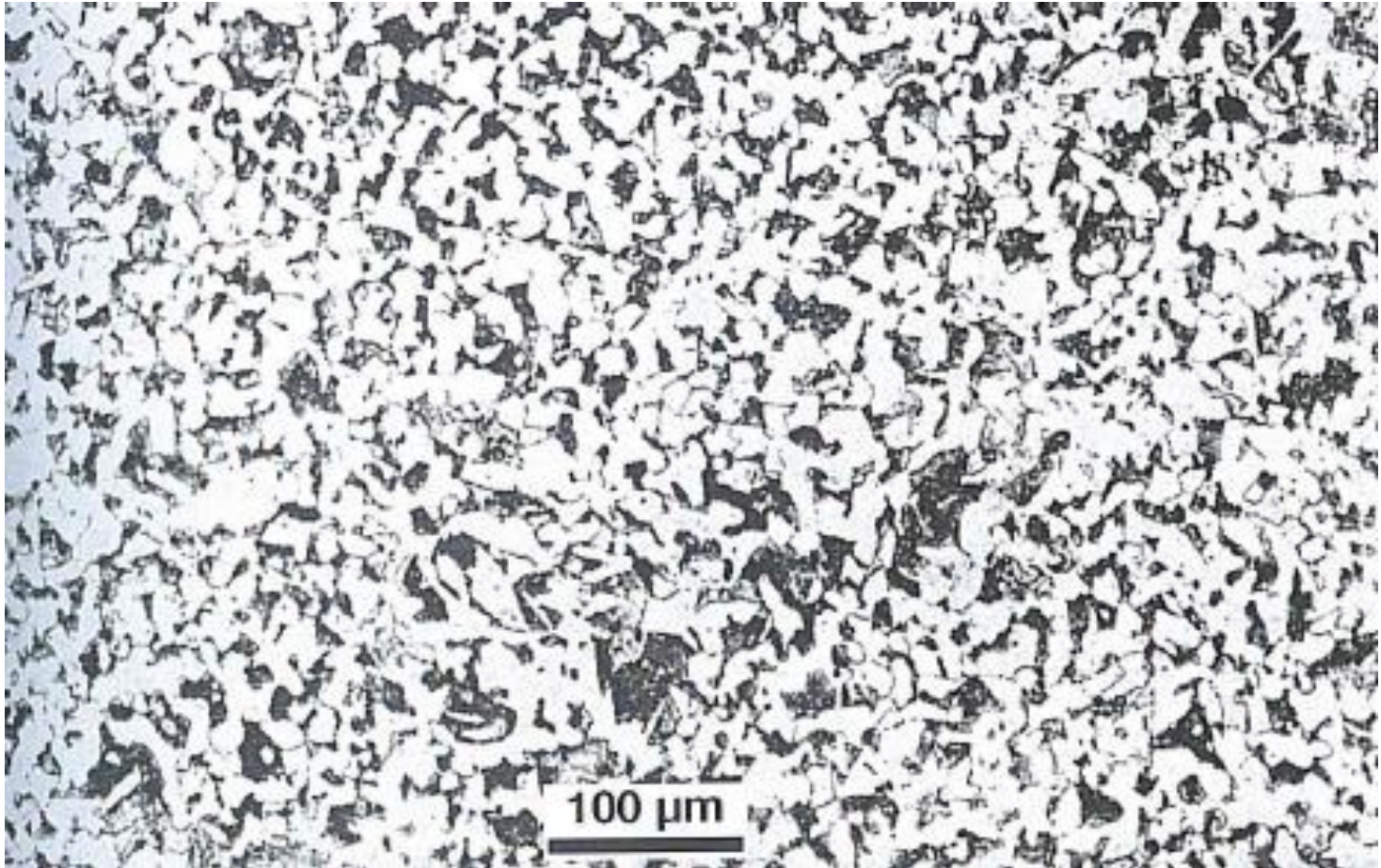
SAE 1010 – ferrita + perlita



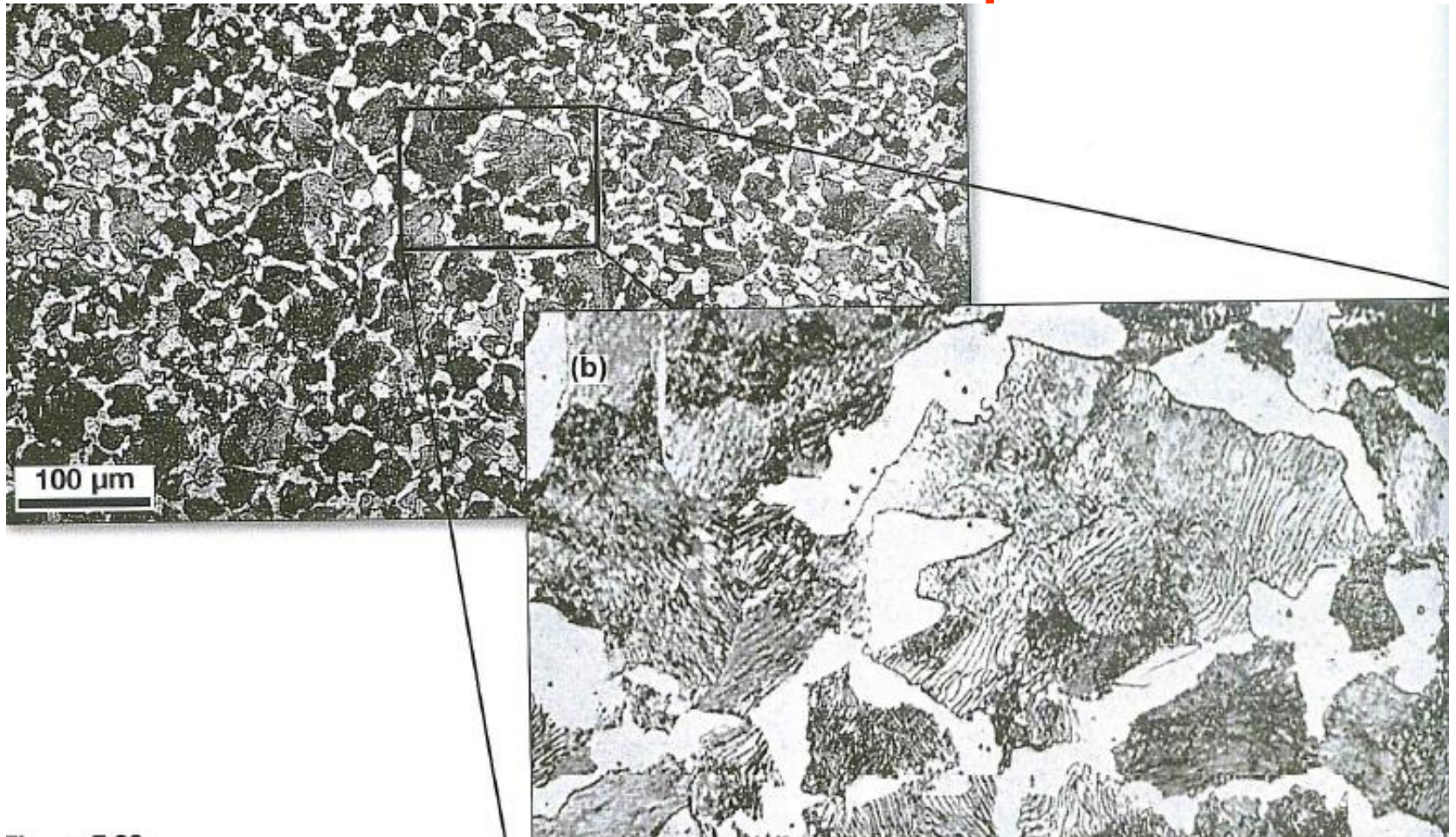
SAE 1015 – ferrita + perlita



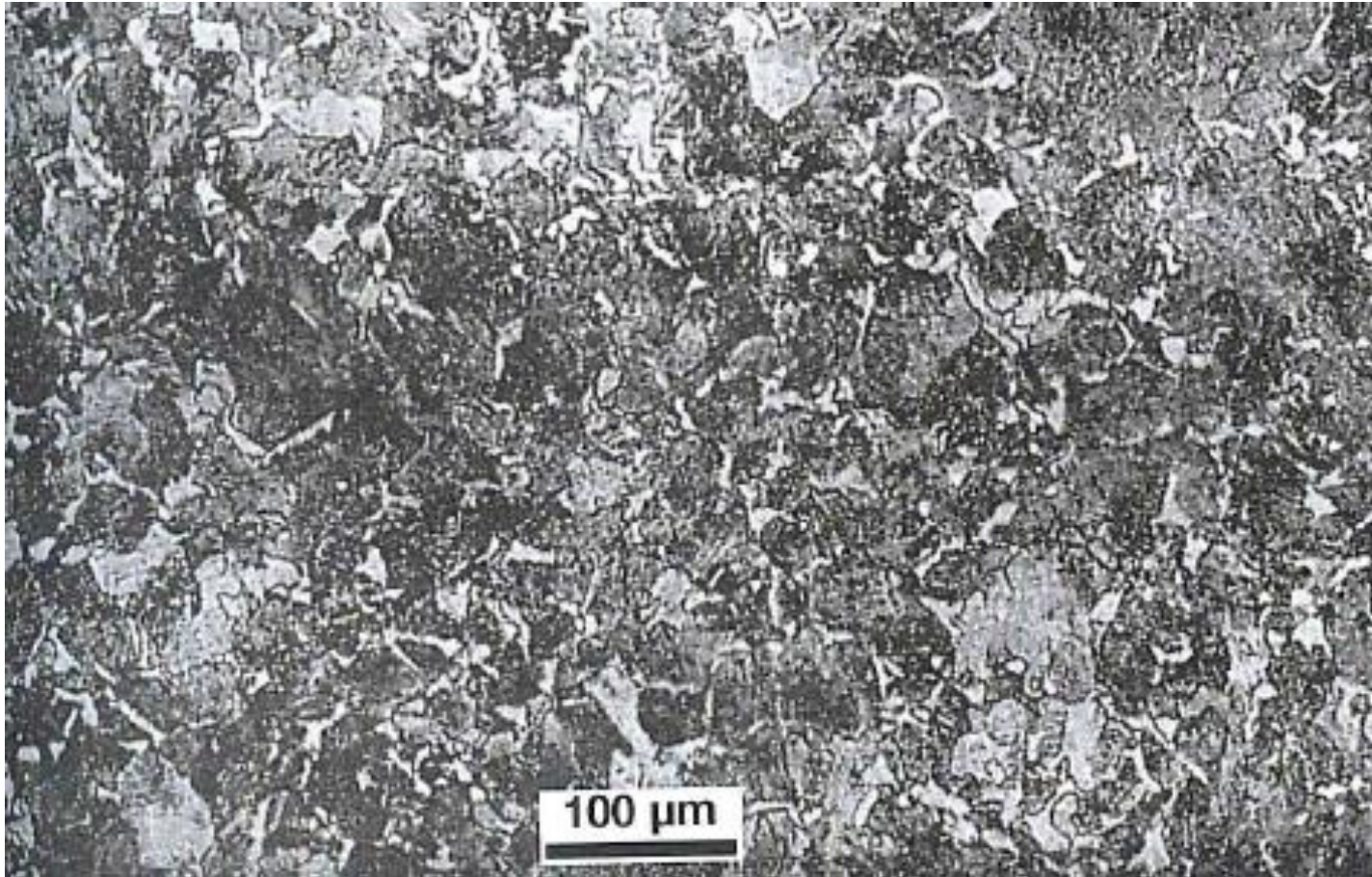
SAE 1030 – ferrita + perlita



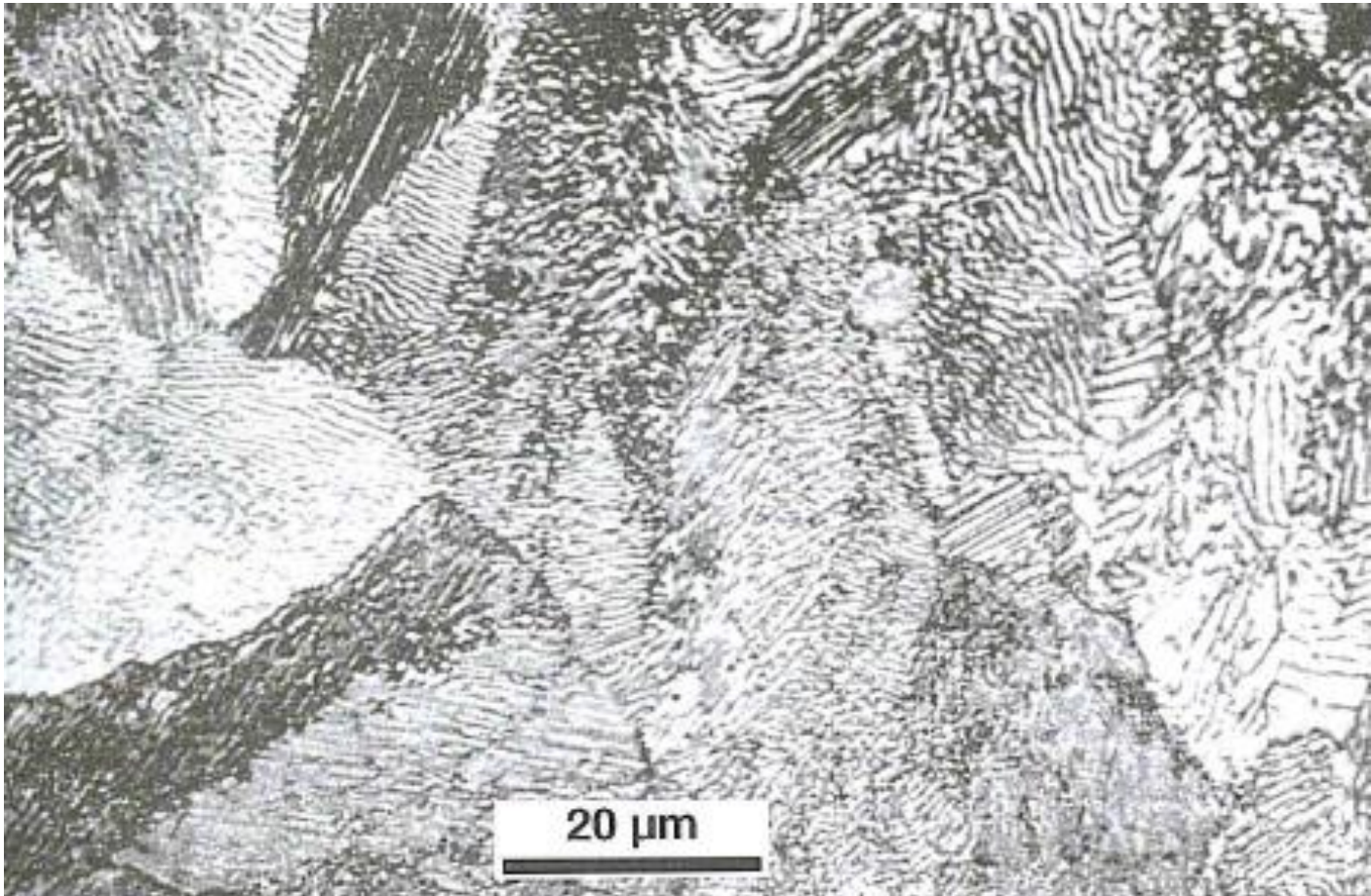
SAE 1050 – ferrita + perlita



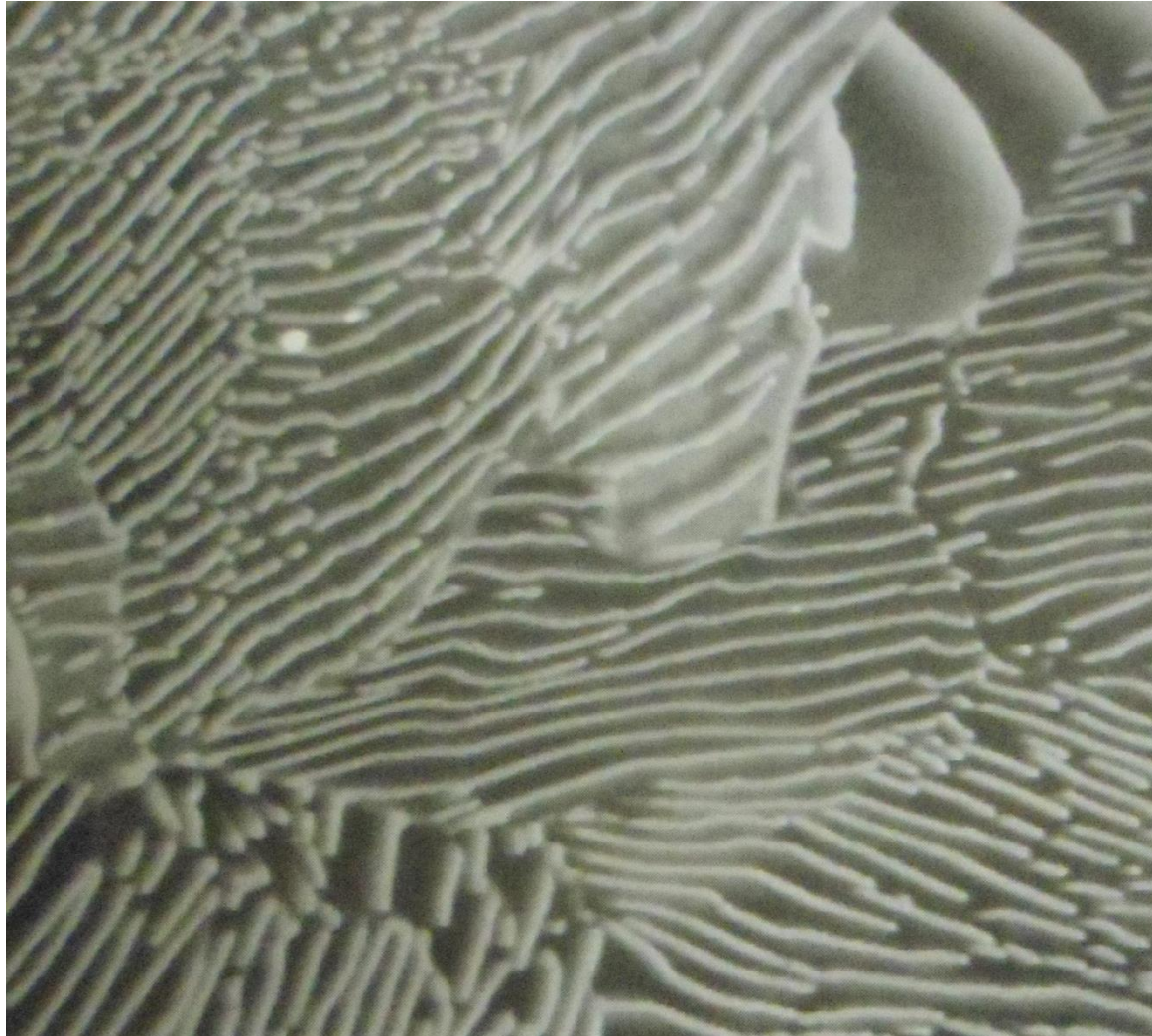
SAE 1070 – ferrita + perlita



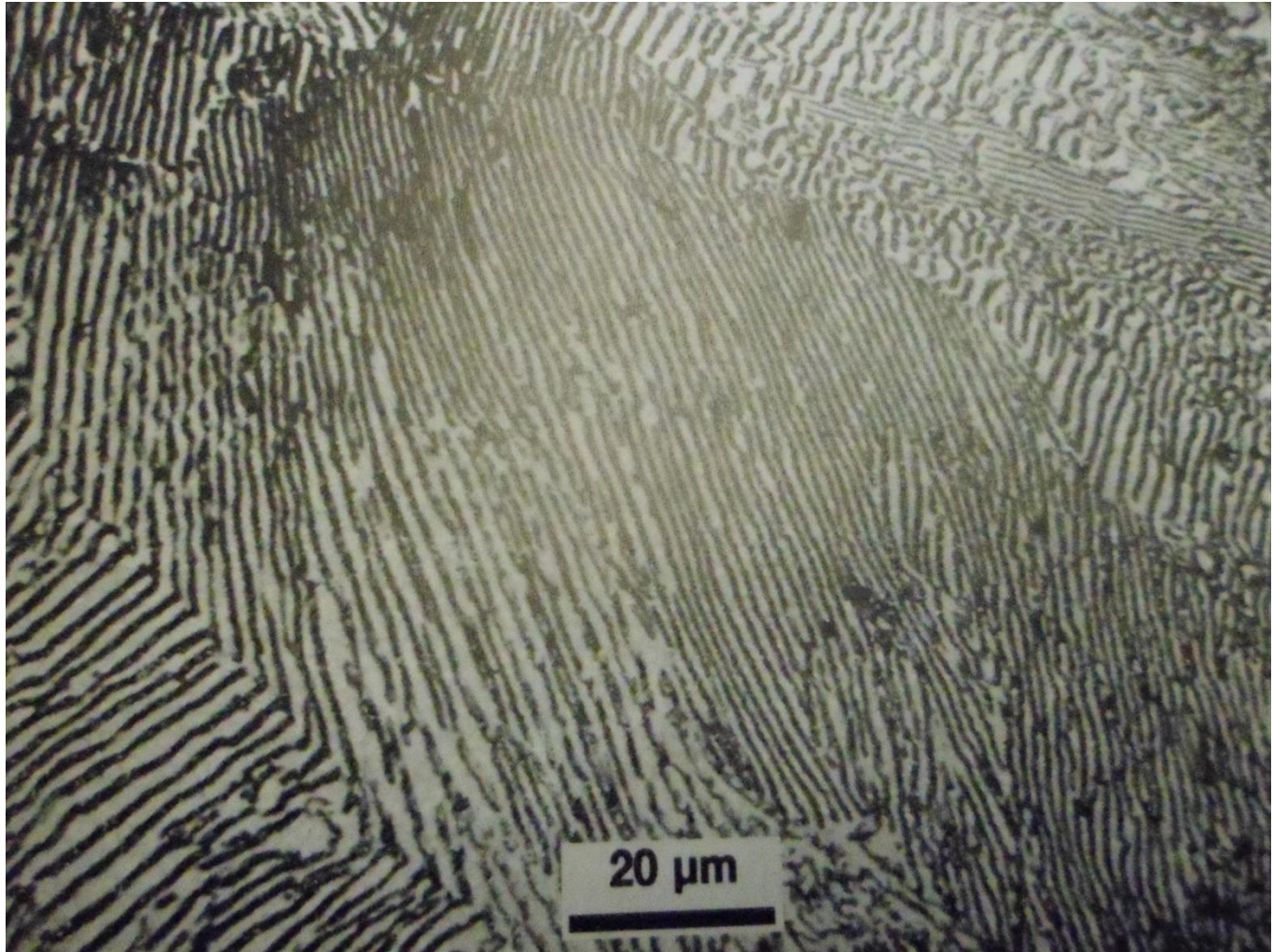
SAE 1076 – perlita



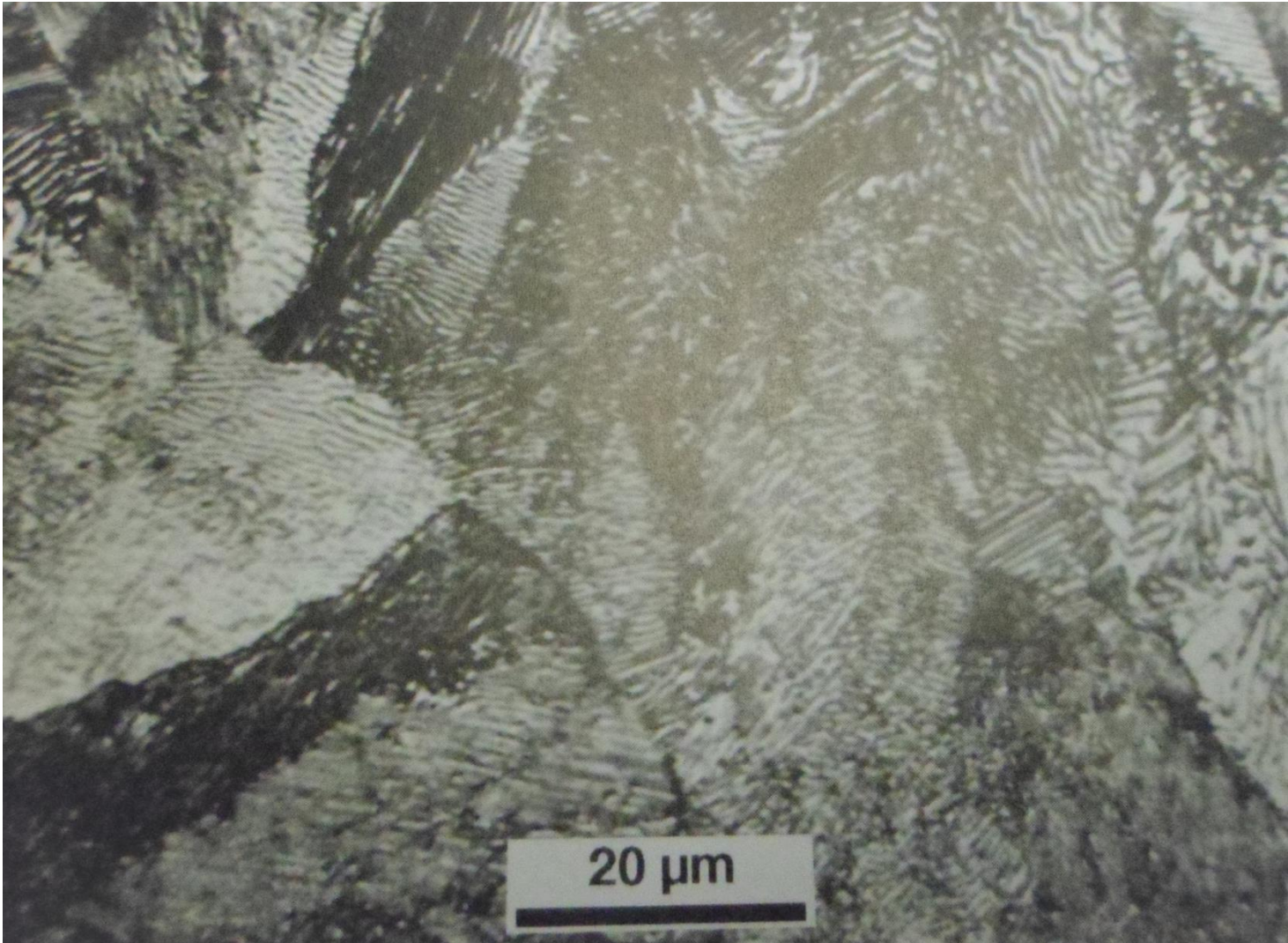
SAE 1076 – perlita



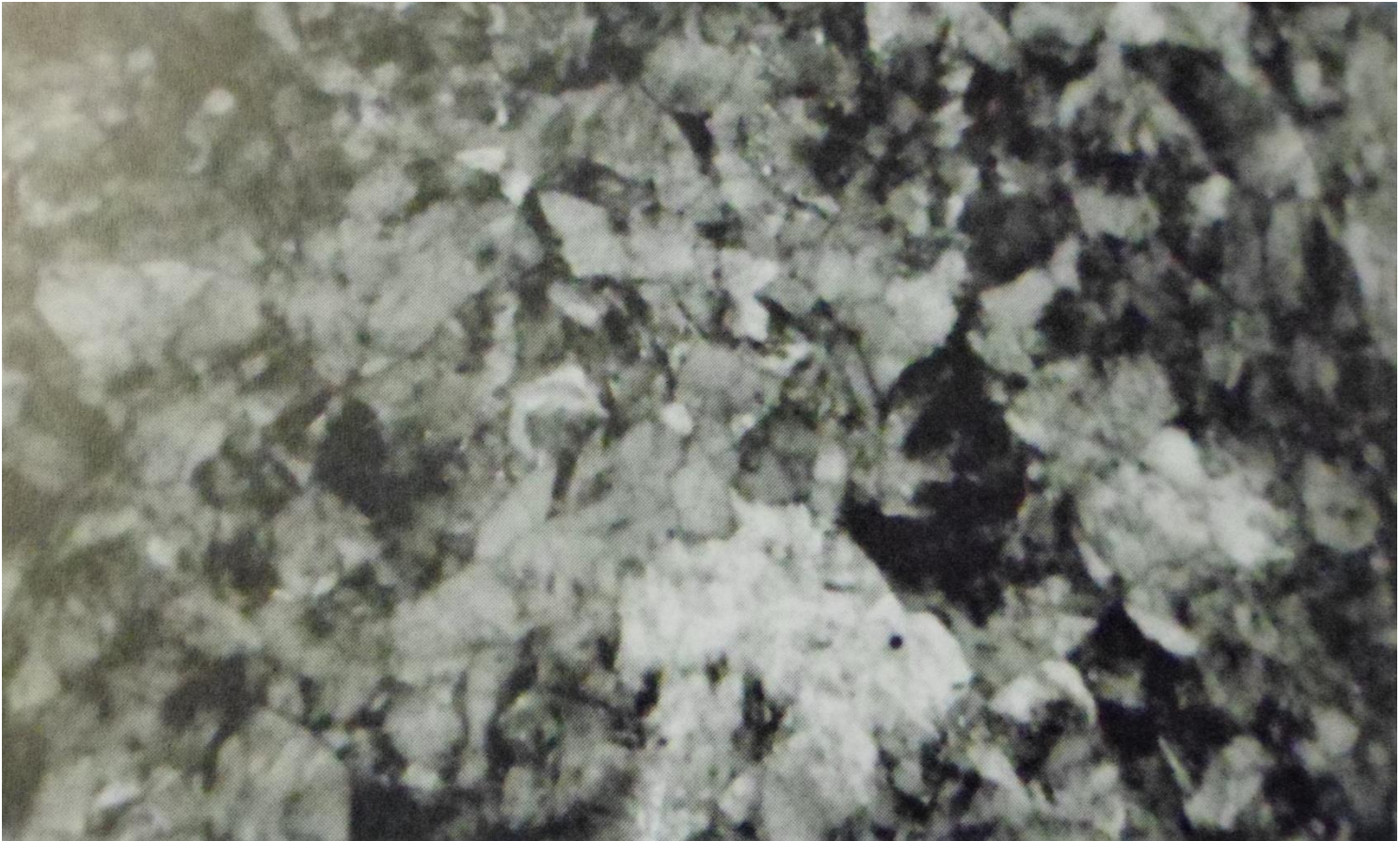
SAE 1076 – perlita



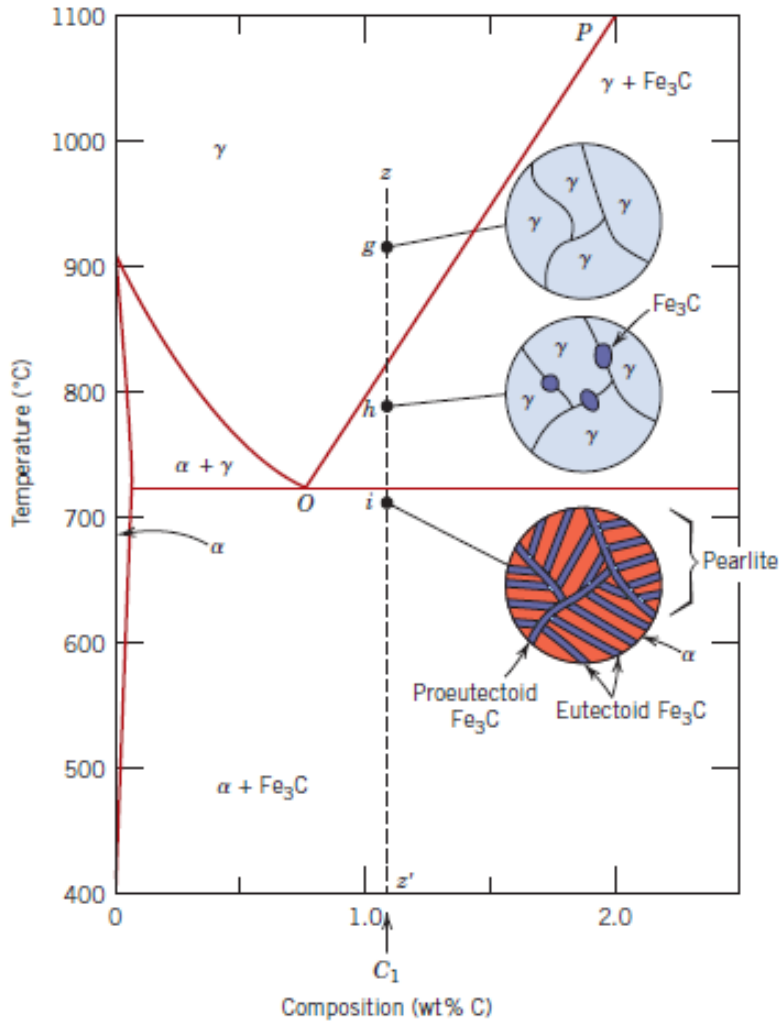
SAE 1076 – perlita



SAE 1076 – perlita



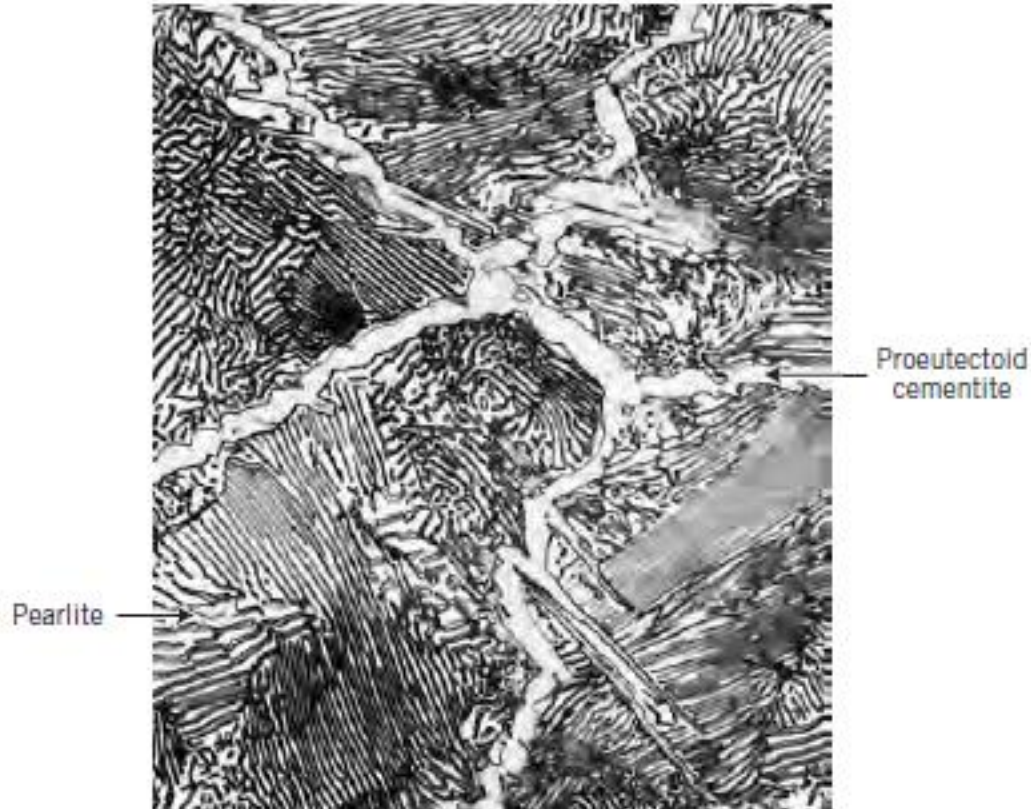
Microestrutura



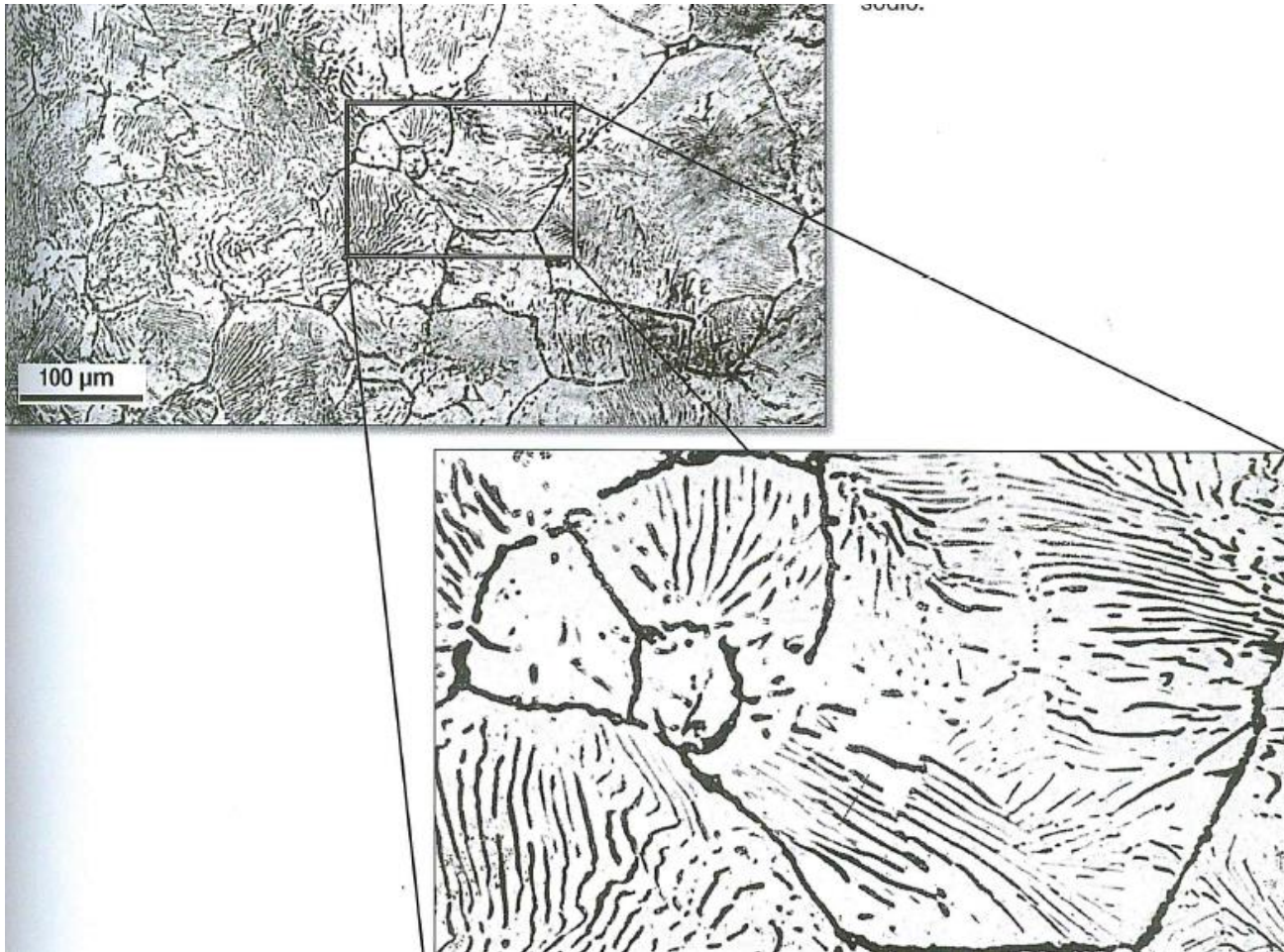
Aço hipereutetóide
 $\%C > 0,76$

Microestrutura

Aço hipereutetóide
 $\%C > 0,76$



Fe_3C + perlita



Recozimento

Resfriamento lento (dentro do forno) – formação de lamelas de ferrita e cementita.

Esta morfologia lamelar é chamada de perlita.

No caso de tratamento térmico de recozimento obtém-se perlita grossa (mais tempo para separação das fases)



Normalização

Resfriamento moderado (ao ar) – formação de lamelas de ferrita e cementita.

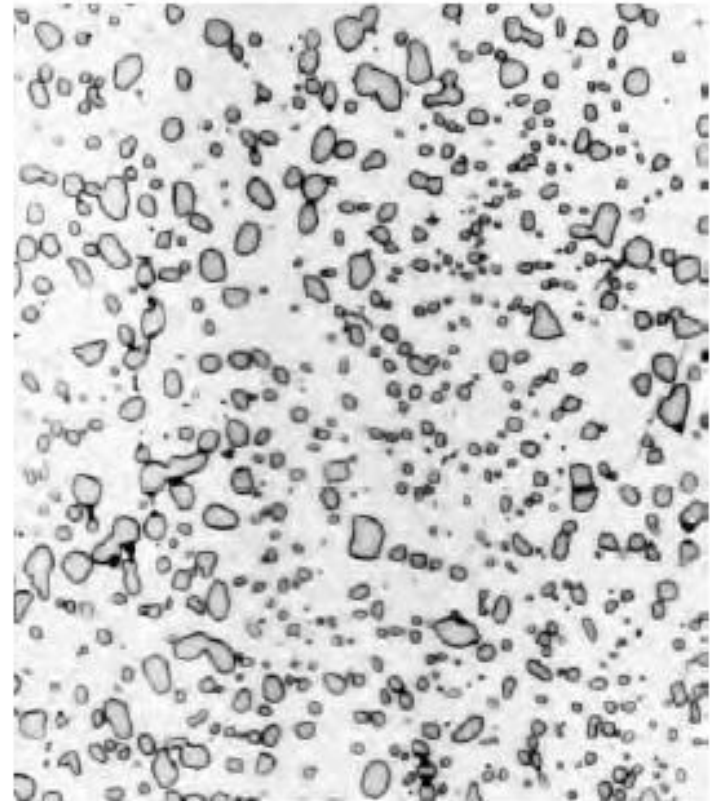
No caso de tratamento térmico de normalização obtém-se perlita fina (menor tempo para separação das fases)



Coalescimento

Resfriamento lento (dentro do forno)
após um longo tempo de patamar a
altas temperaturas.

A perlita se desfaz, com a formação de
cementita de forma esférica



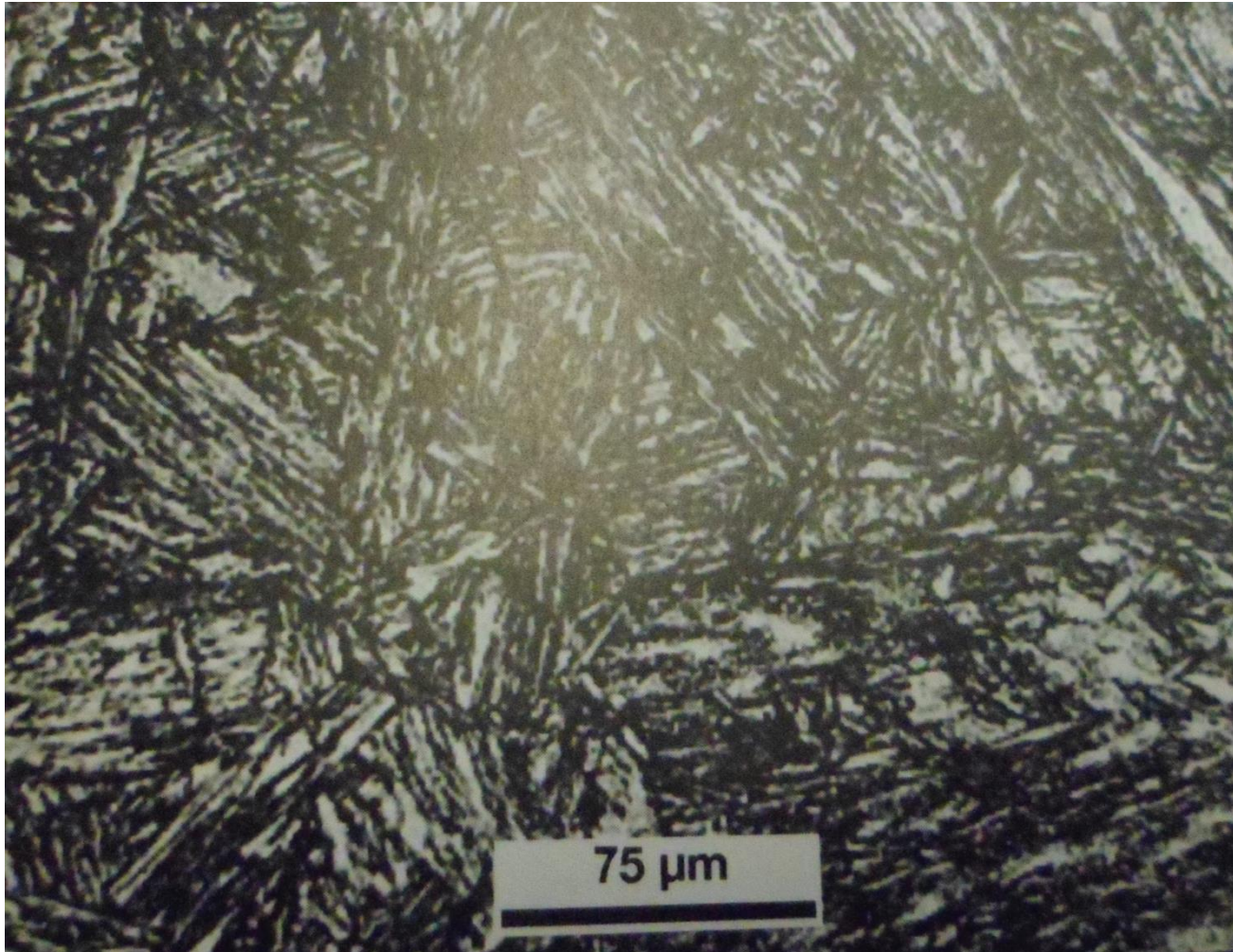
Têmpera

Resfriamento extremamente rápido (água ou óleo) de modo a impedir a separação entre a ferrita e a cementita.

Formação de fase tetragonal de corpo centrado, supersaturada em carbono, com morfologia de agulhas, denominada martensita.



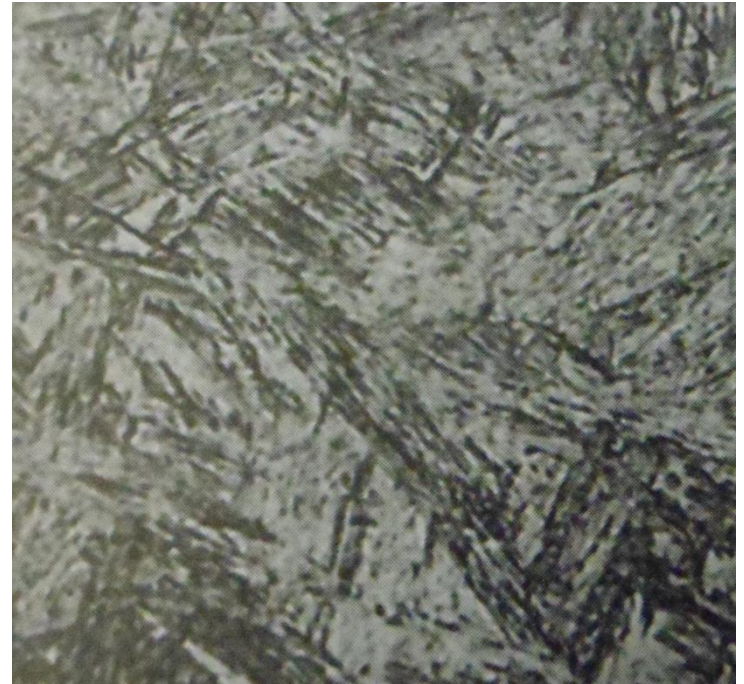
Têmpera → martensita



Revenimento

Realizado após os tratamentos térmicos de têmpera, o revenimento é realizado a temperaturas menores (aquecimento a 200°C a 550 °C), visando reduzir a dureza da martensita.

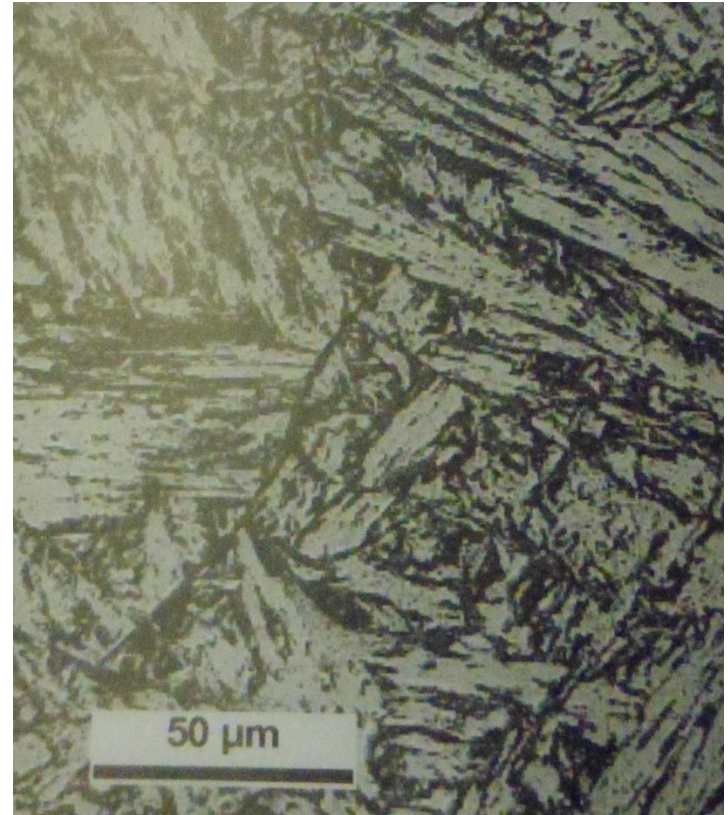
A estrutura resultante é a martensita revenida. Neste tratamento ocorre a transformação da martensita em ferrita e cementita.



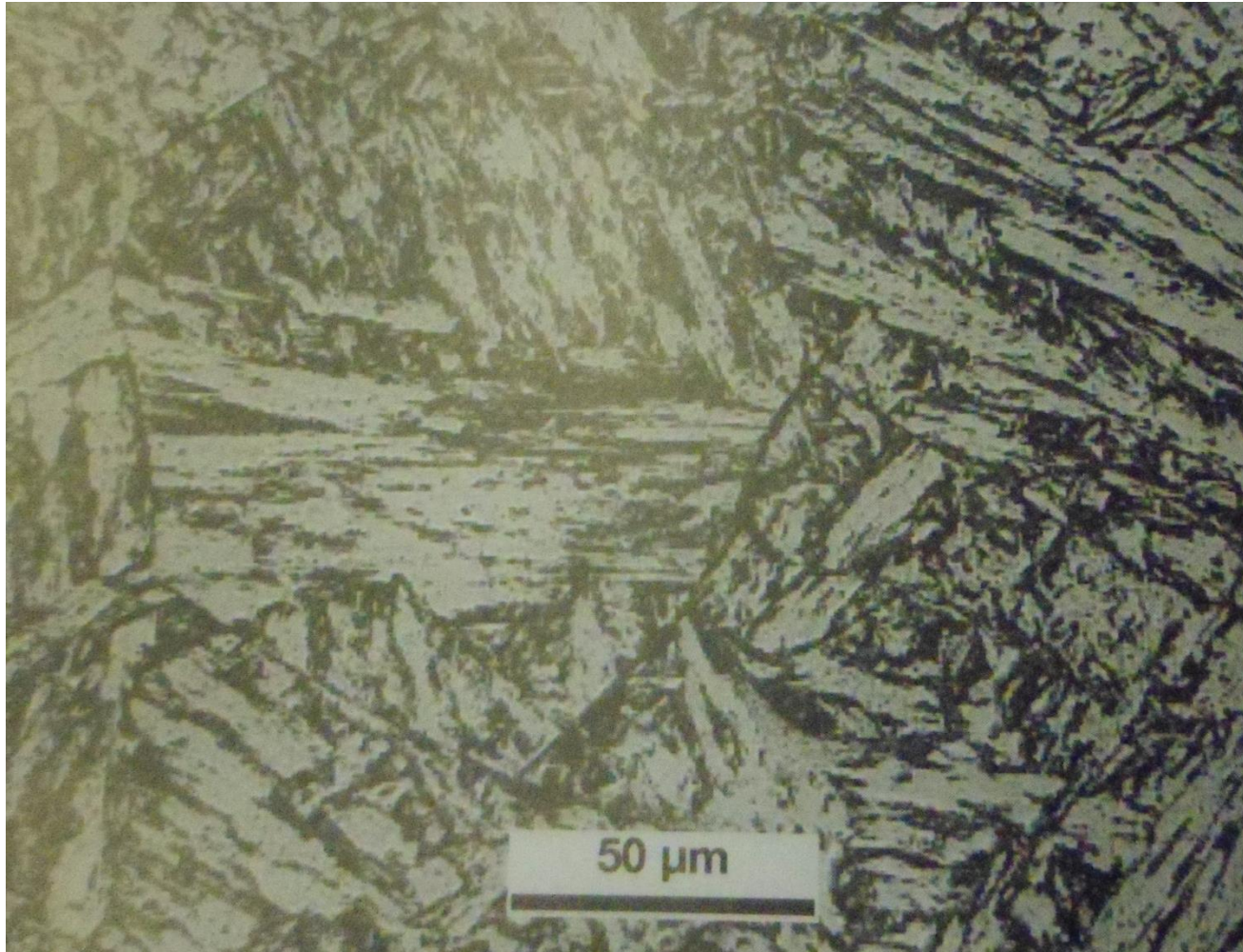
Austêmpera

Tratamento térmico de resfriamento rápido até uma temperatura intermediária (300°C a 500°C), na qual o material é mantido até que ocorra a transformação da austenita em ferrita e cementita.

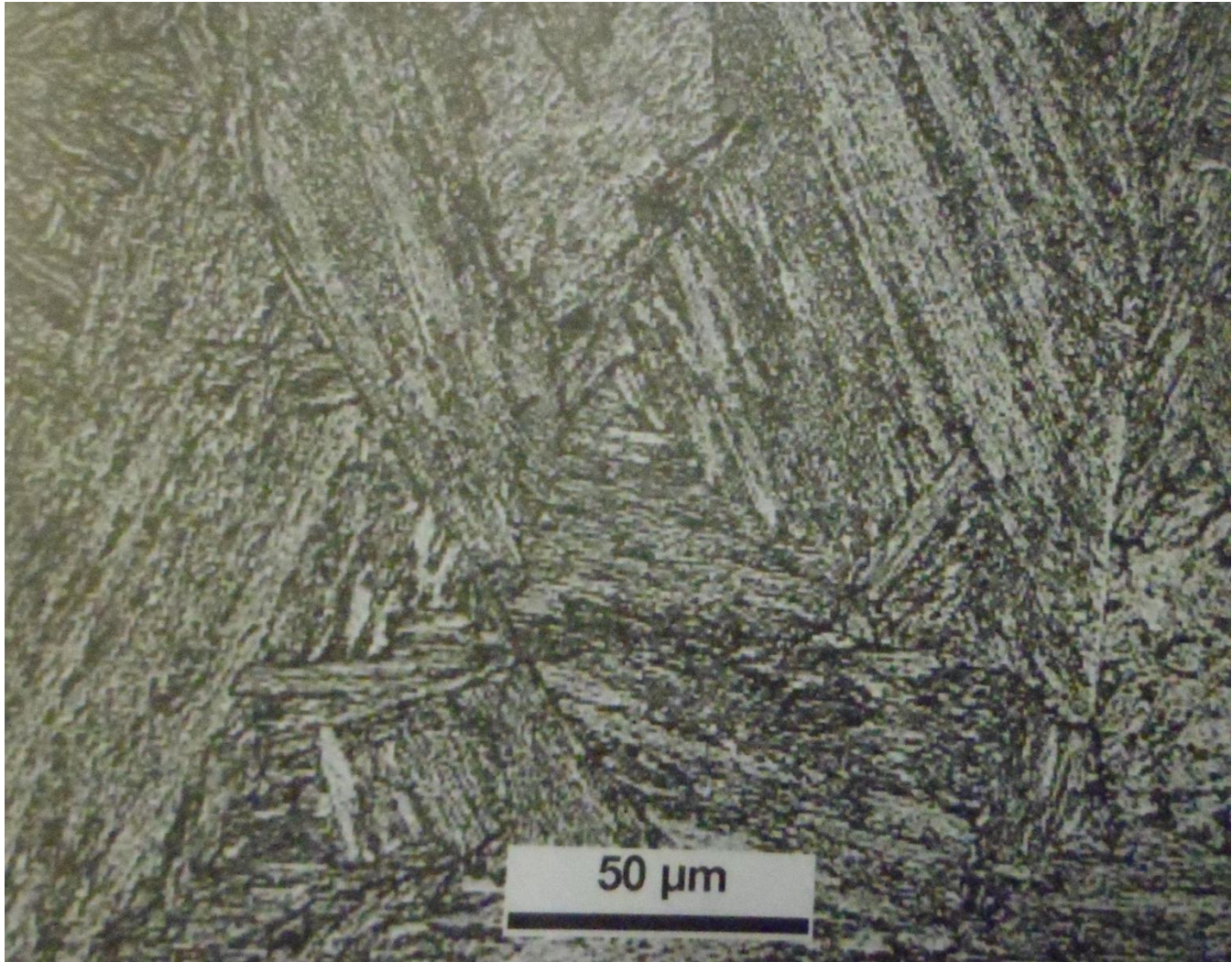
A estrutura resultante é denominada bainita e apresenta menor dureza e maior tenacidade do que a martensita.



Austêmpera → bainita

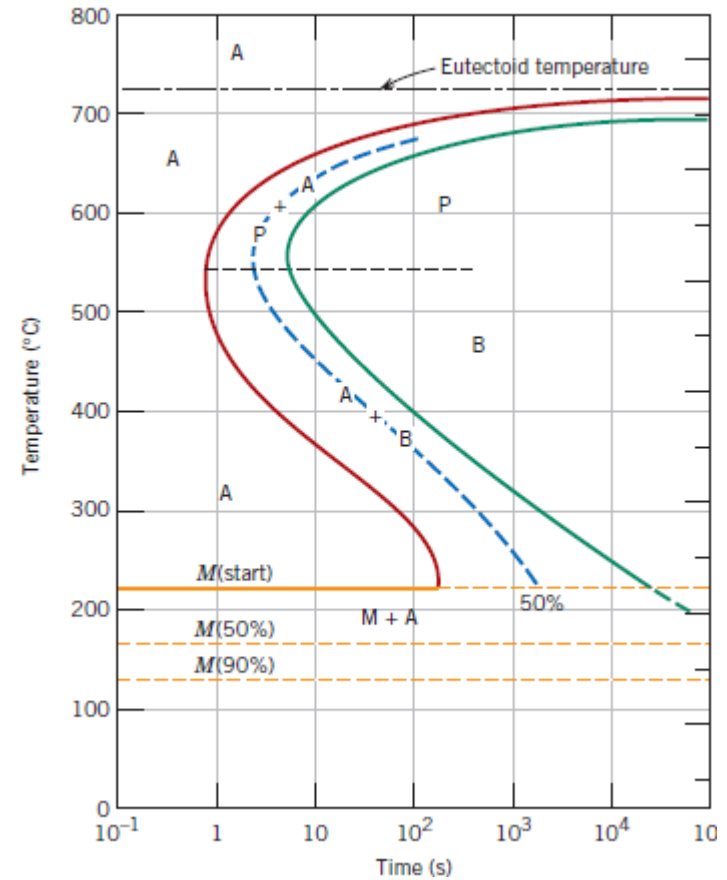


Austêmpera → bainita

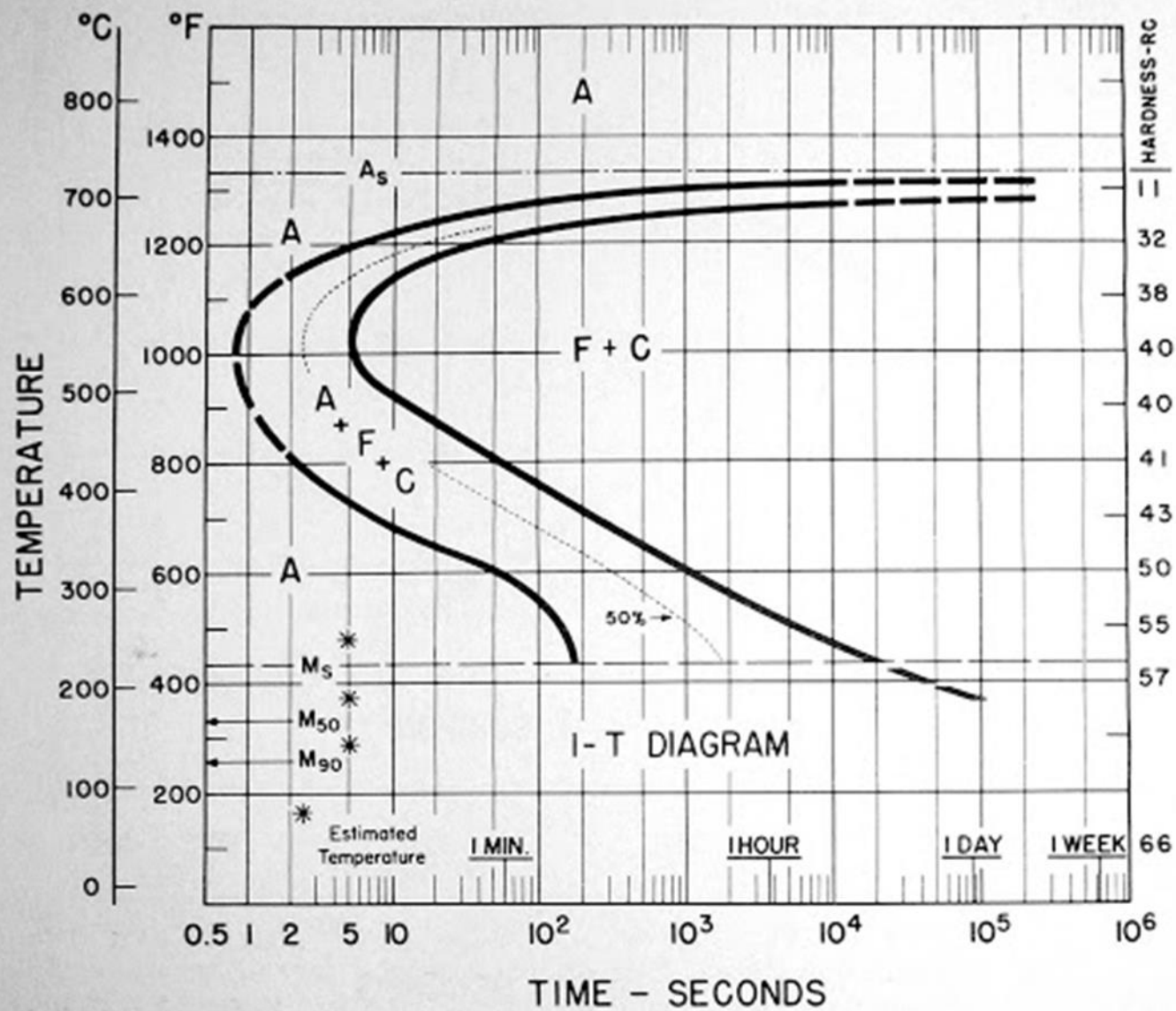


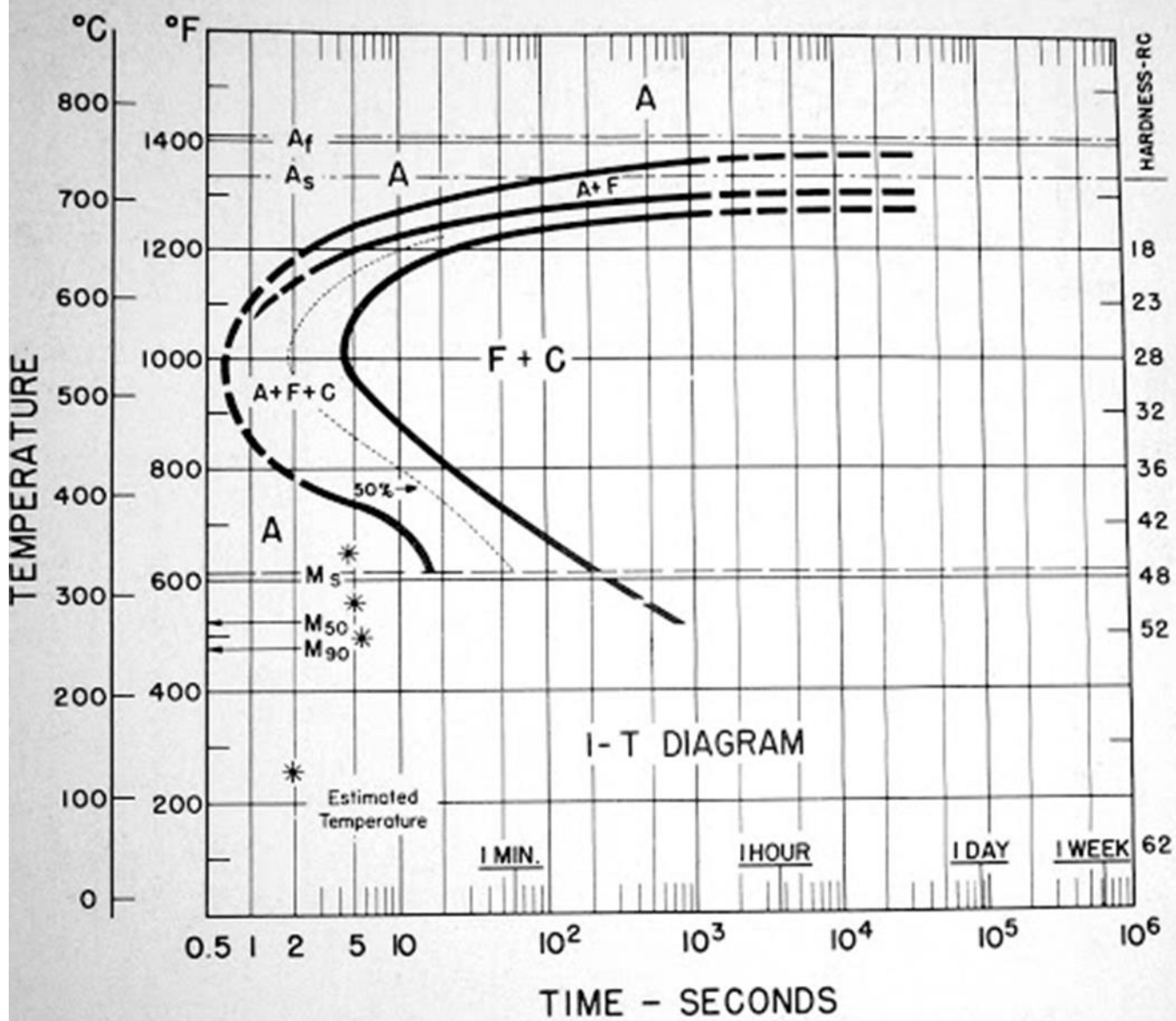
Curvas TTT

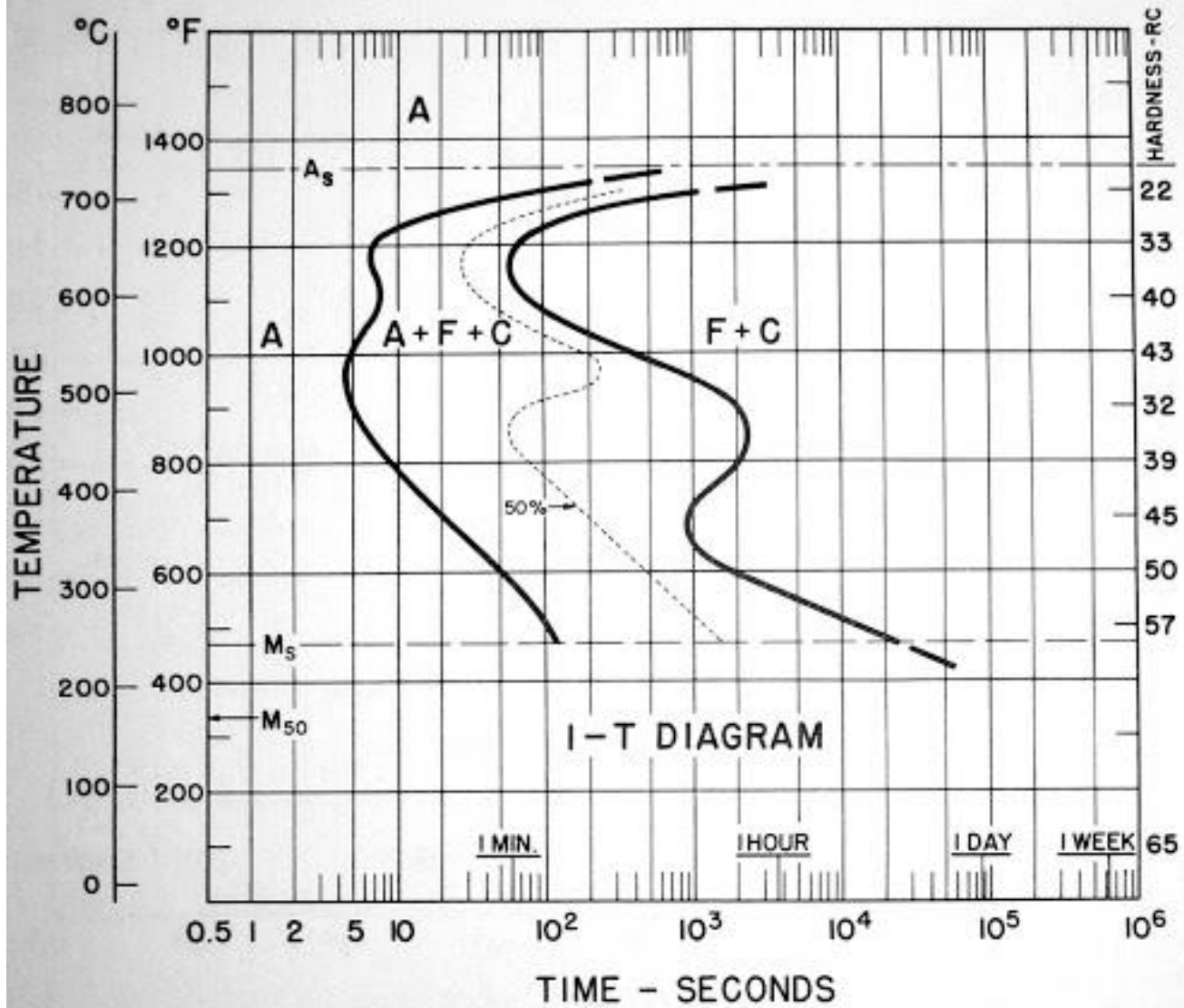
As curvas TTT (transformação tempo/temperatura) indicam quais as fases previstas em função da taxa de resfriamento do material.

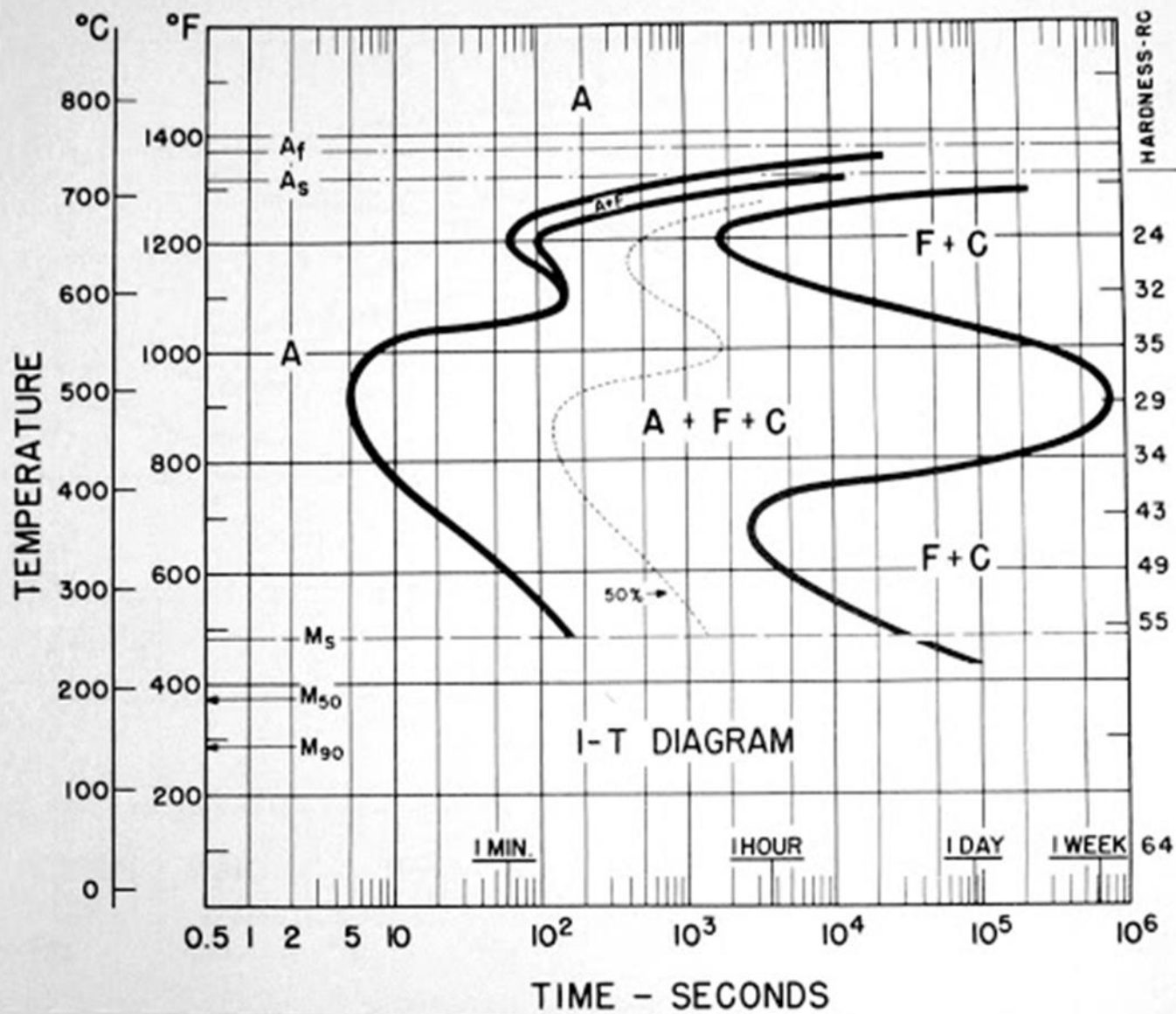


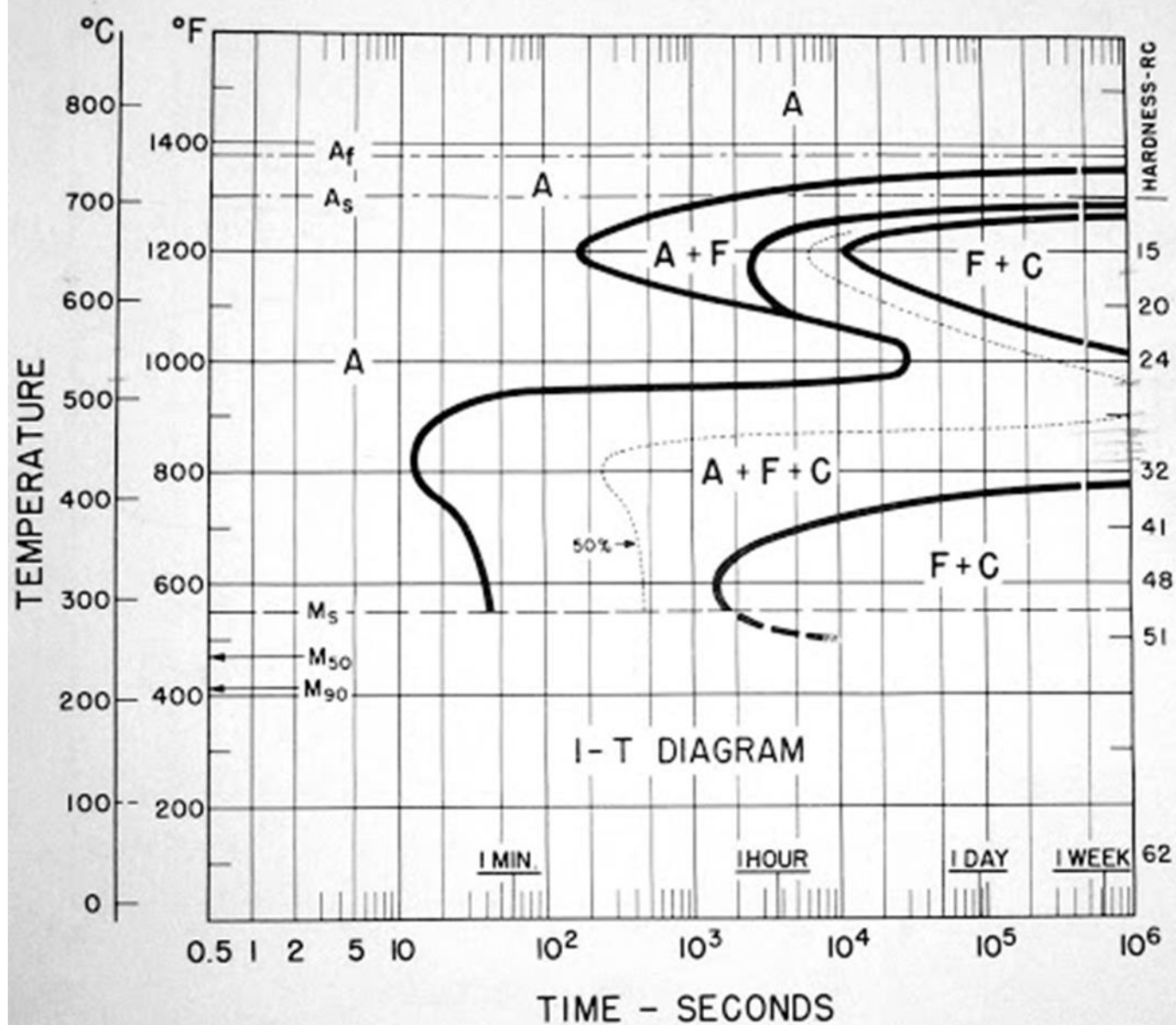
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