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Nucleation of recrystallized grains on grain boundaries

MatCalc 6.04.1003

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Nucleation rate of recrystallized grains

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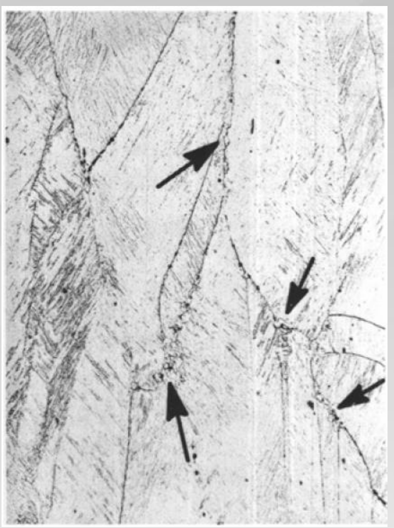
- **Nucleation rate, dN_{rx}/dt** (Number density of new grains per second):

$$\frac{dN_{rx}}{dt} = N_{pot} B_n \frac{dR(X_C)}{dt}$$



N_{pot} - number density of possible nucleation sites [m^{-3}]

B_n - nucleation site saturation factor [-]

$\frac{dR(X_C)}{dt}$ - „critical size subgrain rate“ [s^{-1}]

Number density of potential nucleation sites for recrystallized grains

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$$\frac{dN_{rx}}{dt} = N_{pot} B_n \frac{dR(X_C)}{dt}$$

$$N_{pot} = \frac{A_{gb}}{A_c} f(\varepsilon)$$

$$A_{gb} = \frac{9\left(1 + 2\sqrt{3}\right)}{4\sqrt{2}D}$$

$$A_c = \pi {d_c}^2$$

$$f(\varepsilon) = \frac{(\varepsilon_x \varepsilon_y + \varepsilon_x \varepsilon_z + \varepsilon_y \varepsilon_z)}{3}$$

A_{gb} - available grain boundary area density [m^{-1}]

A_c - critical nucleus area [m^2]

f(ε) - deformation correction function

D - deformed grain diameter [m]

d_c - recrystalized grain diameter [m]

ε_i - aspect ratio in direction *i* [-]

Nucleation site saturation factor

$$\frac{dN_{rx}}{dt} = N_{pot} B_n \frac{dR(X_C)}{dt}$$

$$B_n = 1 - \left(\frac{2d_c}{D}\right)^2$$

D - deformed grain diameter [m]

d_c - recrystalized grain diameter [m]

Critical size subgrain rate (1)

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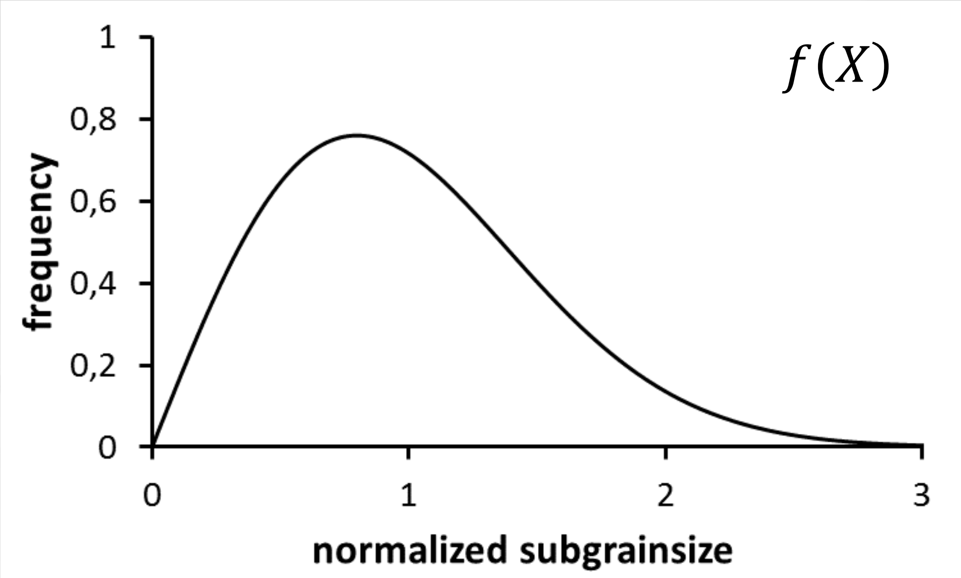
$$\frac{dN_{rx}}{dt} = N_{pot} B_n \boxed{\frac{dR(X_C)}{dt}}$$

- Subgrain sizes: Rayleigh distribution

$$f(X) = \sqrt{\frac{\pi}{2}}\frac{X}{\sigma} exp\left(-\frac{\pi}{4}X^2\right)$$

$$\mathrm{F}(X) = 1 - exp\left(-\frac{\pi}{4}X^2\right)$$



X - Normalized subgrain size [-]

σ - Most frequent subgrain size (distribution model) [-]

$f(X)$ - Probability density function [-]

$F(X)$ - Cumulative distribution function [-]

Critical size subgrain rate (2)

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$$\frac{dN_{rx}}{dt} = N_{pot} B_n \frac{dR(X_C)}{dt}$$

- Subgrain sizes over a critical size → recrystalized grains

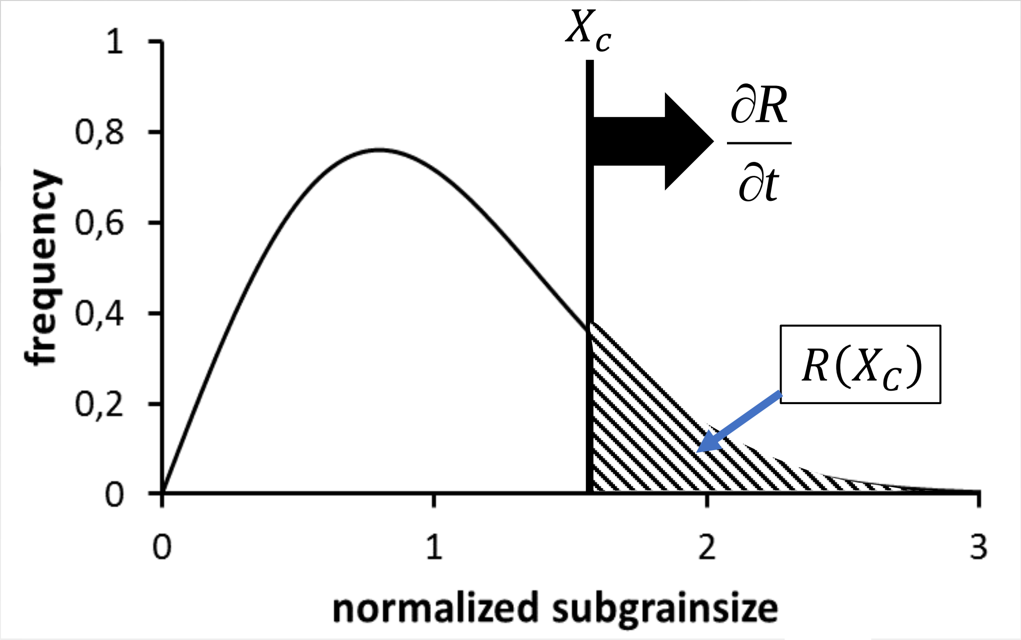
$$\mathrm{R}(X_c) = 1 - F(X_c) = exp\left(-\frac{\pi}{4} X_c^2\right)$$

- Critical size subgrain rate

$$\frac{d\mathrm{R}(X_c)}{dt} = -\frac{\pi}{2} X_c exp\left(-\frac{\pi}{4} X_c^2\right) \frac{dX_c}{dt}$$

X_c - Critical subgrain size (normalized) [-]

$R(X_C)$ - Fraction of subgrains over the critical size [-]



Critical size subgrain rate (3)

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$$\frac{dN_{rx}}{dt} = N_{pot} B_n \boxed{\frac{dR(X_c)}{dt}}$$

$$\frac{d\mathrm{R}(X_c)}{dt} = -\frac{\pi}{2} X_c exp\left(-\frac{\pi}{4} X_c^2\right) \frac{dX_c}{dt}$$

$$X_c = \frac{\delta_c}{\delta_m} \Rightarrow \frac{dX_c}{dt} = \frac{1}{\delta_m^2}\left(\delta_m \frac{d\delta_c}{dt} - \delta_c \frac{d\delta_m}{dt}\right)$$

$$\delta_c = \frac{8\gamma}{\mu b^2 \rho} \Rightarrow \frac{d\delta_c}{dt} = -\frac{8\gamma}{\mu b^2 \rho^2} \frac{d\rho}{dt}$$

δ_c - critical subgrain diameter [m]

δ_m - mean subgrain diameter [m]

γ - grain boundary energy [Jm^{-2}]

μ - shear modulus [Pa]

b - Burgers vector [m]

ρ - dislocation density [m^{-2}]

$\frac{d\rho}{dt}$ → from dislocation density evolution model

$\delta_m, \frac{d\delta_m}{dt}$ → from subgrain evolution model

Acknowledgments

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Thank you for your attention!