Refrakter Metaller

Sinterleme

Sinterleme

Sinter kelimesi Almanca kül anlamına gelmektedir.

Teknik anlamda sinterleme, metal ve/veya seramik tozlarına termal enerji uygulanması ile yoğunluk kontrollü malzemeler geliştirme prosesidir.

Diğer bir tanıma göre sinterleme, toz esaslı malzemelerin ana bileşenin ergime sıcaklığının altında sıcaklıklara ısıtılması ile tozların biraraya gelerek dayanımı yüksek ürünler elde edilmesi işlemidir.

Katı faz sinterlemesi, sıvı faz sinterlemesi ve reaktif sinterleme olarak üç ana başlık altında toplamak mümkündür.

Sinterleme sırasında basınç uygulanıp uygulanmadığına göre de basınçsız sinterleme ve basınçlı sinterleme olarak iki sınıfa ayırmak mümkündür.

Sinterleme

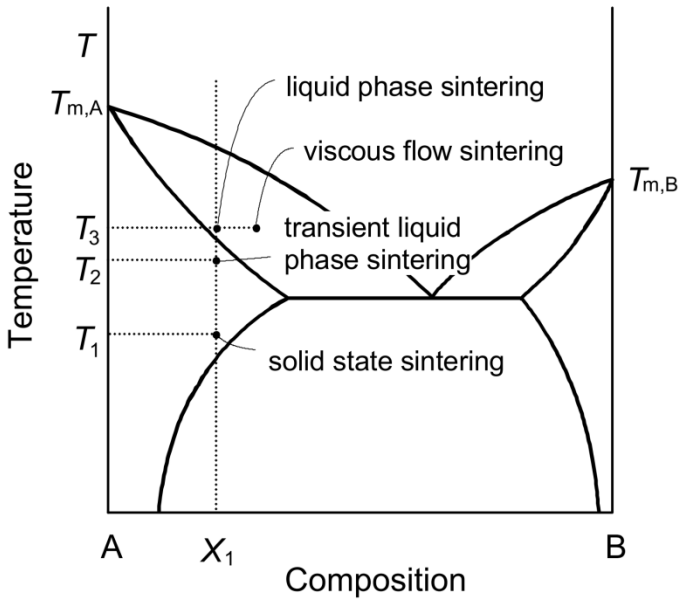


Figure I.3. Illustration of various types of sintering.

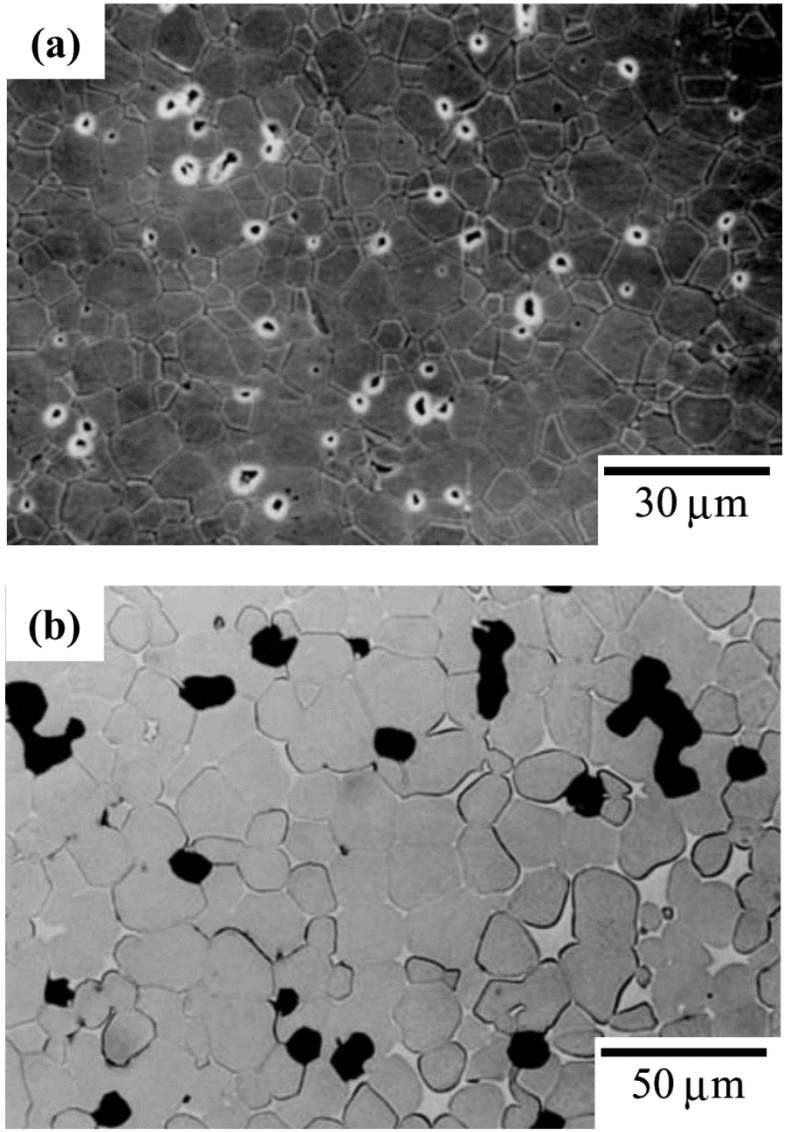


Figure I.4. Typical microstructures observed during (a) solid state sintering (Al_2O_3) and (b) liquid phase sintering (98W-1Ni-1Fe(wt%)).

Sinterleme

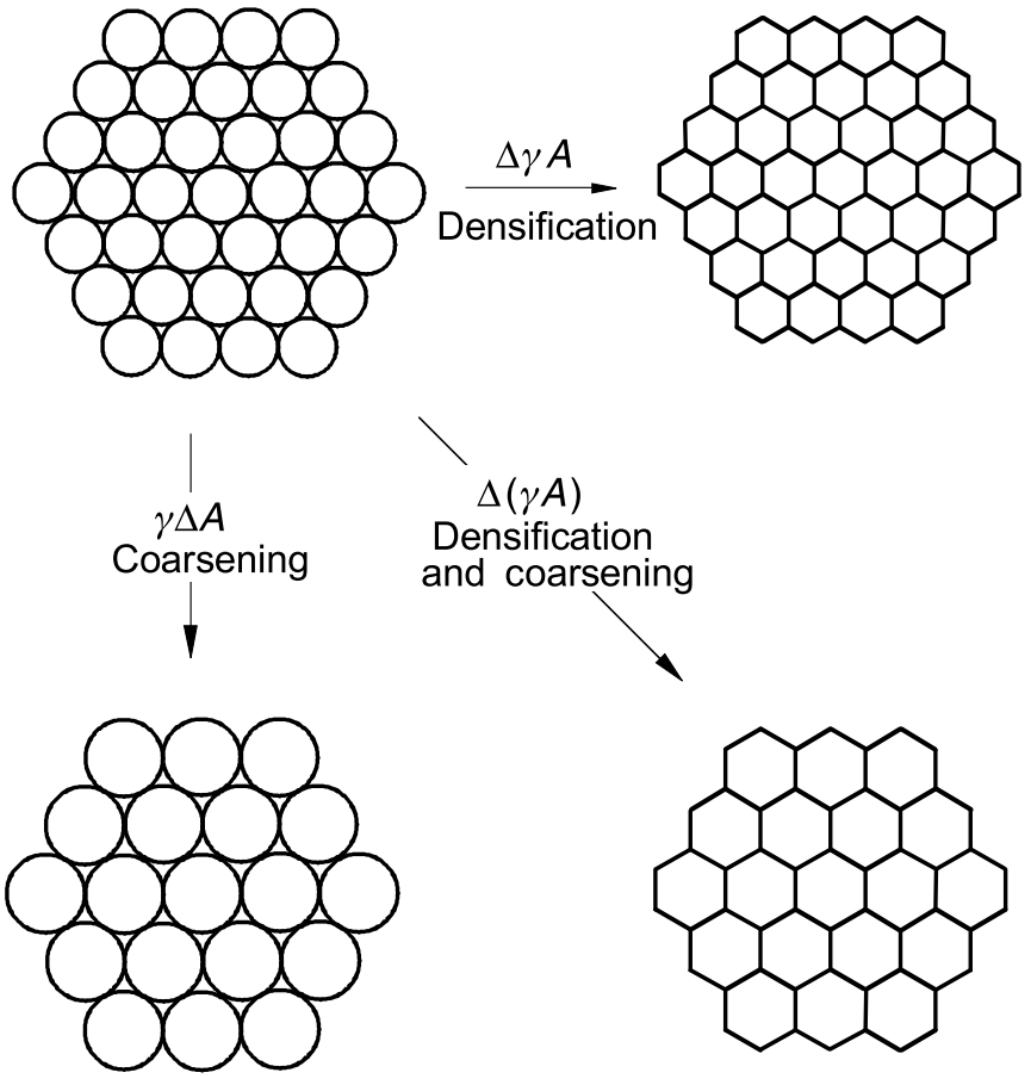


Figure I.5. Basic phenomena occurring during sintering under the driving force for sintering, $\Delta(\gamma A)$.

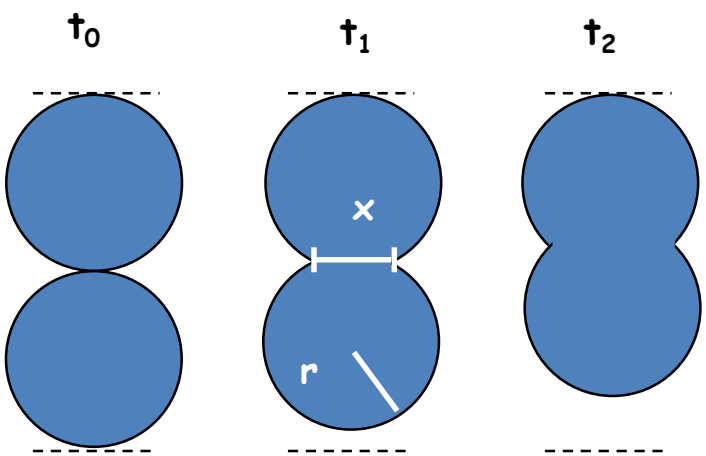
Sinterleme

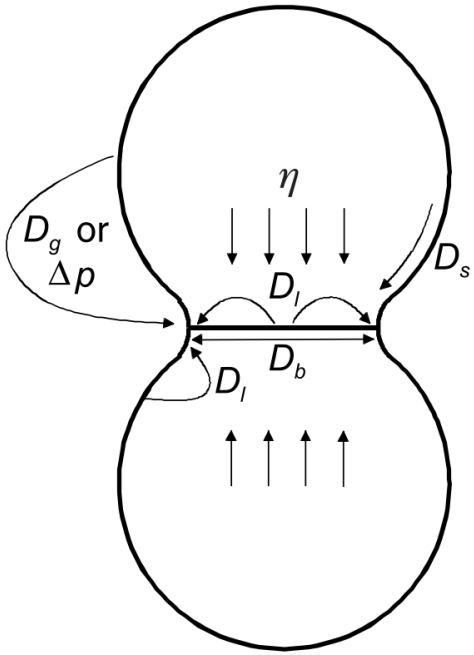
Table I.I. Variables affecting sinterability and microstructure

Variables related to raw materials (material variables)	Powder: shape, size, size distribution, agglomeration, mixedness, etc. Chemistry: composition, impurity, non-stoichiometry, homogeneity, etc.
Variables related to sintering condition (process variables)	Temperature, time, pressure, atmosphere, heating and cooling rate, etc.

1. **Toz Hazırlama Aşamasında:** Parçacık boyutu, şekli, boyut dağılımı.
2. **Çok Bileşenli Sistemlerde:** İkincil fazların dağılımı
3. **Toz Presleme Aşamasında:** Ham yoğunluk, gözenek boyutu dağılımı
4. **Sinterleme Aşamasında:** Sinterleme sıcaklığı, ısıtma hızları, sinterleme süresi, uygulanan basınç, sinterleme atmosferi.

Katı Faz Sinterlemesi





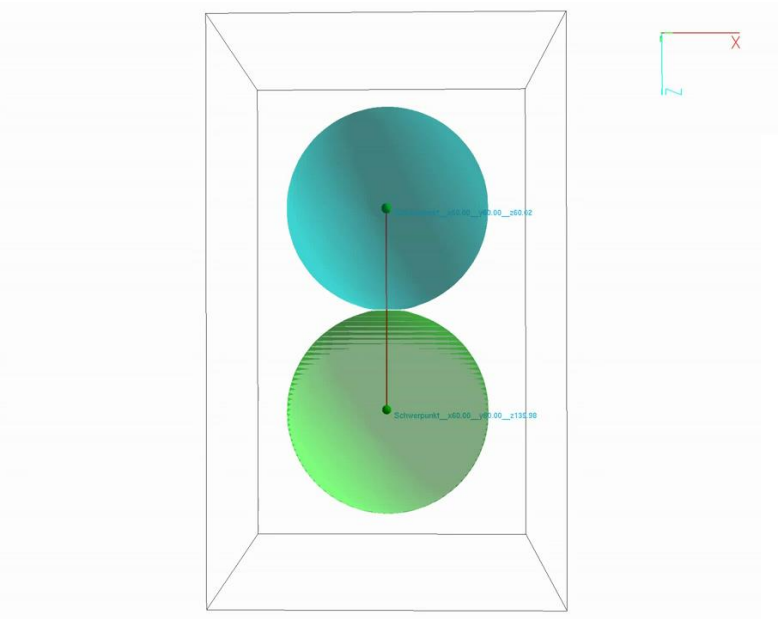
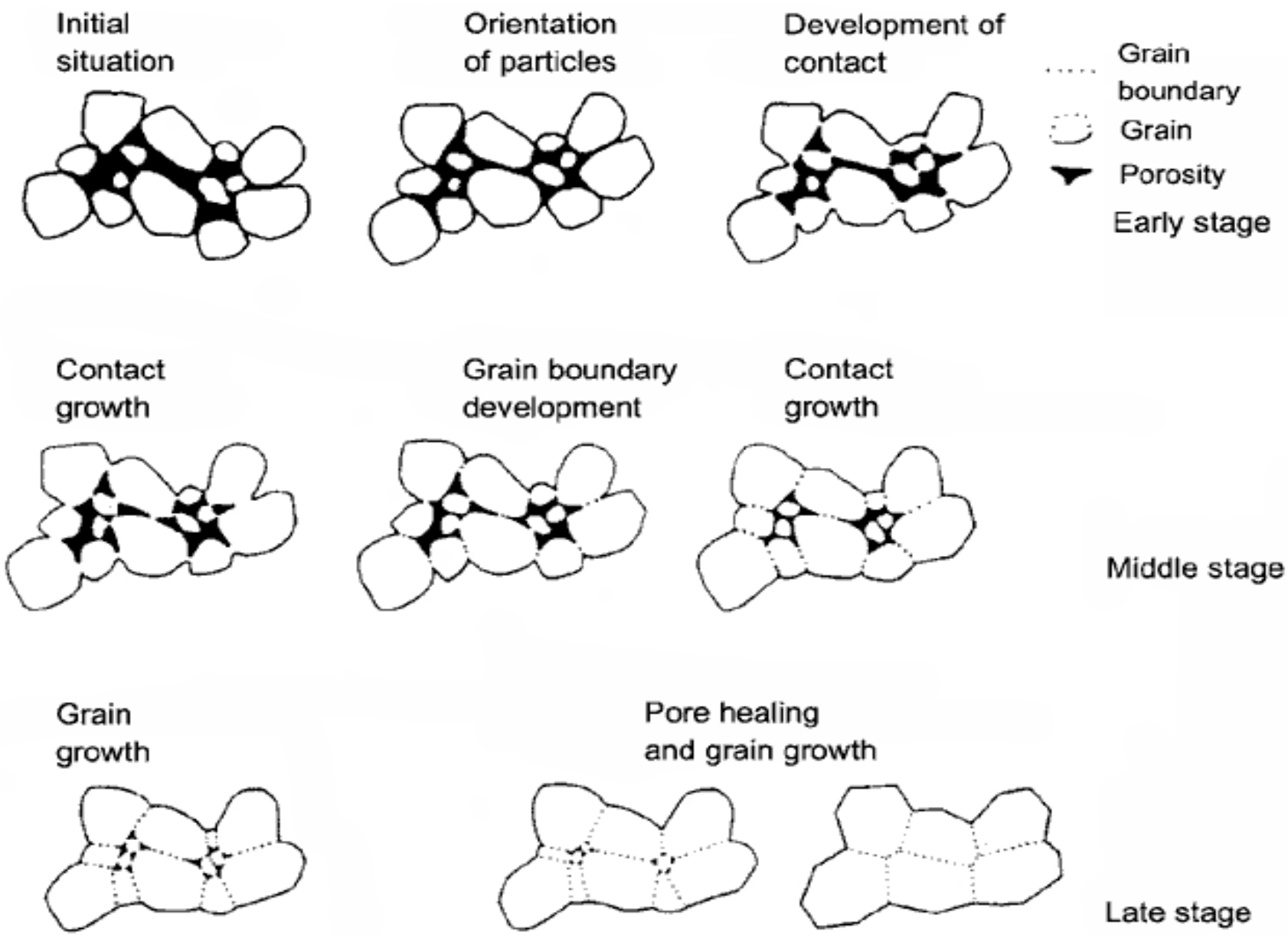


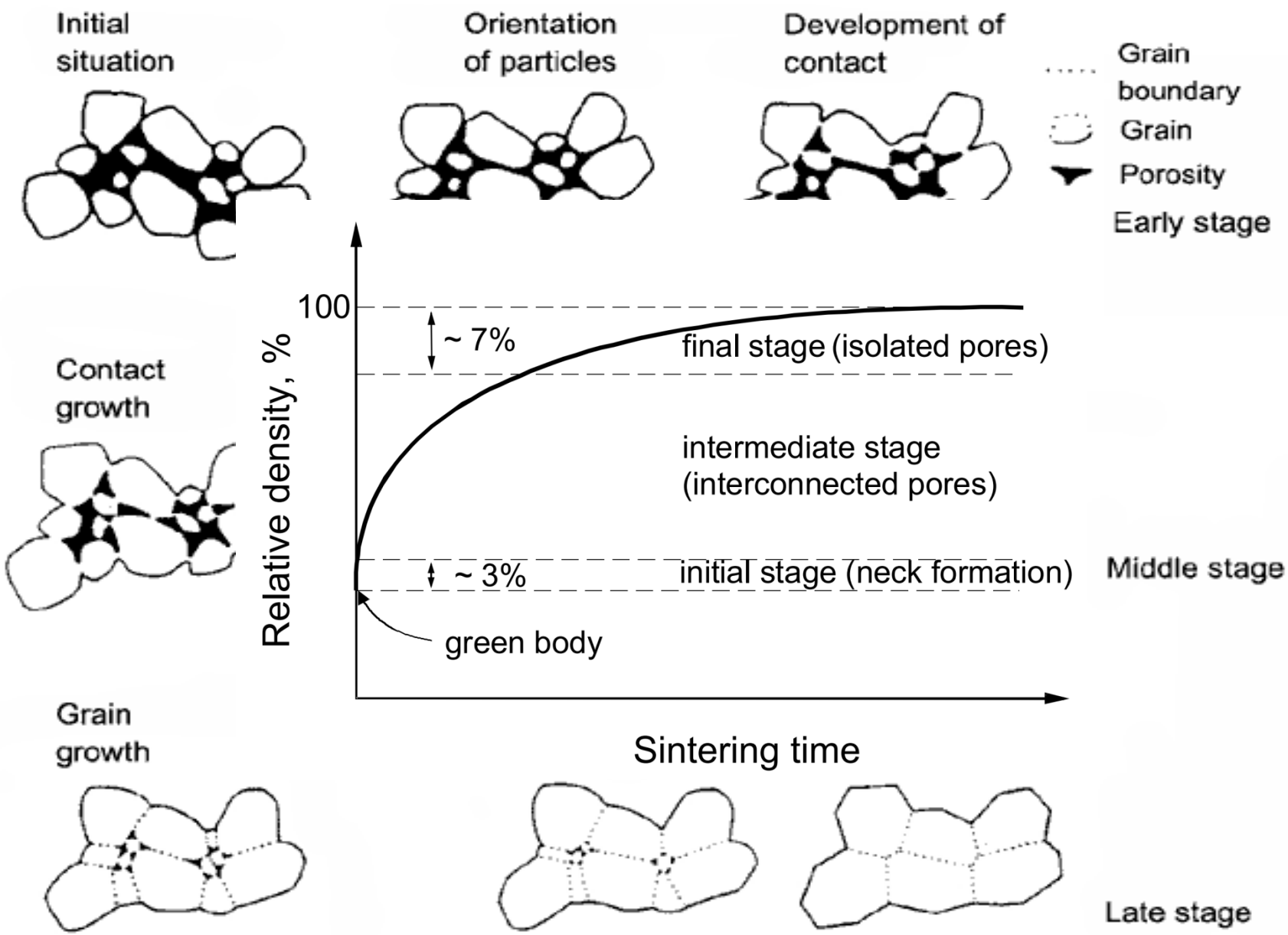
Table 4.1. Material transport mechanisms during sintering

Material transport mechanism	Material source	Material sink	Related parameter
1. Lattice diffusion	Grain boundary	Neck	Lattice diffusivity, D_l
2. Grain boundary diffusion	Grain boundary	Neck	Grain boundary diffusivity, D_b
3. Viscous flow	Bulk grain	Neck	Viscosity, η
4. Surface diffusion	Grain surface	Neck	Surface diffusivity, D_s
5. Lattice diffusion	Grain surface	Neck	Lattice diffusivity, D_l
6. Gas phase transport			
6.1. Evaporation/ condensation	Grain surface	Neck	Vapour pressure difference, Δp
6.2. Gas diffusion	Grain surface	Neck	Gas diffusivity, D_g

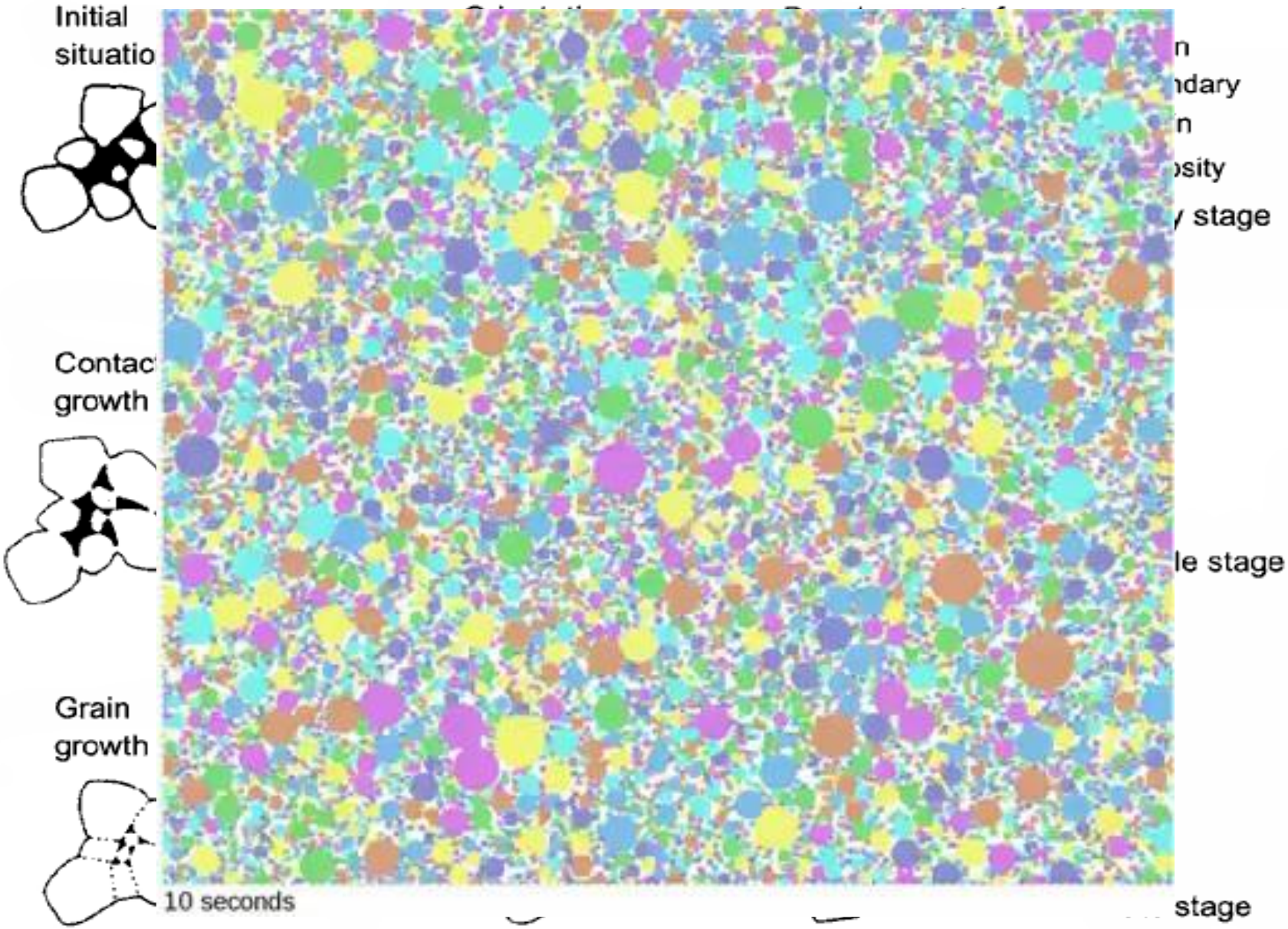
Katı Faz Sinterlemesi



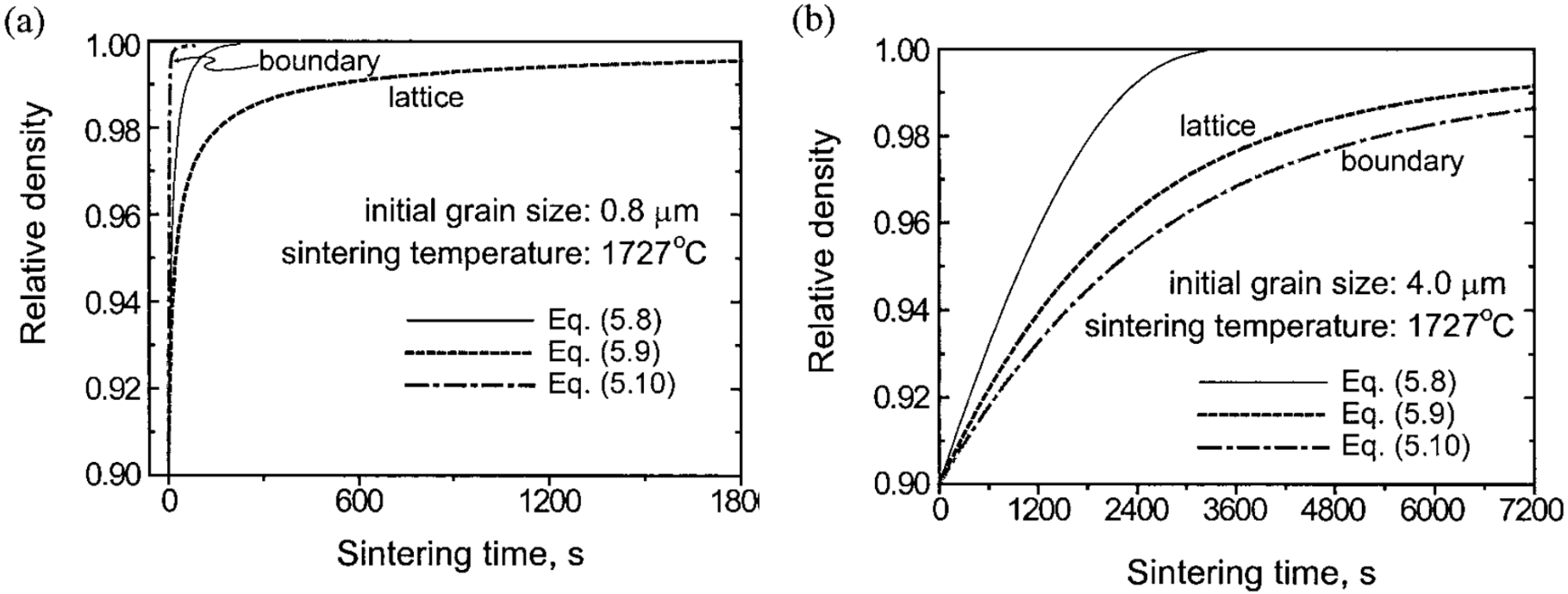
Katı Faz Sinterlemesi



Katı Faz Sinterlemesi

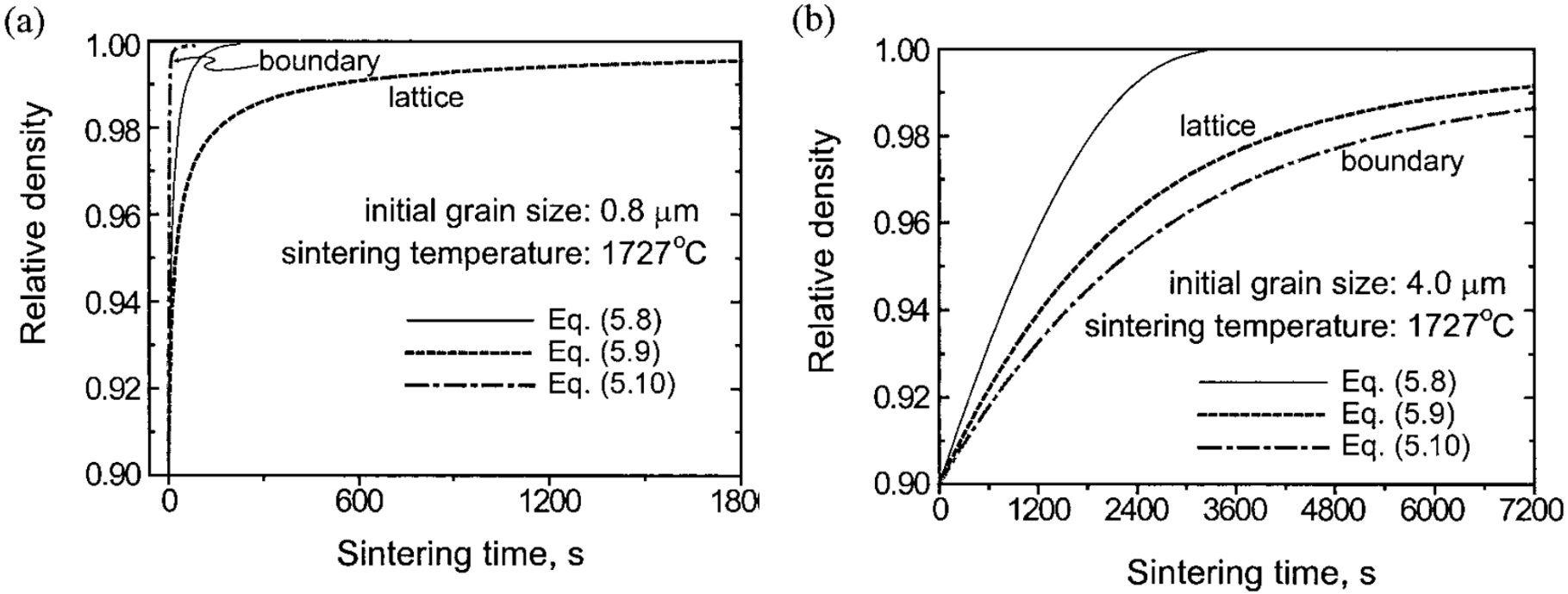


Katı Faz Sinterlemesi



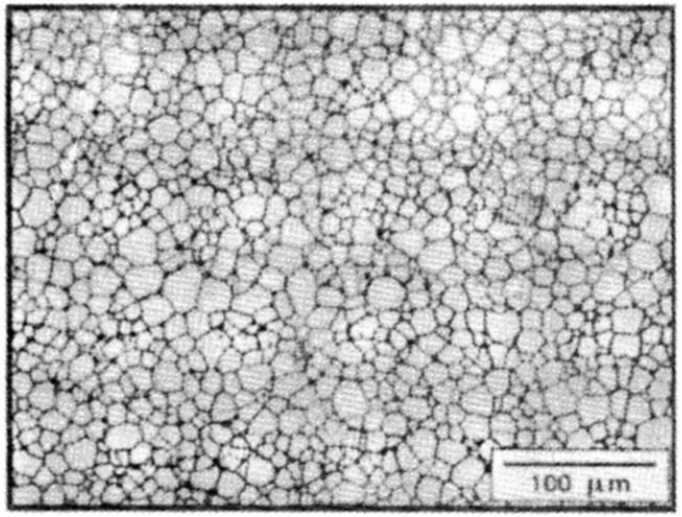
1727 derecede sinterlenen Al_2O_3 için hesaplanmış sinterleme süresi yoğunluk grafikleri

Katı Faz Sinterlemesi

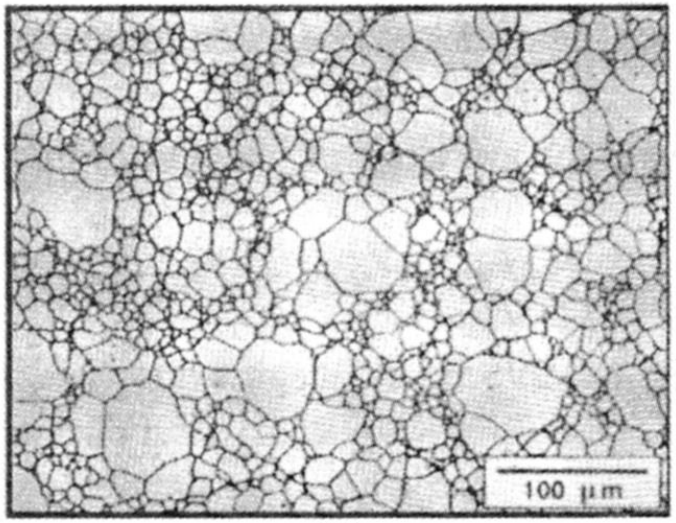


1727 derecede sinterlenen Al_2O_3 için hesaplanmış sinterleme süresi yoğunluk grafikleri

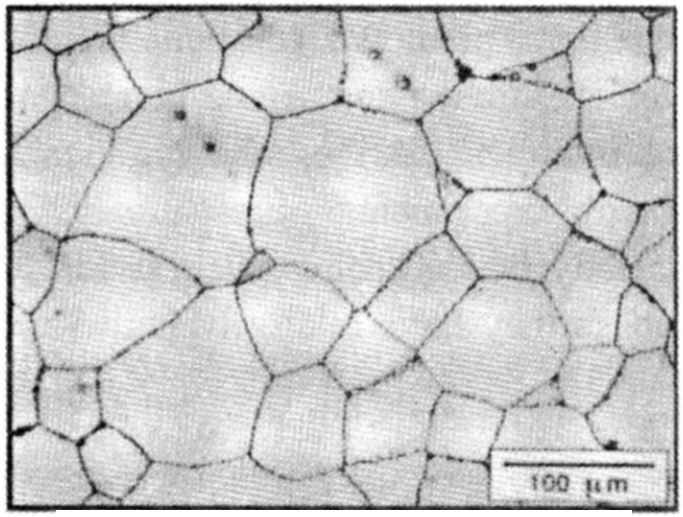
Katı Faz Sinterlemesi



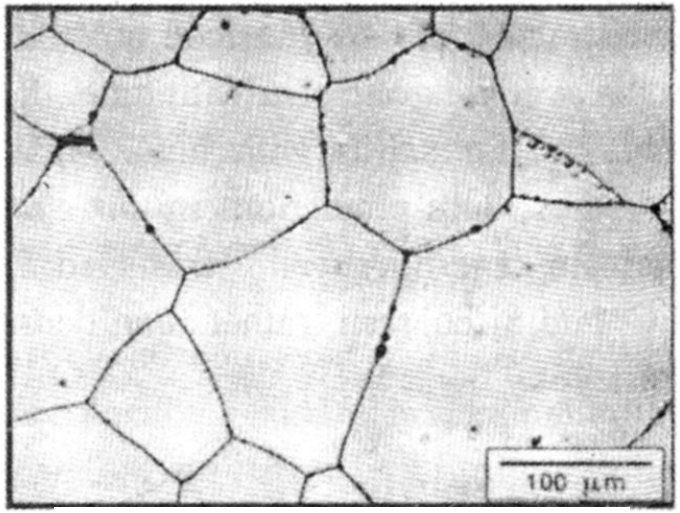
5 dakika



20 dakika



60 dakika



120 dakika

Katı Faz Sinterlemesi

Sintered material	Sintering temperatures, °C
Aluminum alloys	590-620
Bronze	740-780
Brass, 890-910	
Iron, carbon steels, low-alloyed steels (Cu, Ni)	1120-1150
Low-alloyed steels (Cu, Ni, Mo; Distaloy)	1120-1200
High-alloyed ferritic and austenitic steels (Cr, Cr-Ni)	1200-1280
Hard magnets (Alnico)	1200-1350
Hard metals (cemented carbides)[(a)]	1350-1450
Molybdenum and molybdenum-alloys	1600-1700
Tungsten[(b)]	200-2300
Heavy metal (W alloy)	~1400
Ferrites (soft and hard)	1100-1300
Silicon nitride (with different additives)[(c)]	1750-2000
Silicon carbide (with different additives)[(d)(e)]	1750-2100
Alumina[(e)]	1400-1800
Zirconia (with different additives)[(e)]	1400-1750

(a) TiC-based hard metals (cermets) up to 1600 °C.

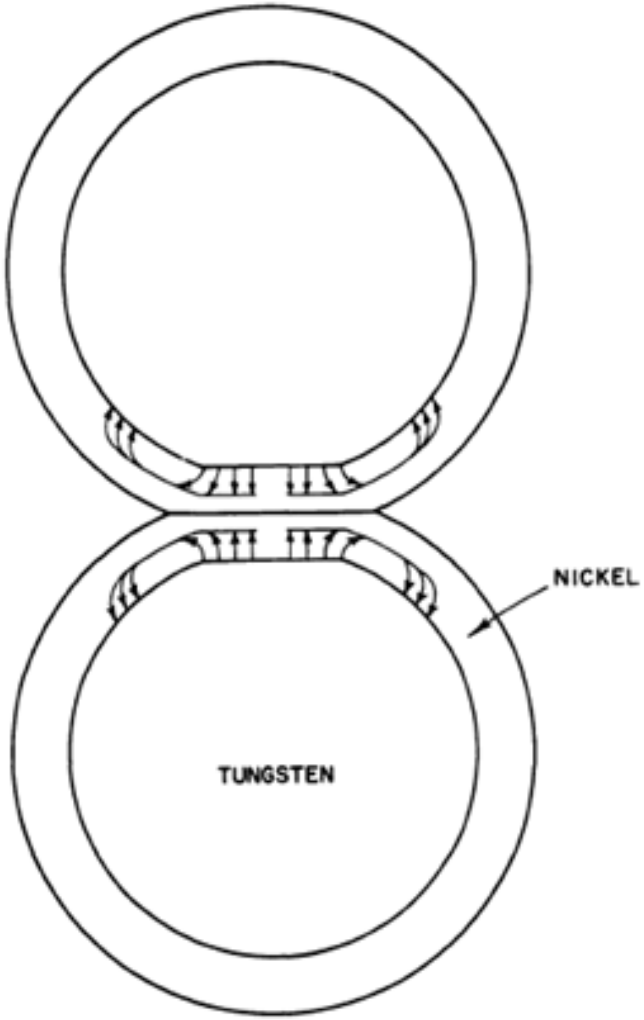
(b) ~3000 °C, when direct sintering is used.

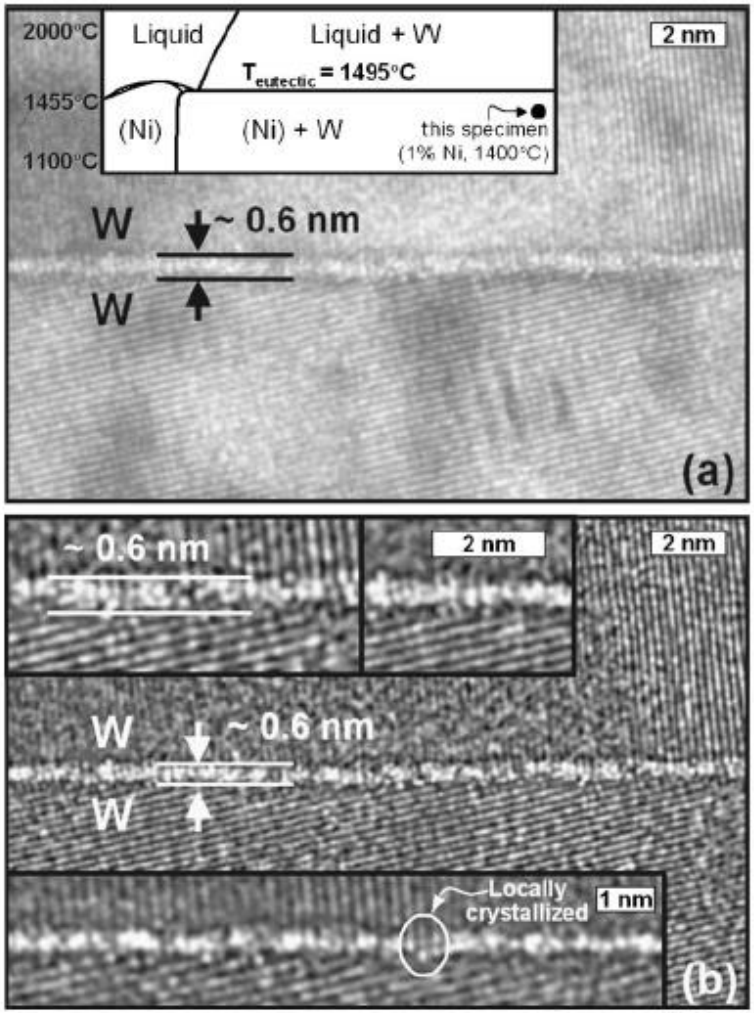
(c) Highest temperature under pressured N_2 atmosphere or in powder bed.

(d) Low temperatures for liquid phase sintering.

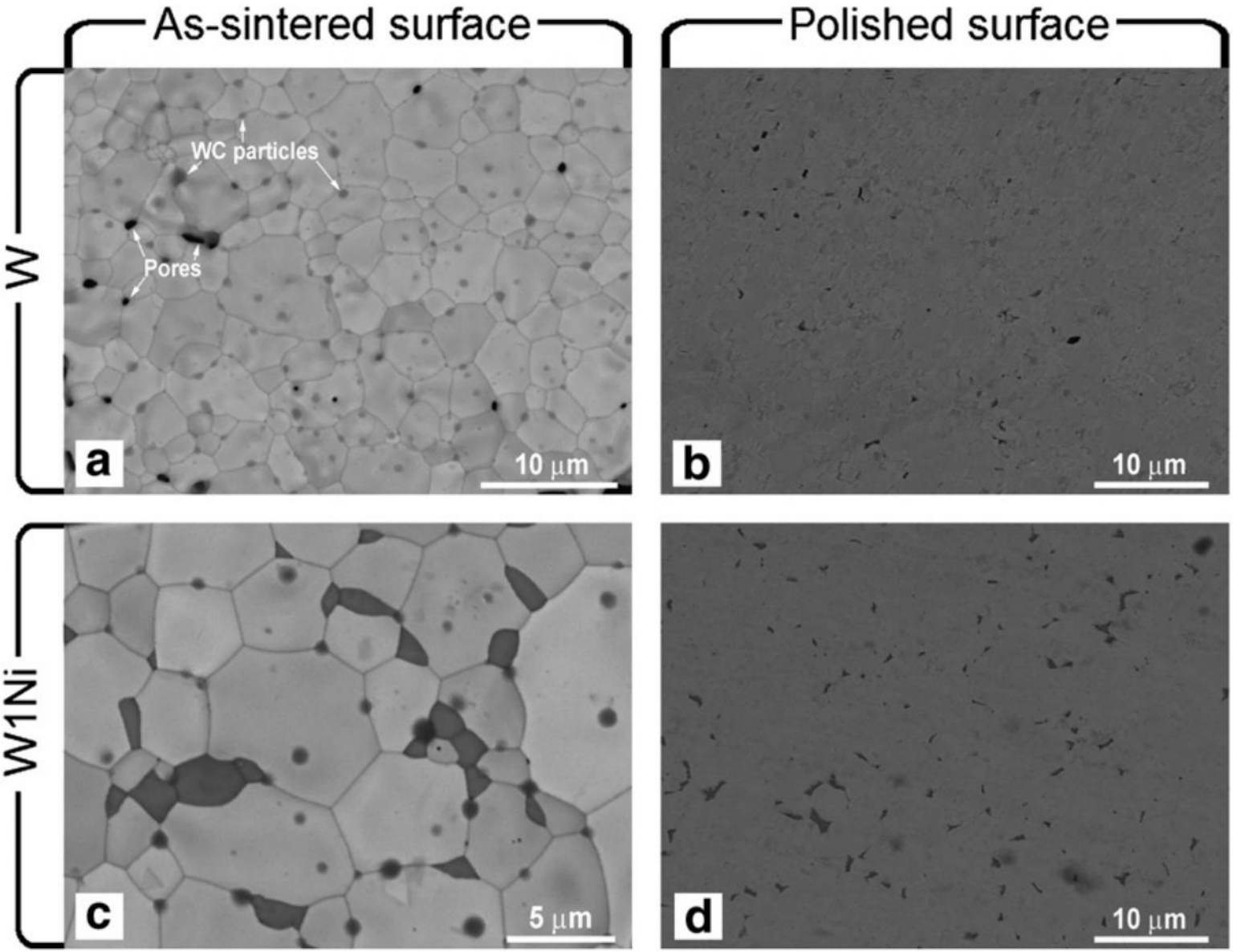
(e) Low temperatures for highly active powders.

Aktifleştirilmiş Sinterleme

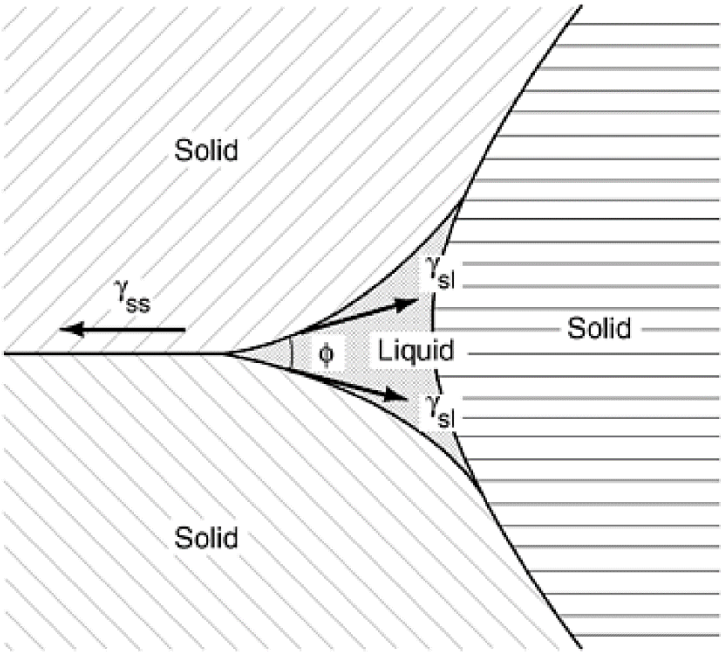


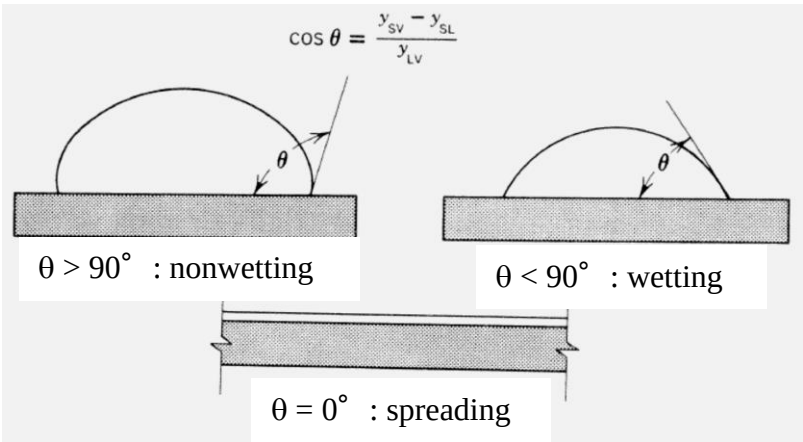


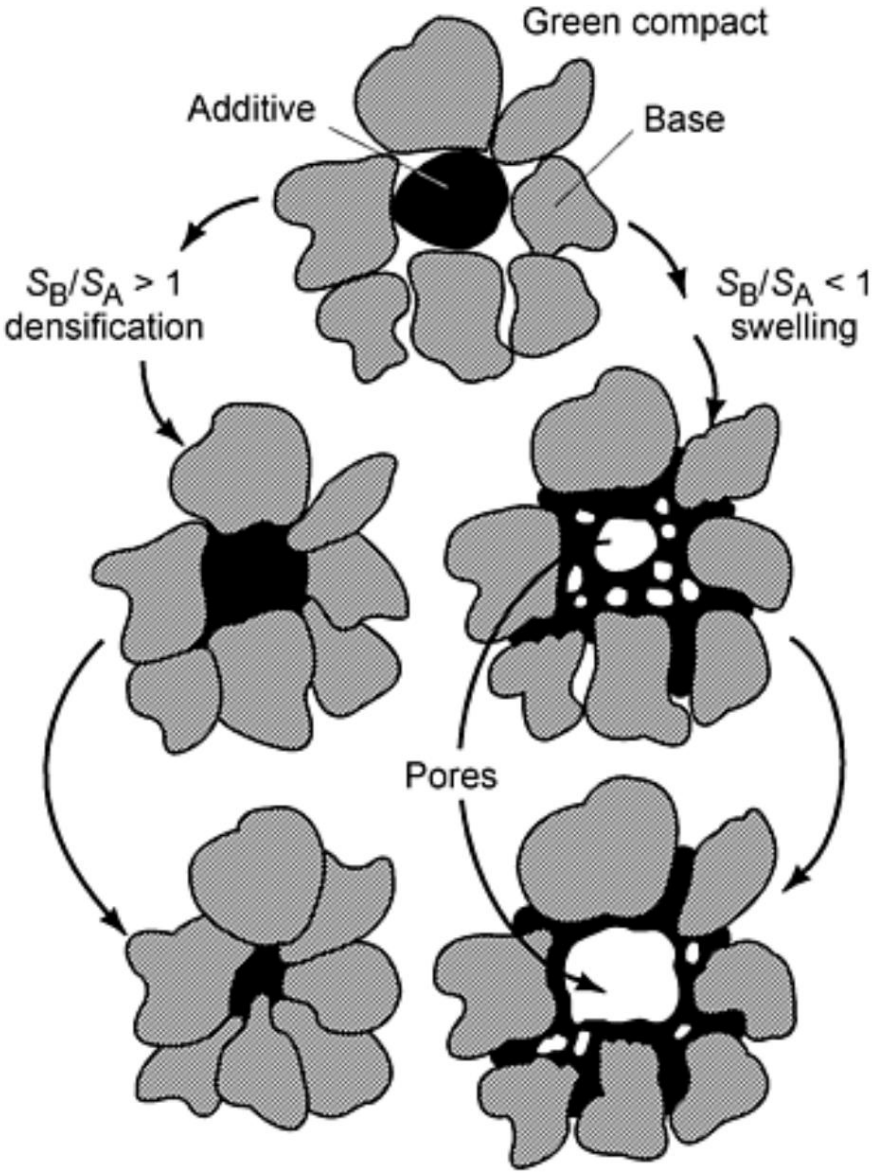
Aktifleştirilmiş Sinterleme



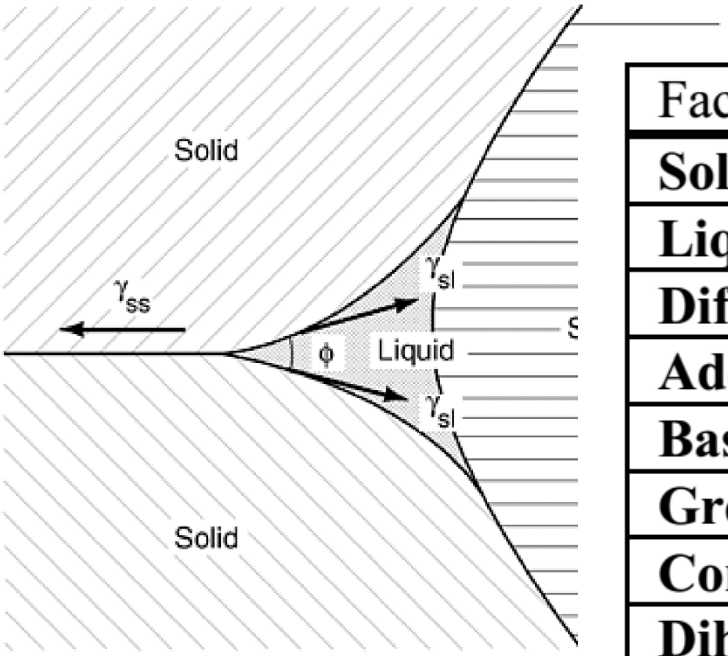
Sıvı Faz Sinterlemesi



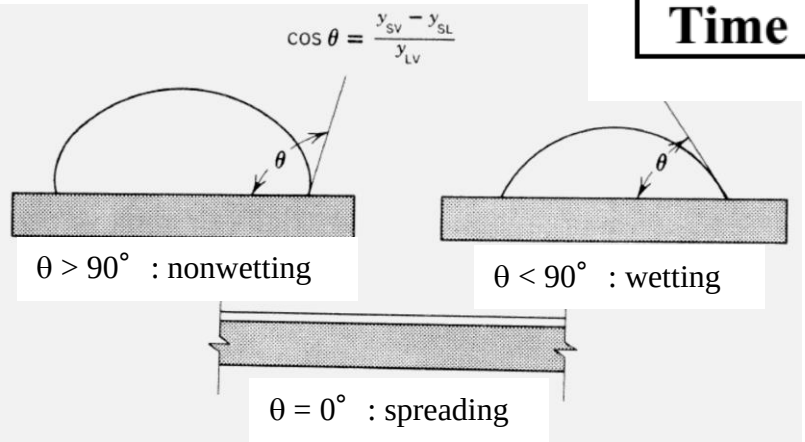




Sıvı Faz Sinterlemesi



Factor	Swelling	Shrinkage
Solid solubility in liquid	Low	High
Liquid solubility in solid	High	Low
Diffusivities	Unequal	Equal
Additive particle size	Large	Small
Base particle size	Large	Small
Green density	High	Low
Contact angle	High	Low
Dihedral angle	High	Low
Temperature	Low	High
Time	Short	Long



Sıvı Faz Sinterlemesi

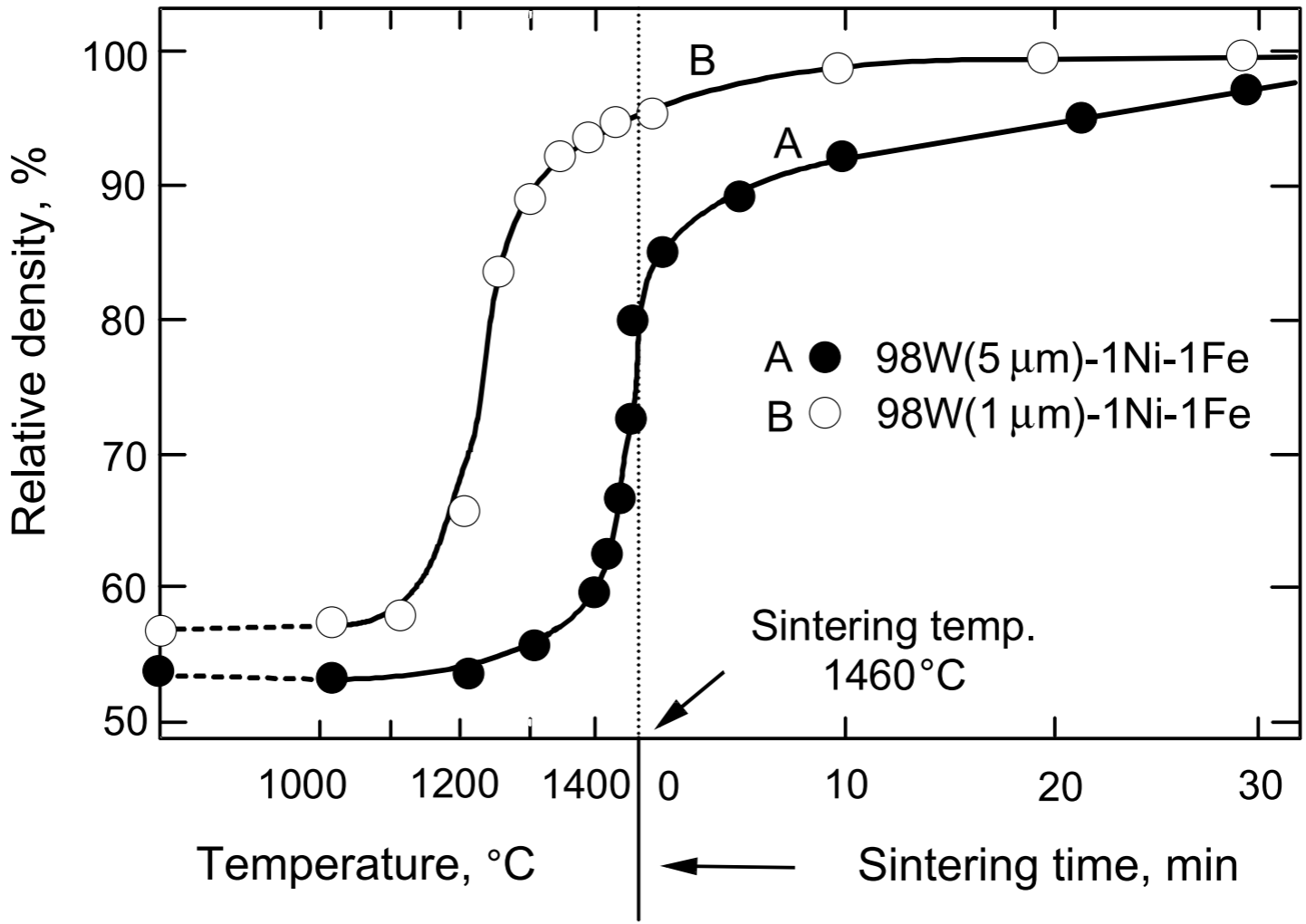
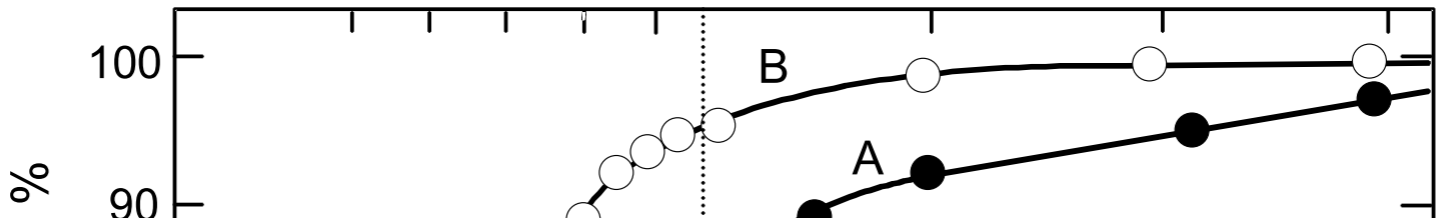


Figure 14.1. Densification curves of 98W-1Ni-1Fe(wt%) alloys during heating to and isothermal liquid phase sintering at 1460°C.[1]

Sıvı Faz Sinterlemesi



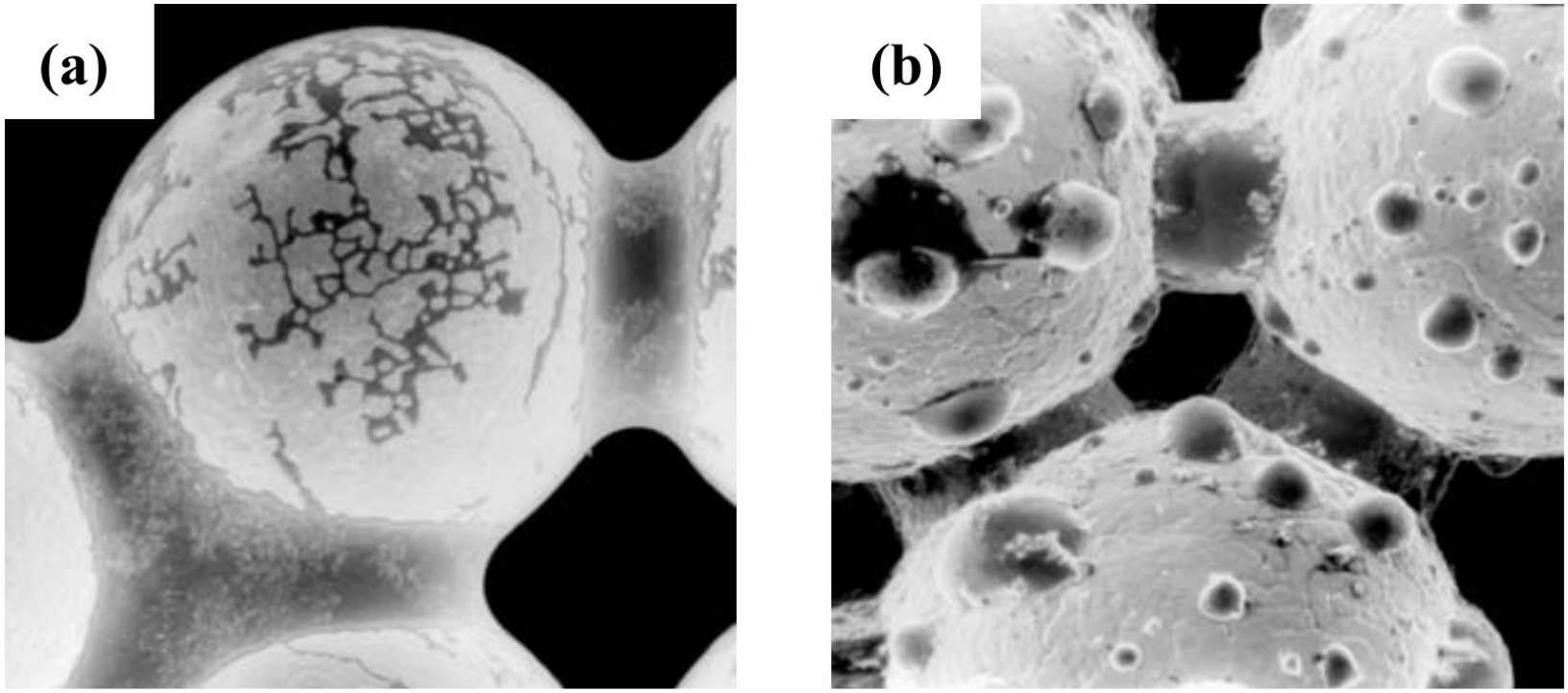
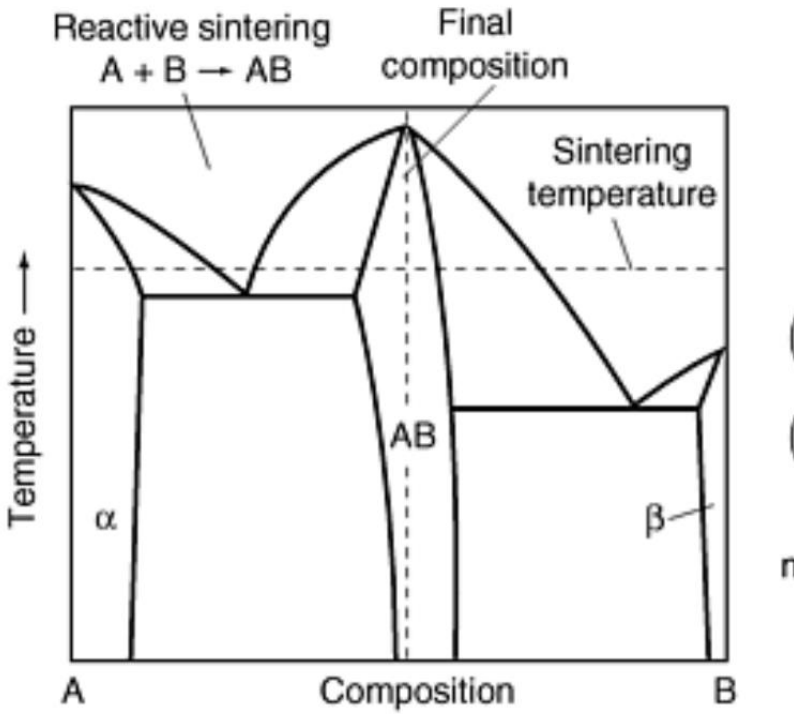
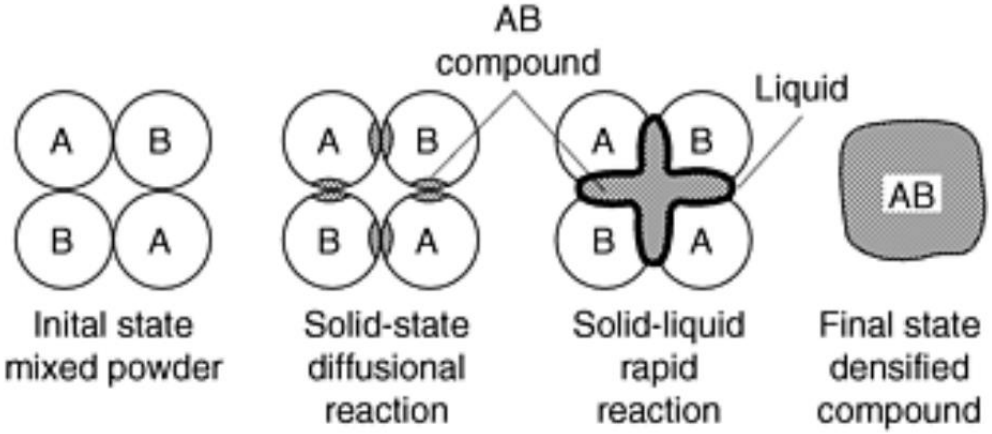


Figure 14.5. Distribution of liquid Cu between W spheres (~200 μm diameter) for a wetting angle θ of (a) 8° and (b) 85°.[2]

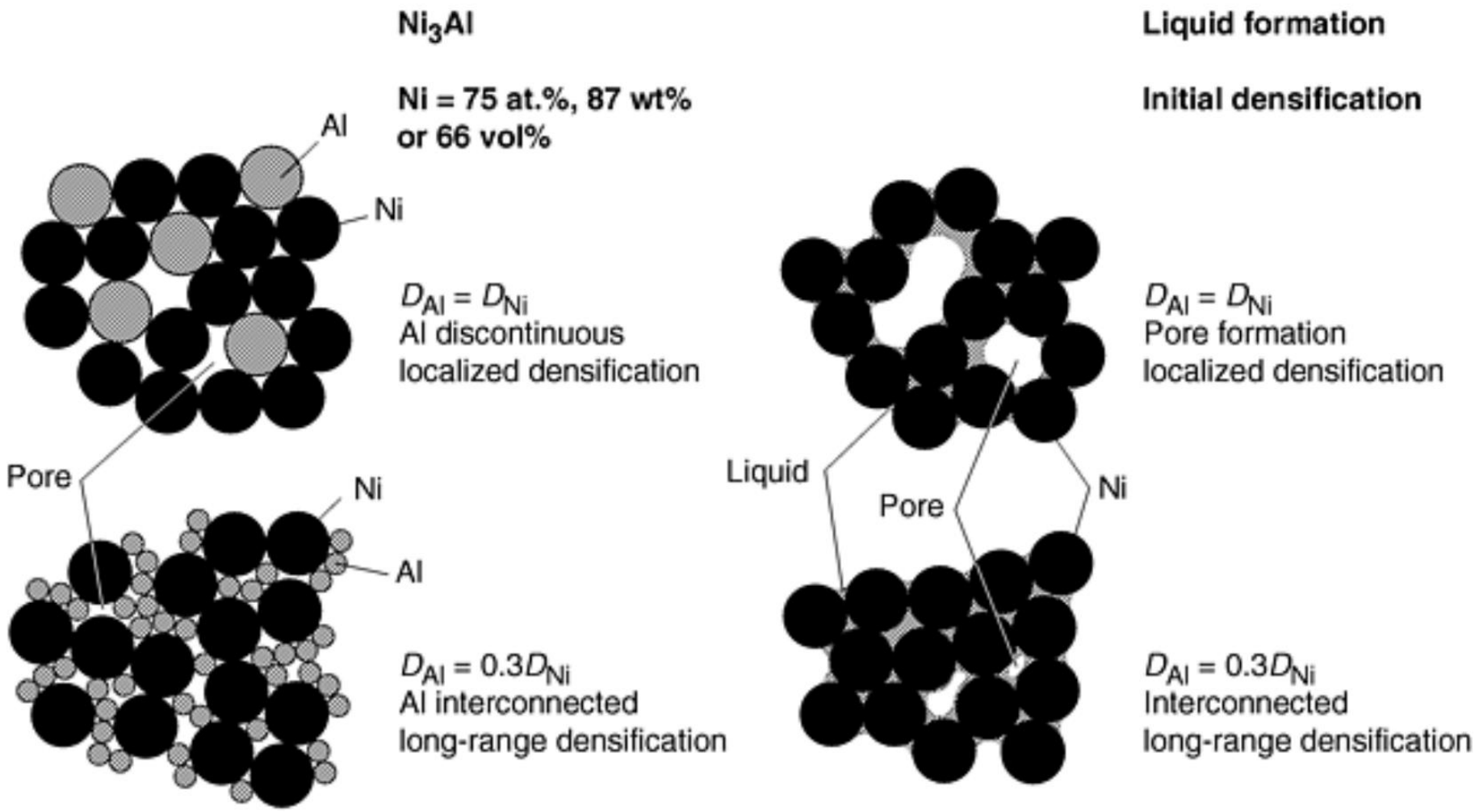
Reaktif Sinterleme



Start with a mixture of A and B powders
finish with a sintered compact of AB compound



Reaktif Sinterleme



Kaynaklar

ASM Handbook Volume 7: Powder Metal Technologies and Applications, 1998.

Introduction to Powder Metallurgy, by F. Thümmler and R. Oberacker, 1993.

Sintering: Densification, Grain Growth & Microstructure, by Suk-Joong L. Kang, Elsevier, 2005.

Handbook of Non-Ferrous Metal Powders: Technologies and Applications, Edited by O.D. Nejkov, S.S. Naboychenko, G. Dowson, Elsevier, 2009.

J. Luo et al. APPLIED PHYSICS LETTERS 87, 231902 2005.