Glass and Glass-Ceramics for Wireless Communication

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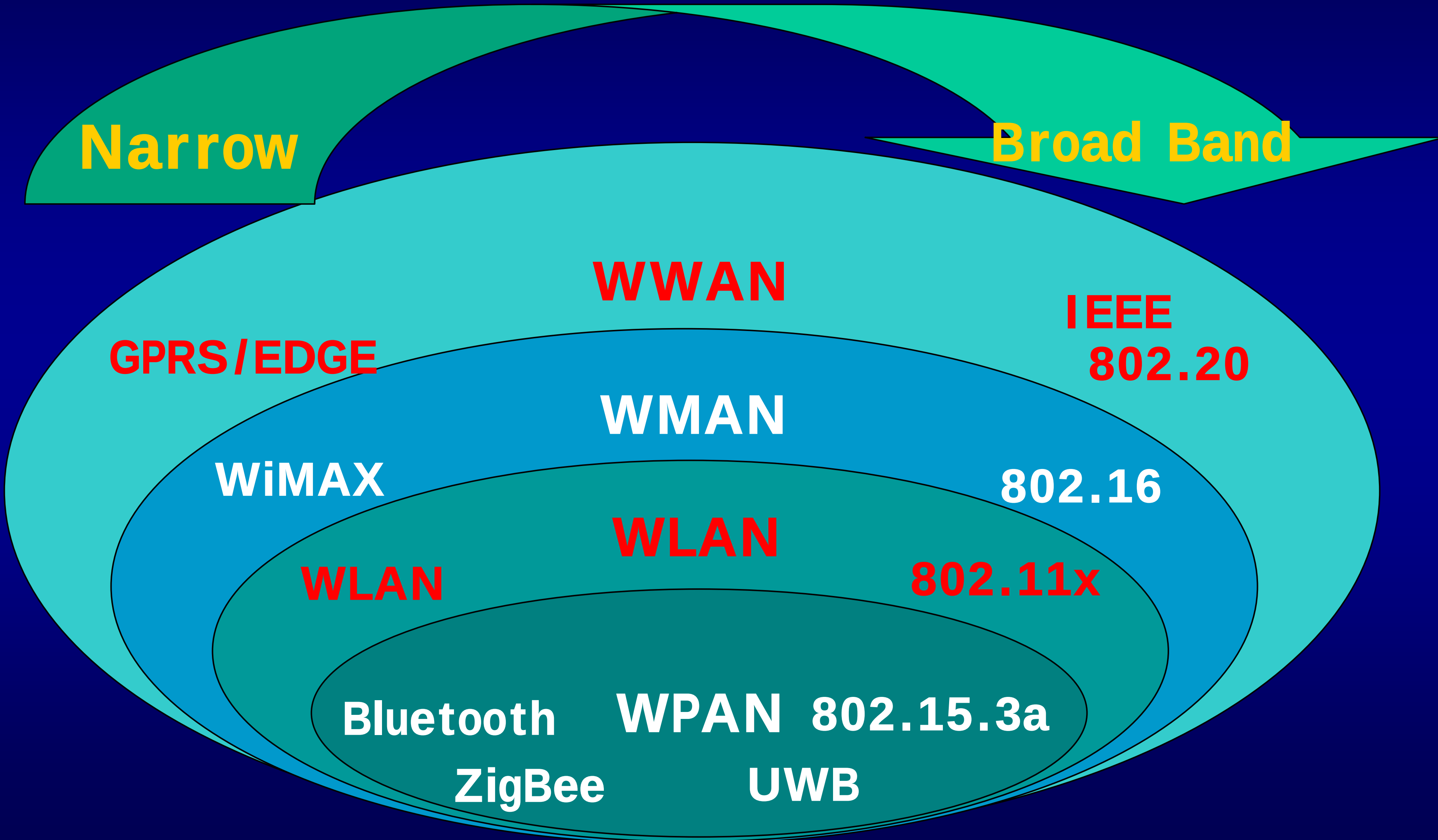
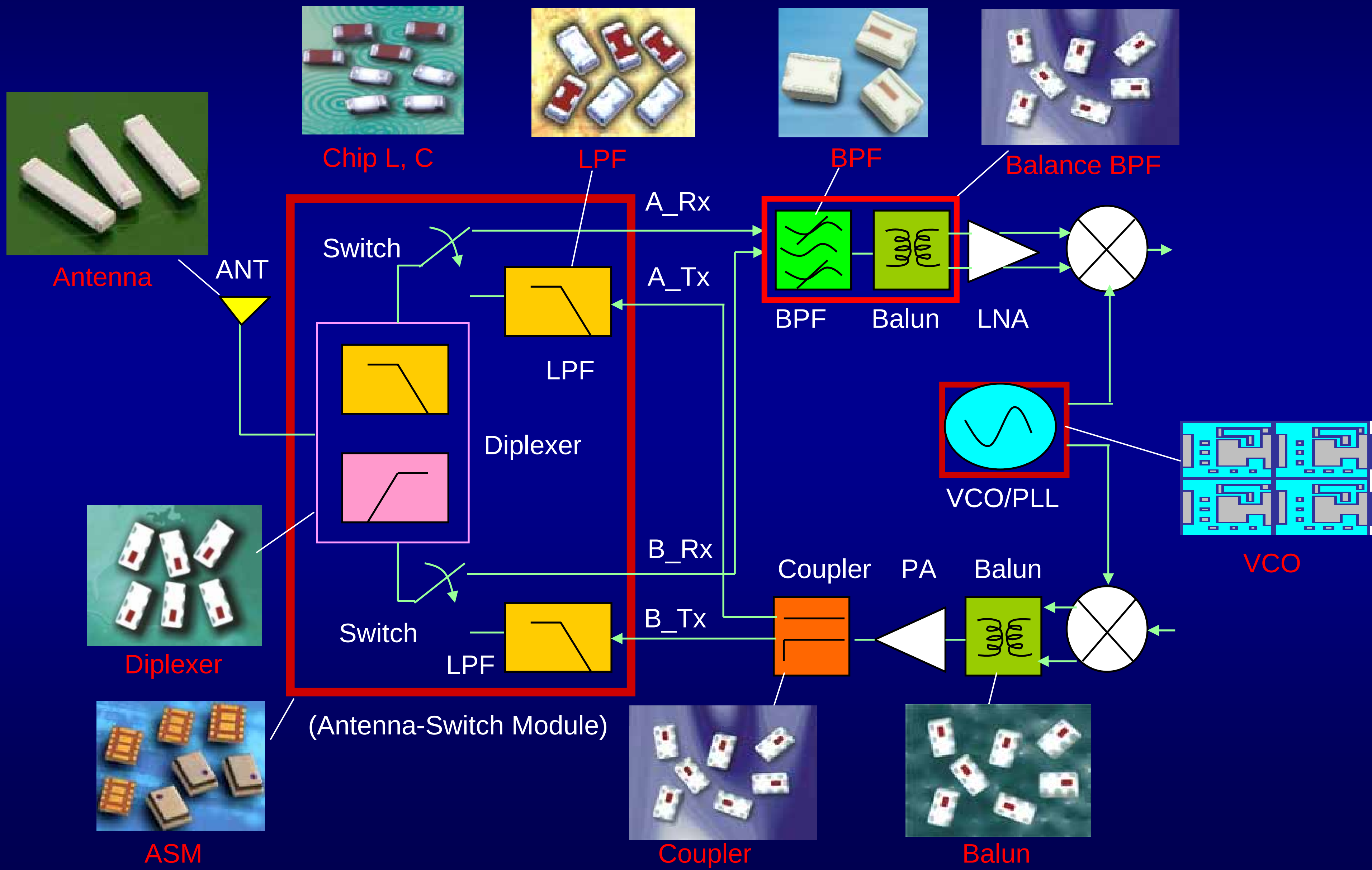
Wireless Wonders

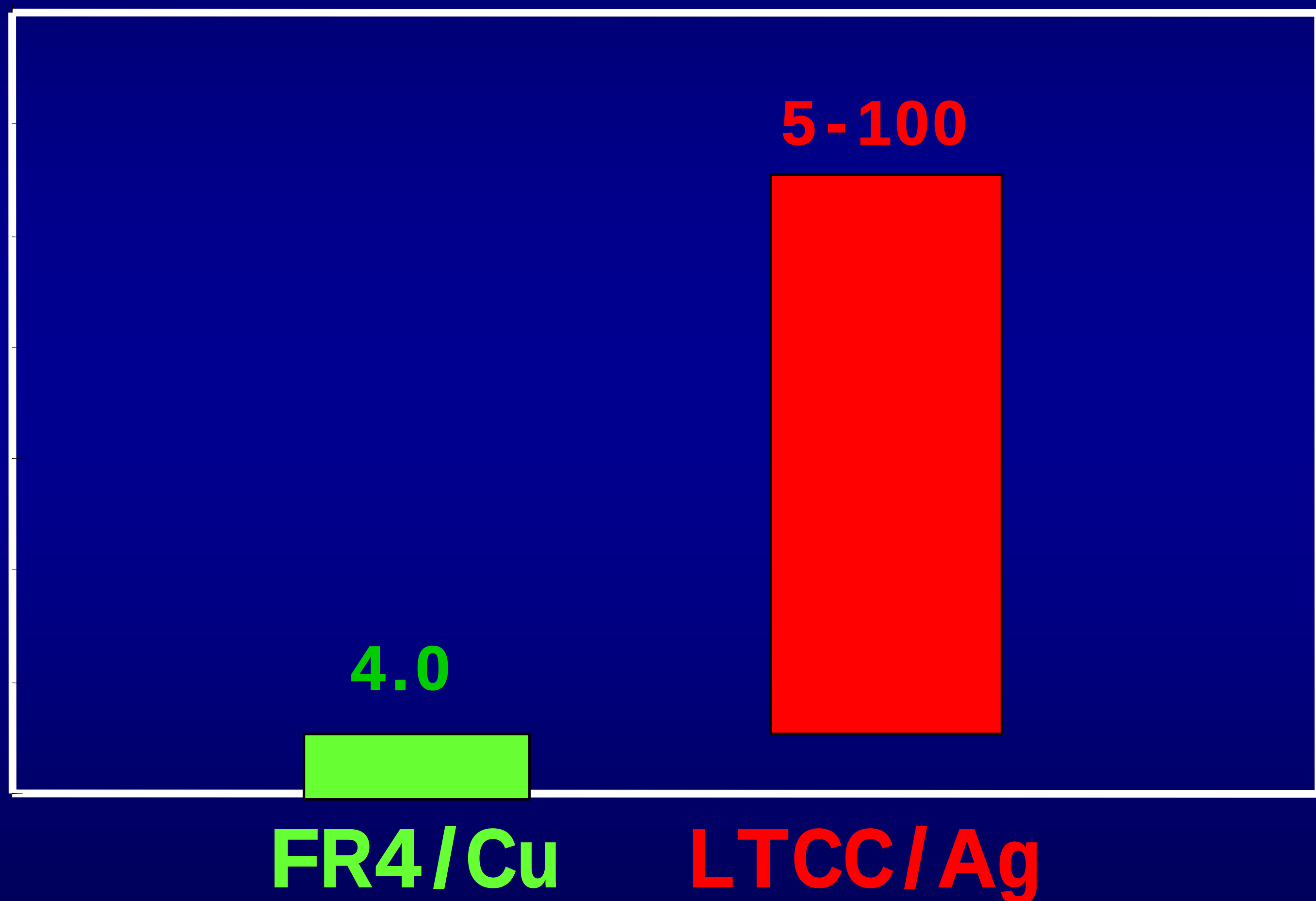


LTCC devices for RF Front-end



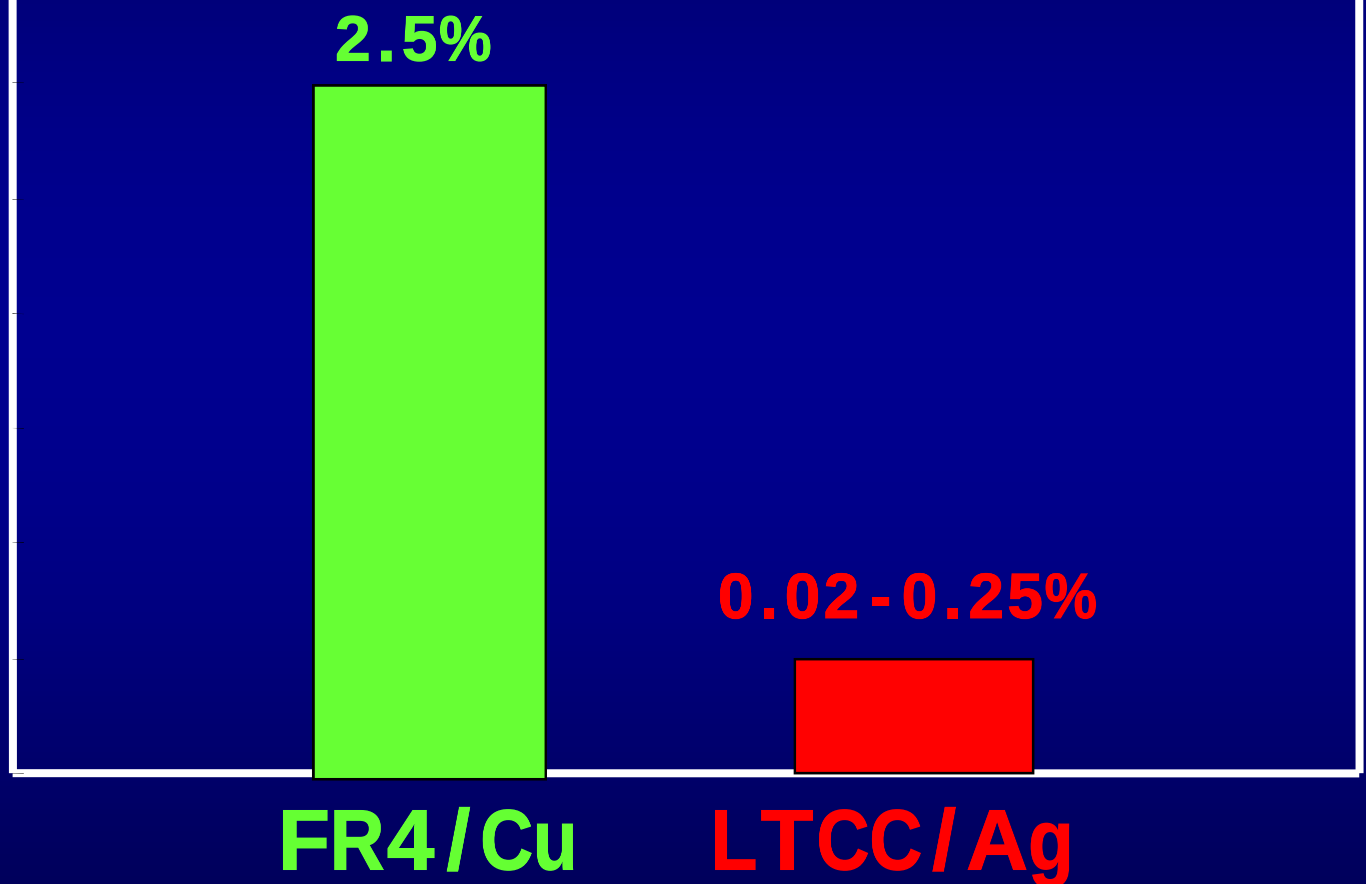
Why Ceramics ???????

Dielectric Constant



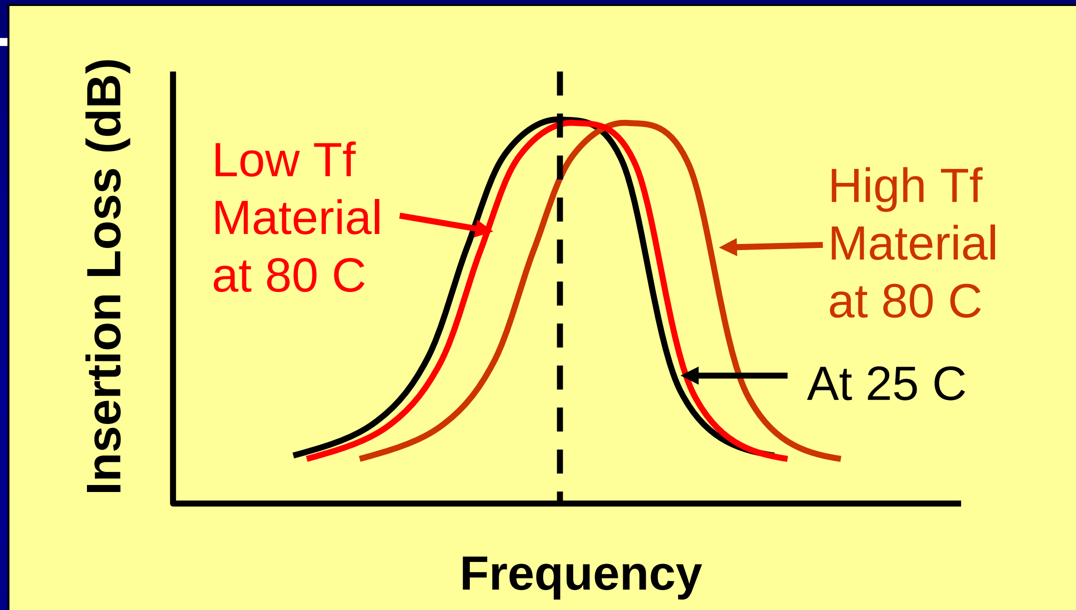
@4GHz

Dielectric Loss



@4GHz

Temp. Coefficient of Resonant Frequency (T_f)



$T_f \cong -1/2T_k - TCE$

10 ppm/K

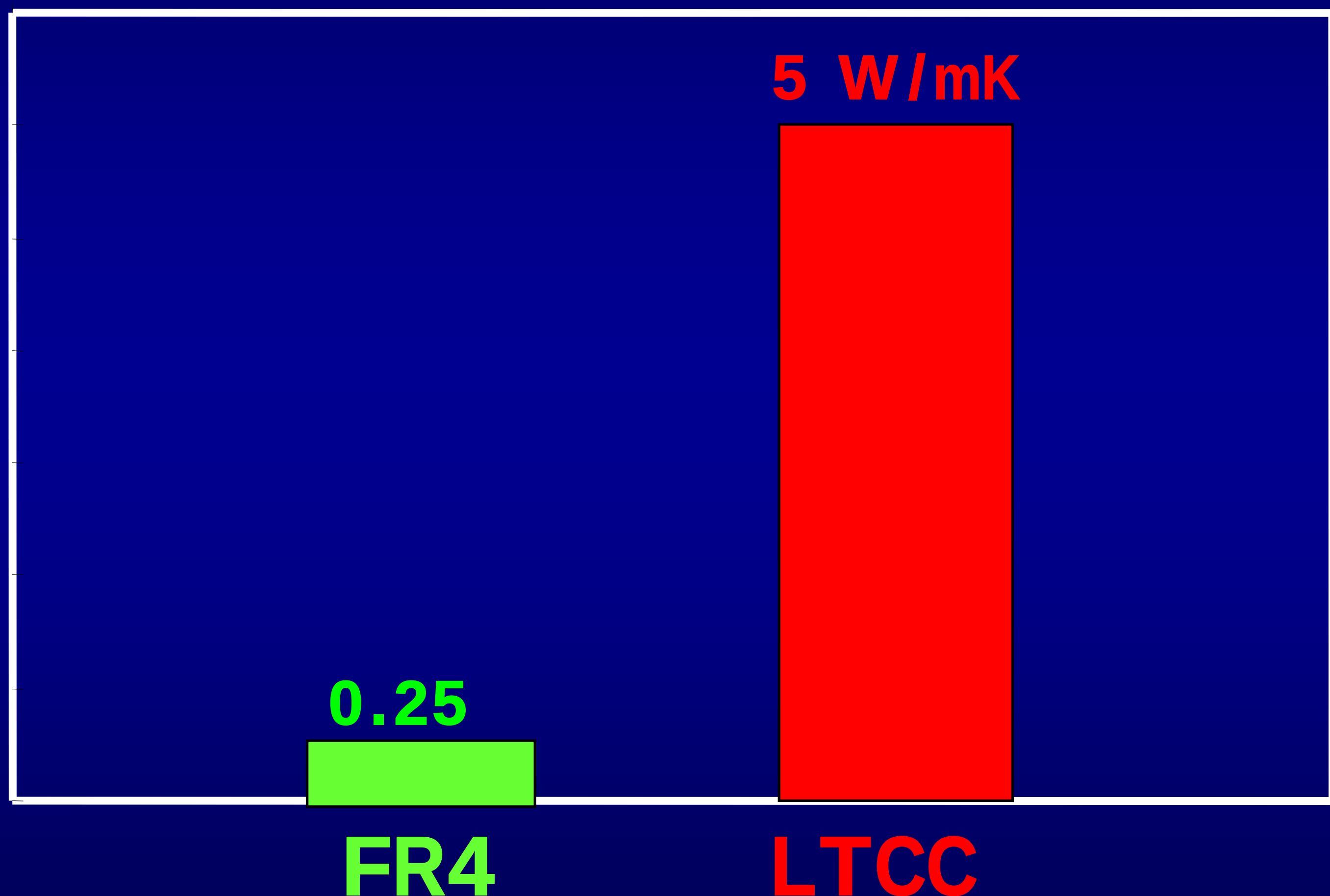
T_k :Temp. coefficient of capacitance

TCE: Thermal expansion coefficient

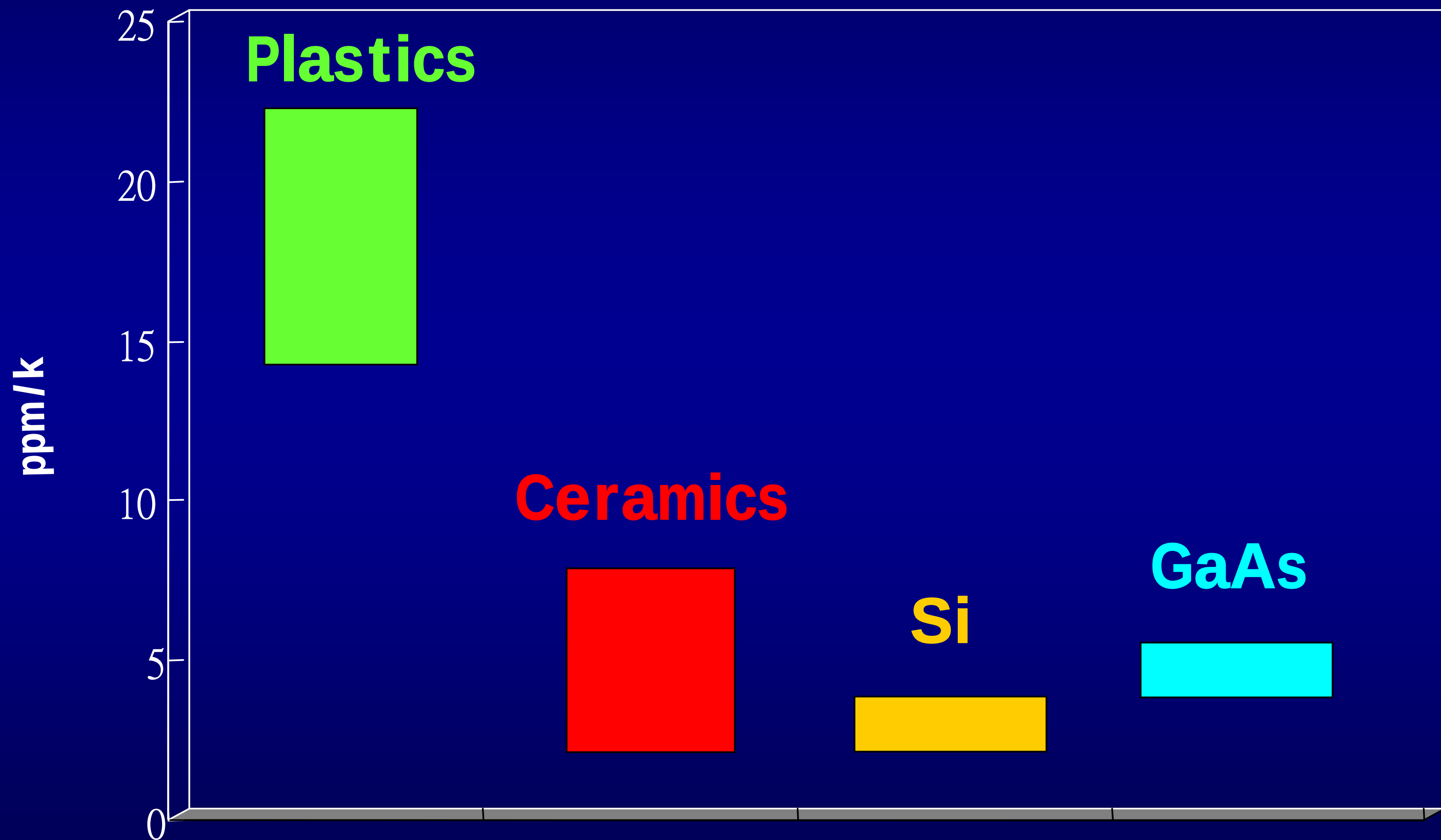
FR4/Cu

LTCC/Ag

Thermal Conductivity



Thermal Expansion Coefficient



Why LTCC ????????

LTCC

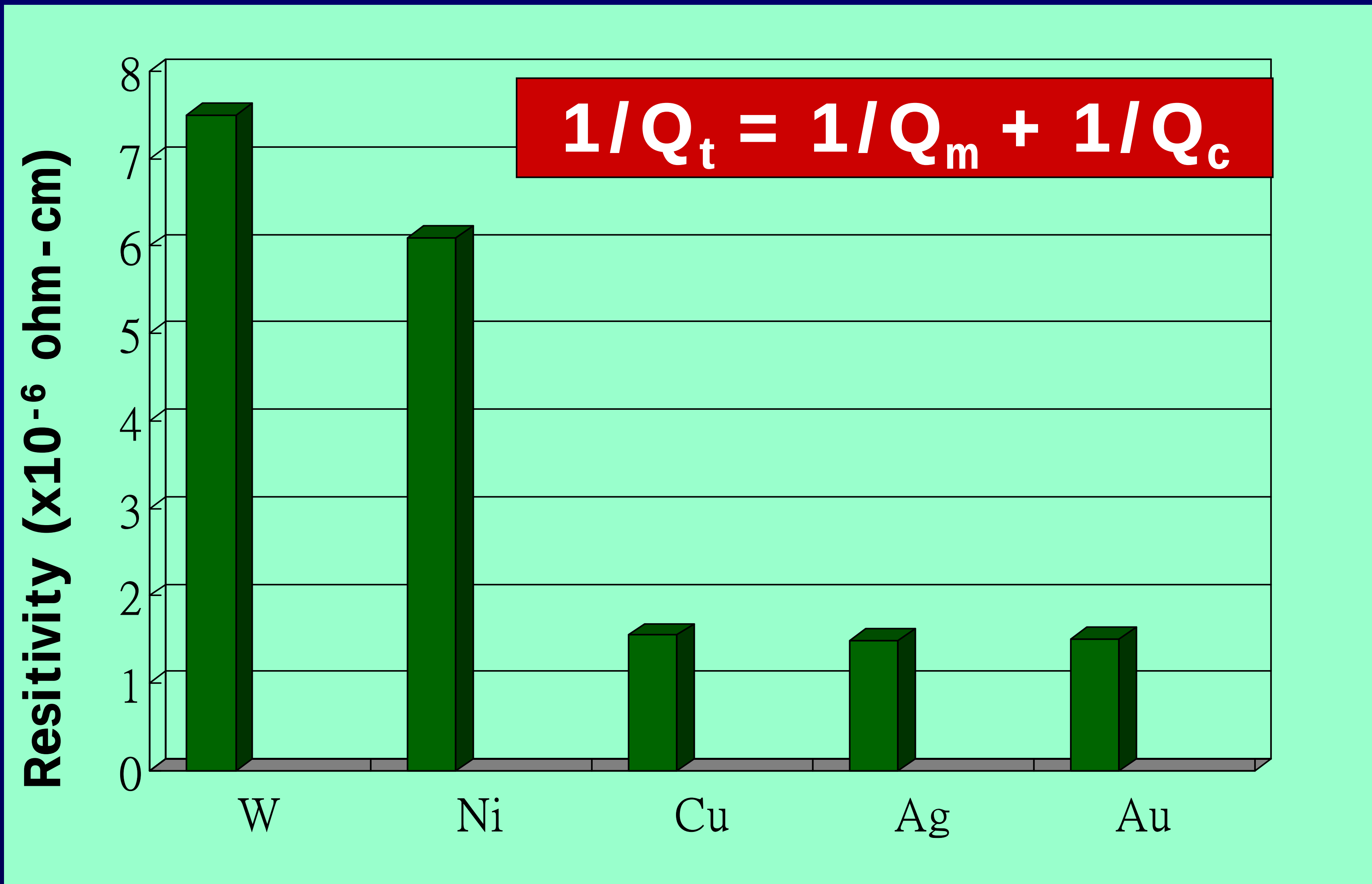
***L**ow **T**emperature **C**ofired **C**eramics*

<1000 ºC

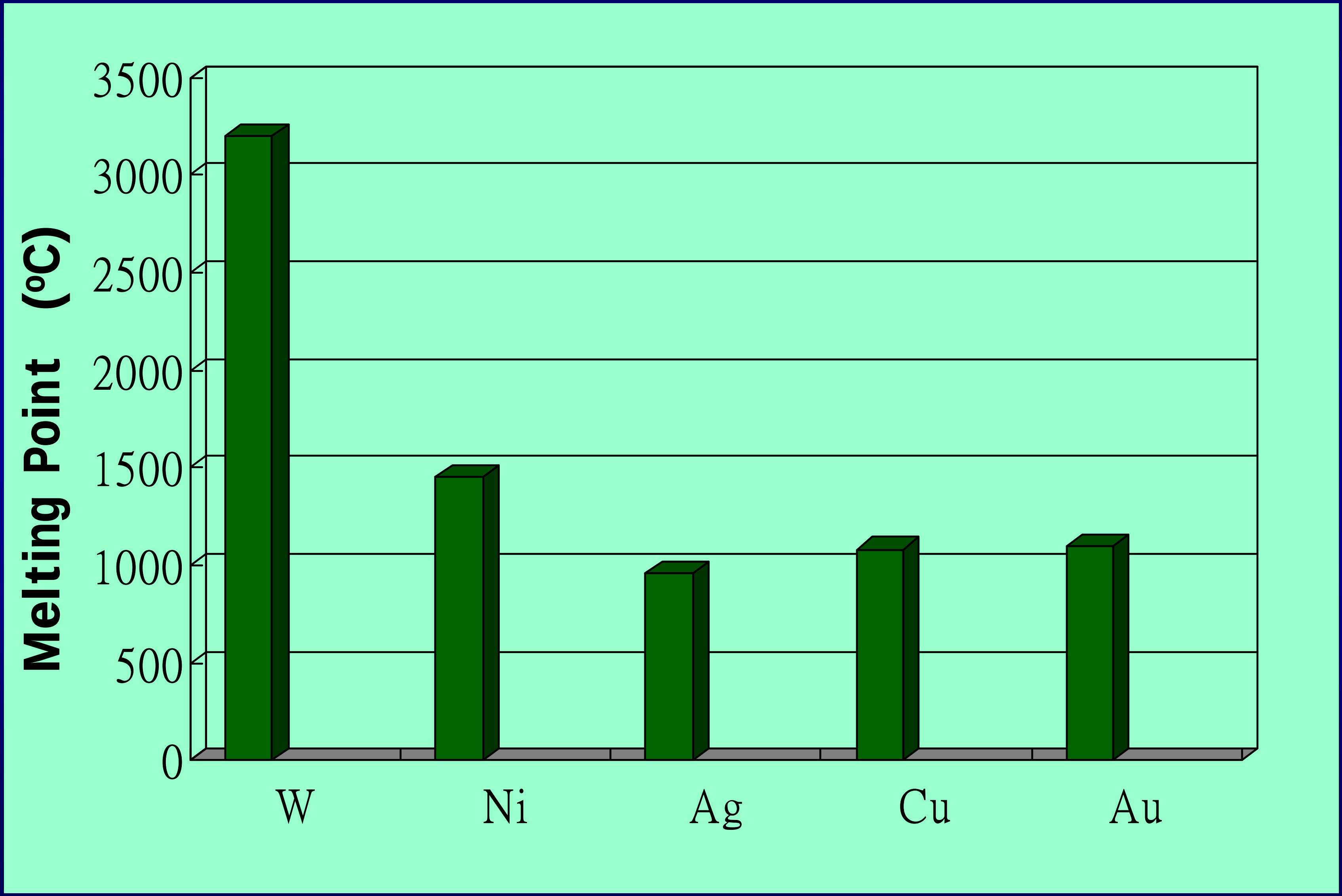
One fire

Ceramic base

Electrical Resistivity of Conductors



Melting Point of Conductors



LTCC Materials and Processes

Dielectric:

* Glass-Ceramics, Glass+ceramics
* Dielectric Constant: 5-100
* Dielectric Loss: 0.01-0.5%

Conductors: Ag, Cu and Au

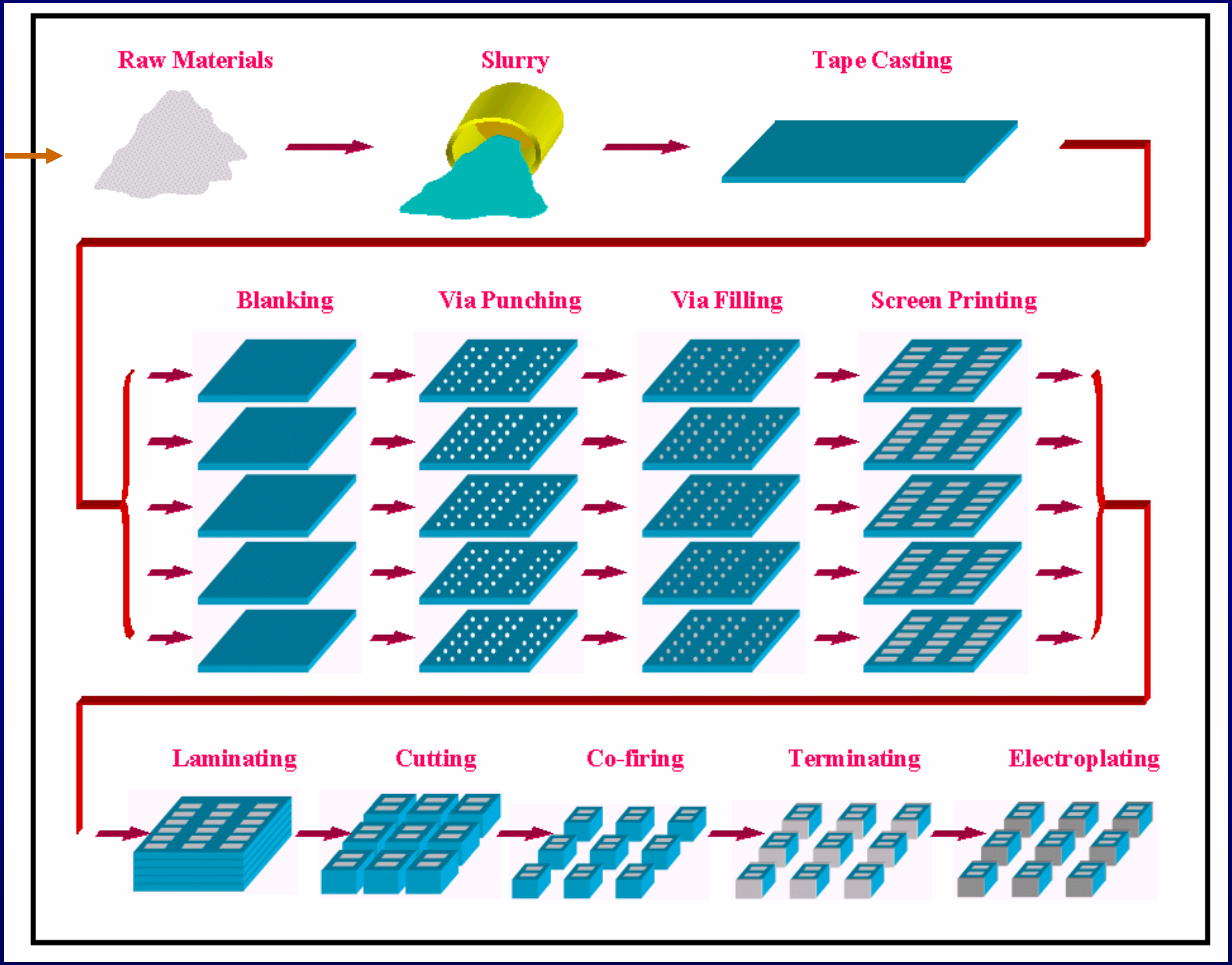
Resistors: RuO_2+Glass

Firing conditions:

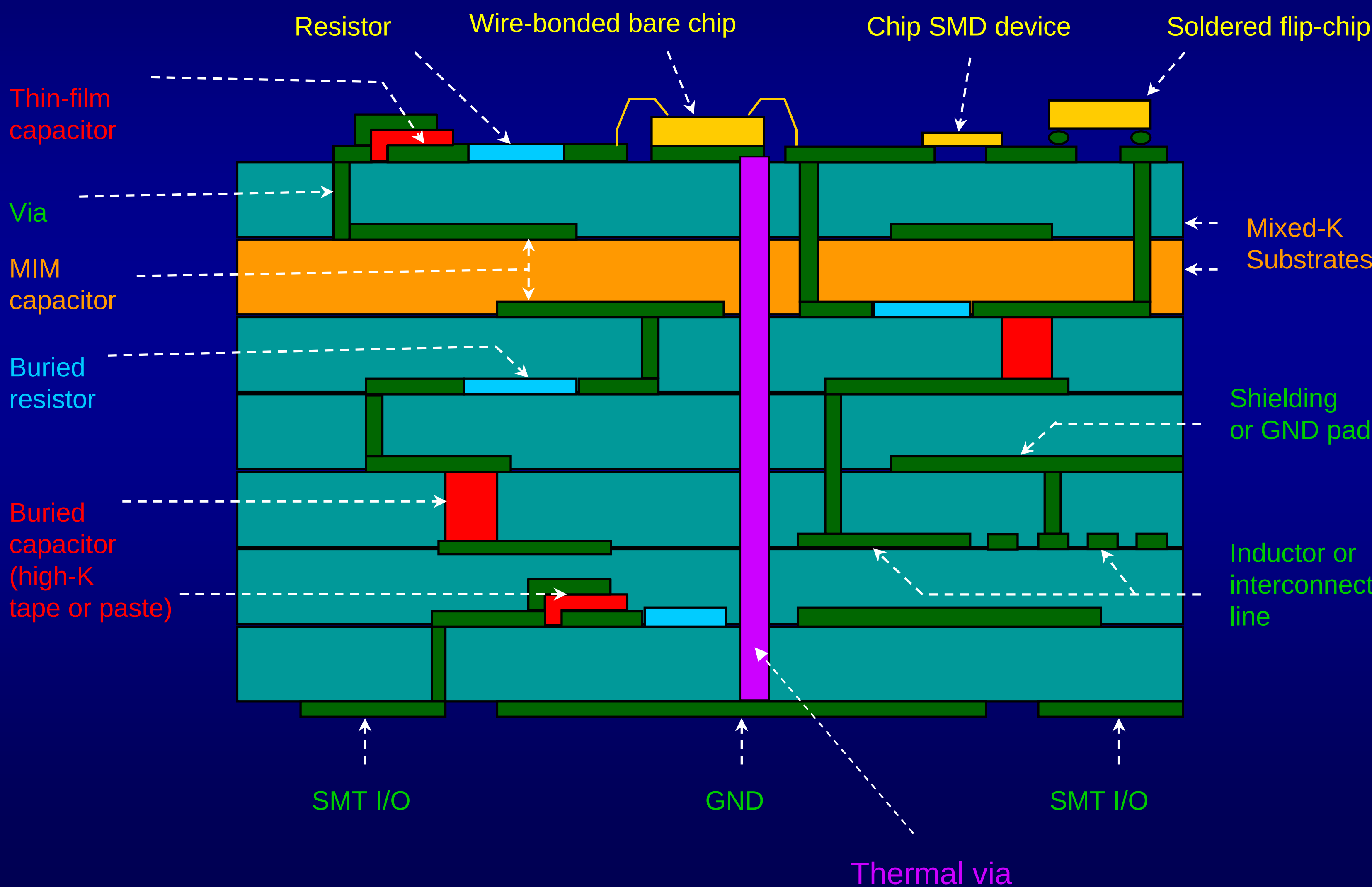
* **Temp.:800-1000ºC**
* **Time: 10-60 min**
* **Atmosphere: Air, $H_2+N_2+H_2O$**

Low Temperature Cofired Ceramics

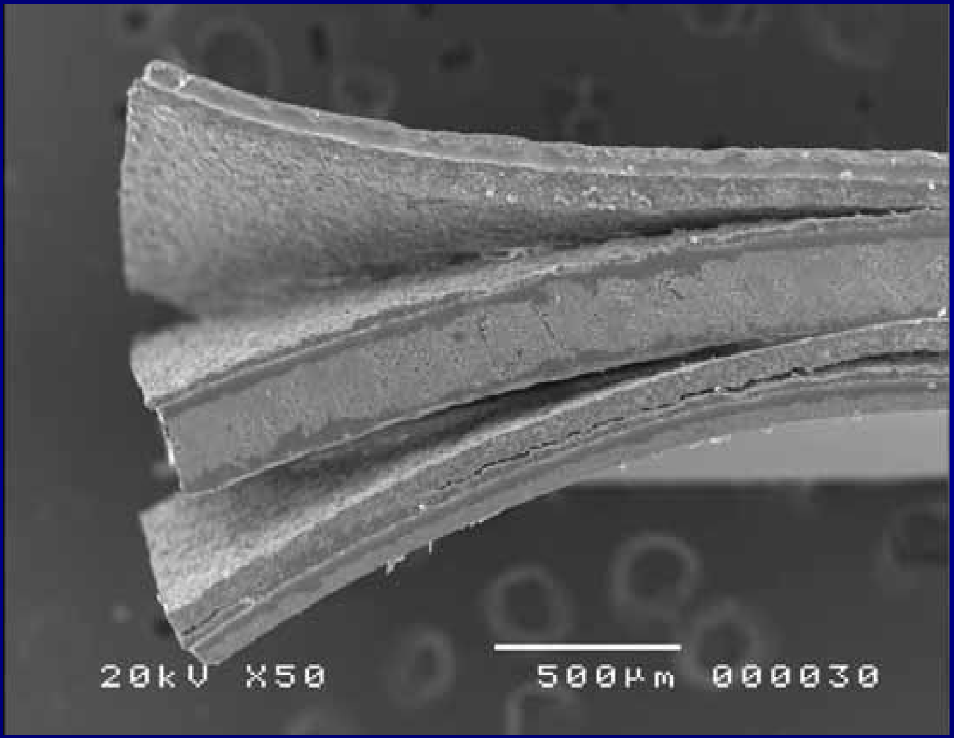
<1000 °C   One fire   Ceramic base

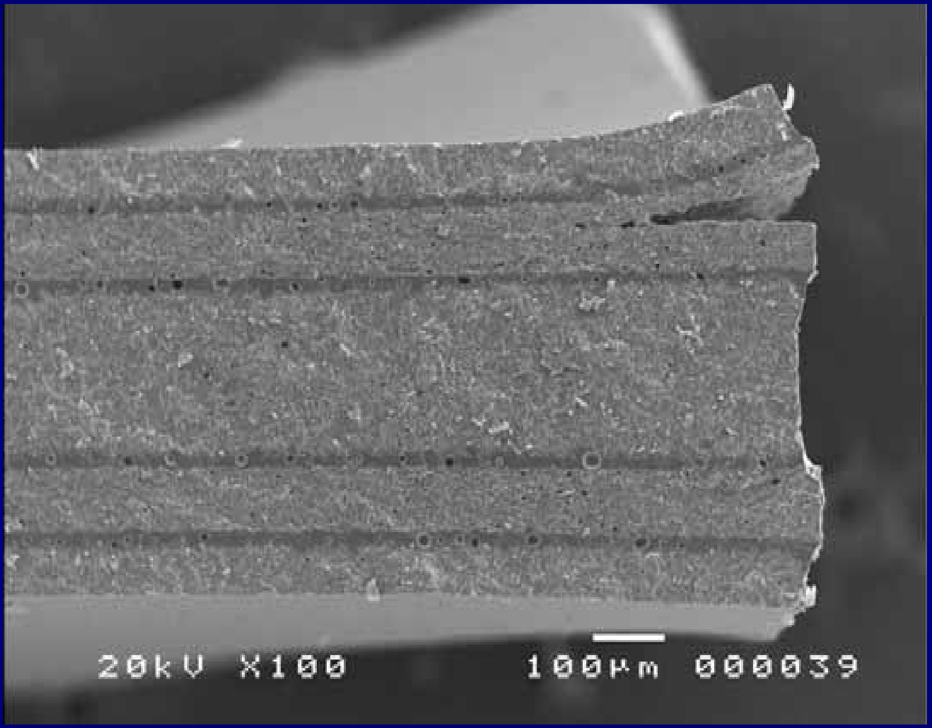


Integrated RF Module

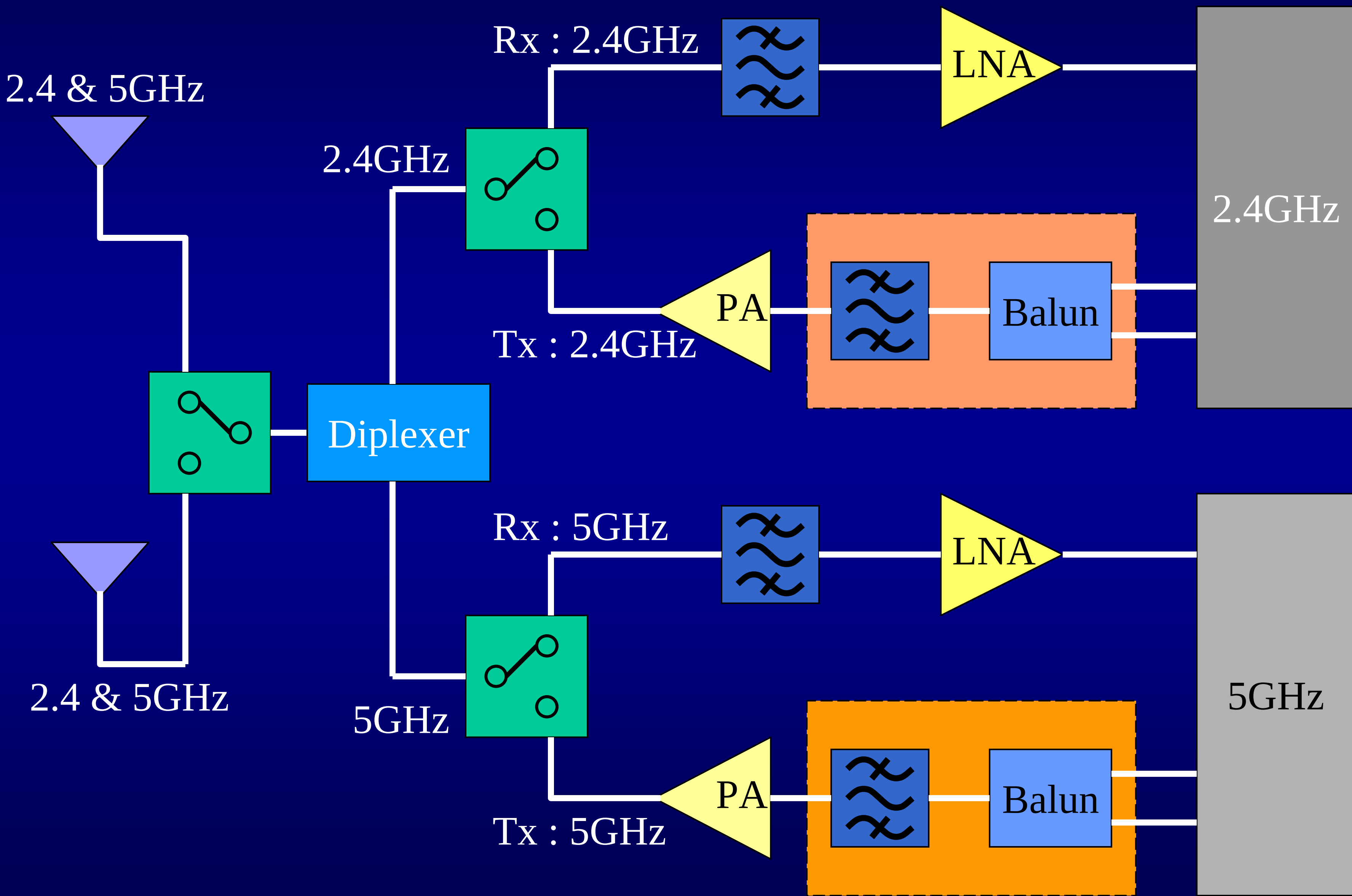


Cofiring Defects

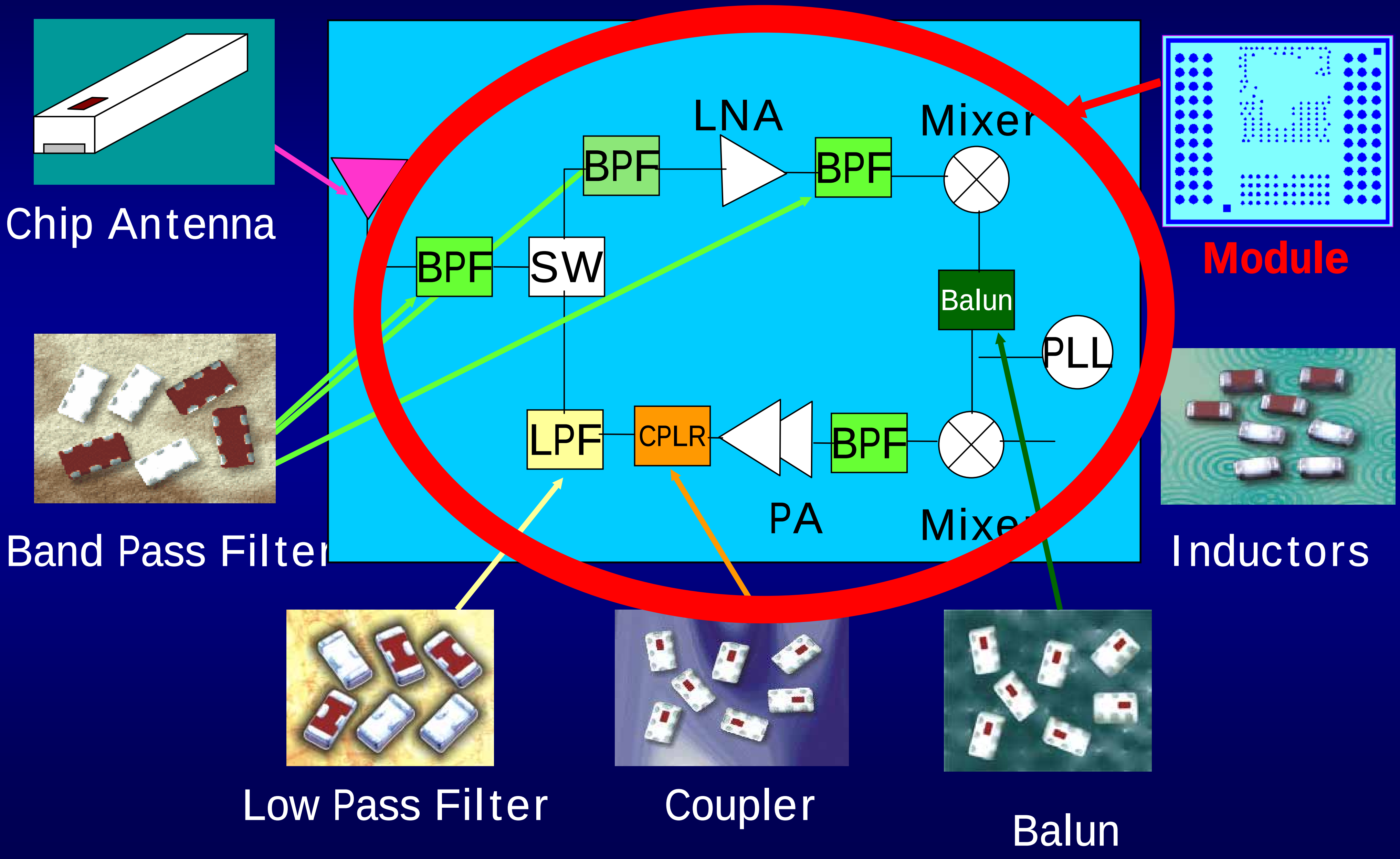




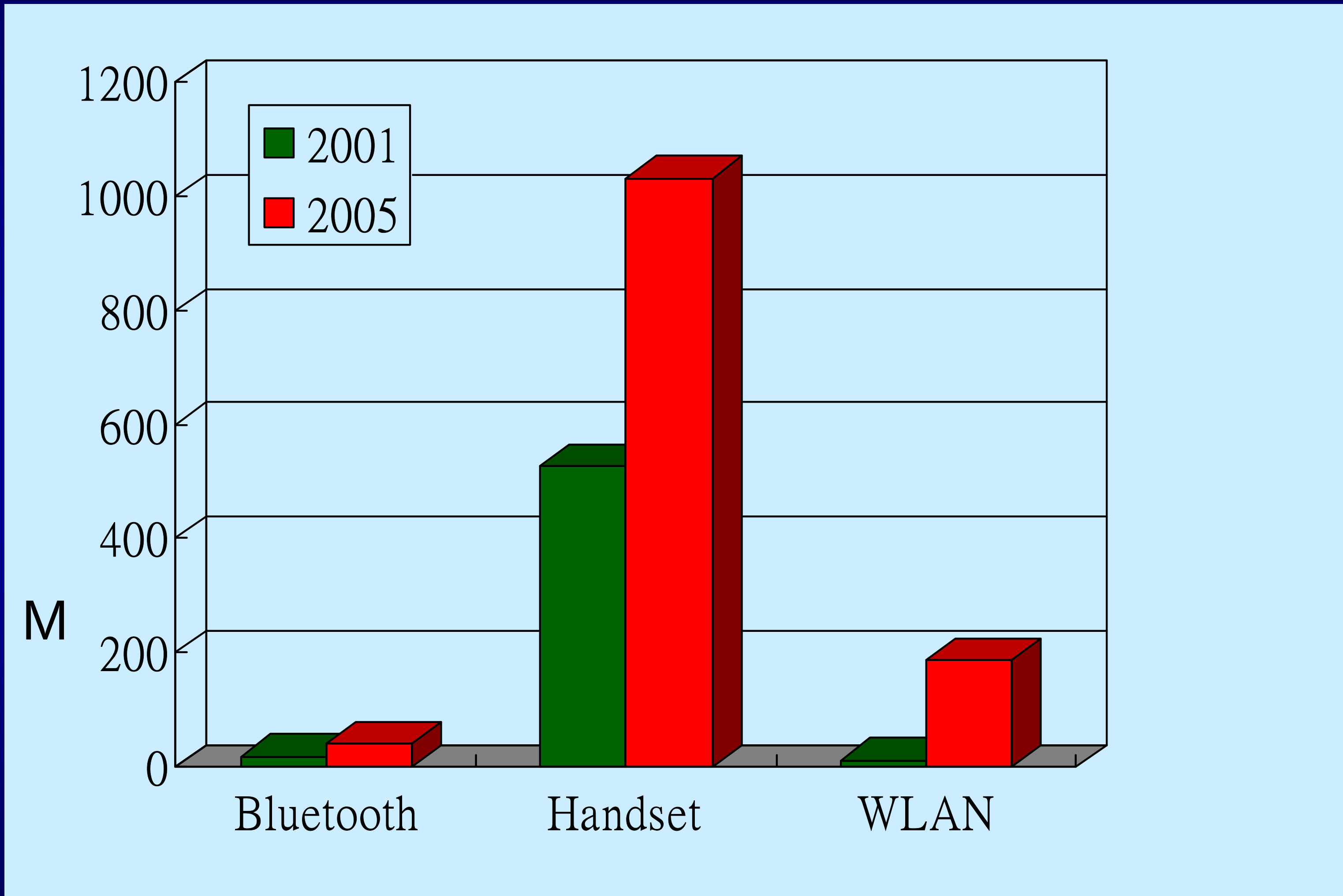
WLAN 802.11a+b+g



LTCC Solutions to Bluetooth



LTCC Market in Wireless Communication



Design of LTCC Compositions

Green **Sintered**

Type1: Glass+Ceramics

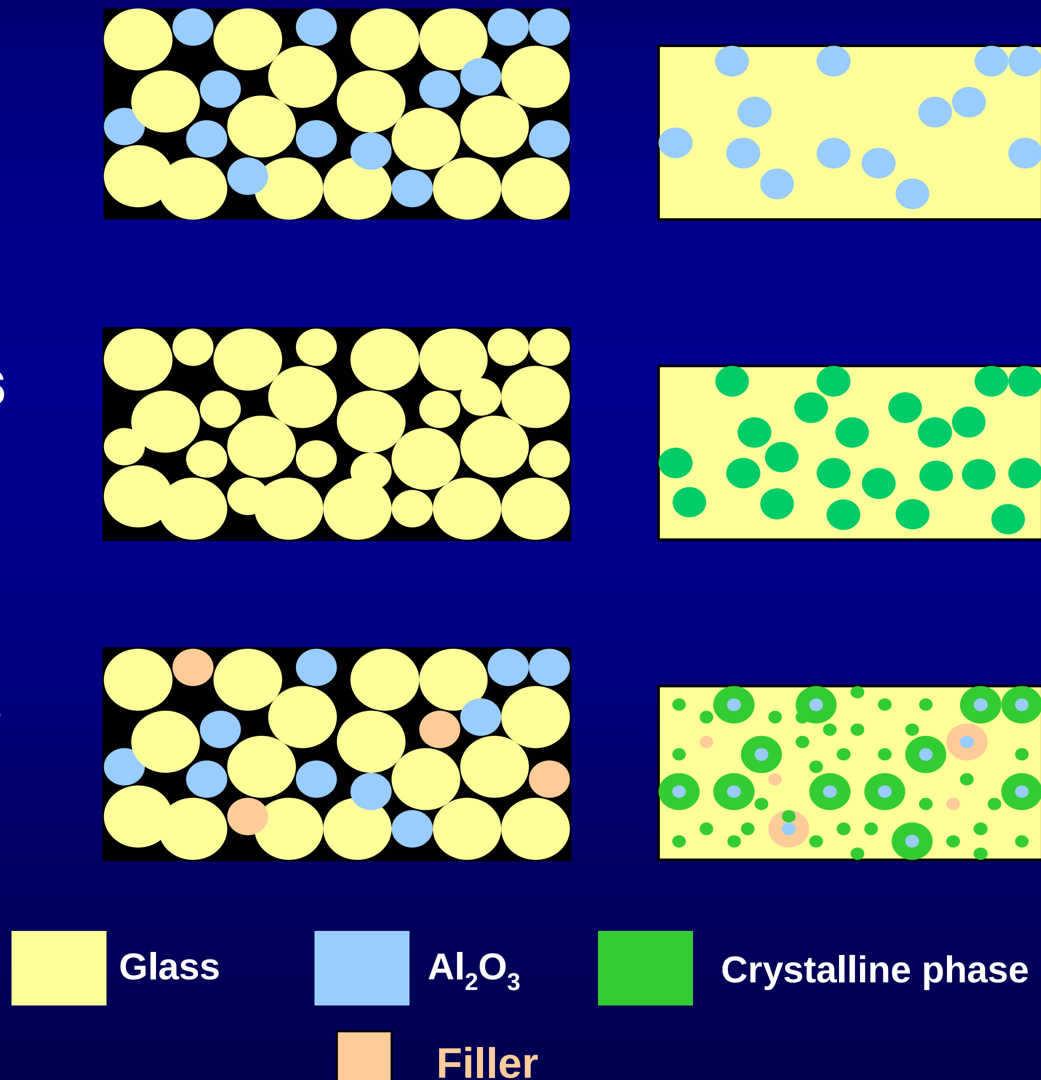
e.g., DuPont 951

Type 2: Glass-Ceramics

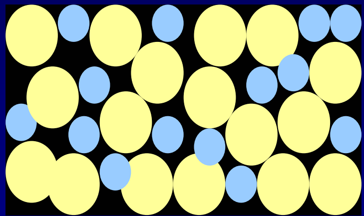
e.g., Ferro A6

Type 3: Glass±Ceramics

e.g., Heraeus CT2000



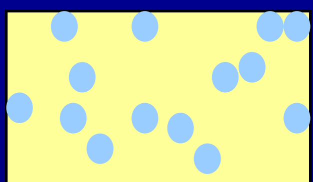
Type I: Glass+Ceramics



Glass: PbO, K_2O, B_2O_3, SiO_2
V_{glass} : 60-70%

Ceramic Filler: Al_2O_3
V_{Al2O3} : 30-40%

Sintering
850~ 900 °C



Glass
K=6-7
Q= 100-150
V_{glass}=60-70%

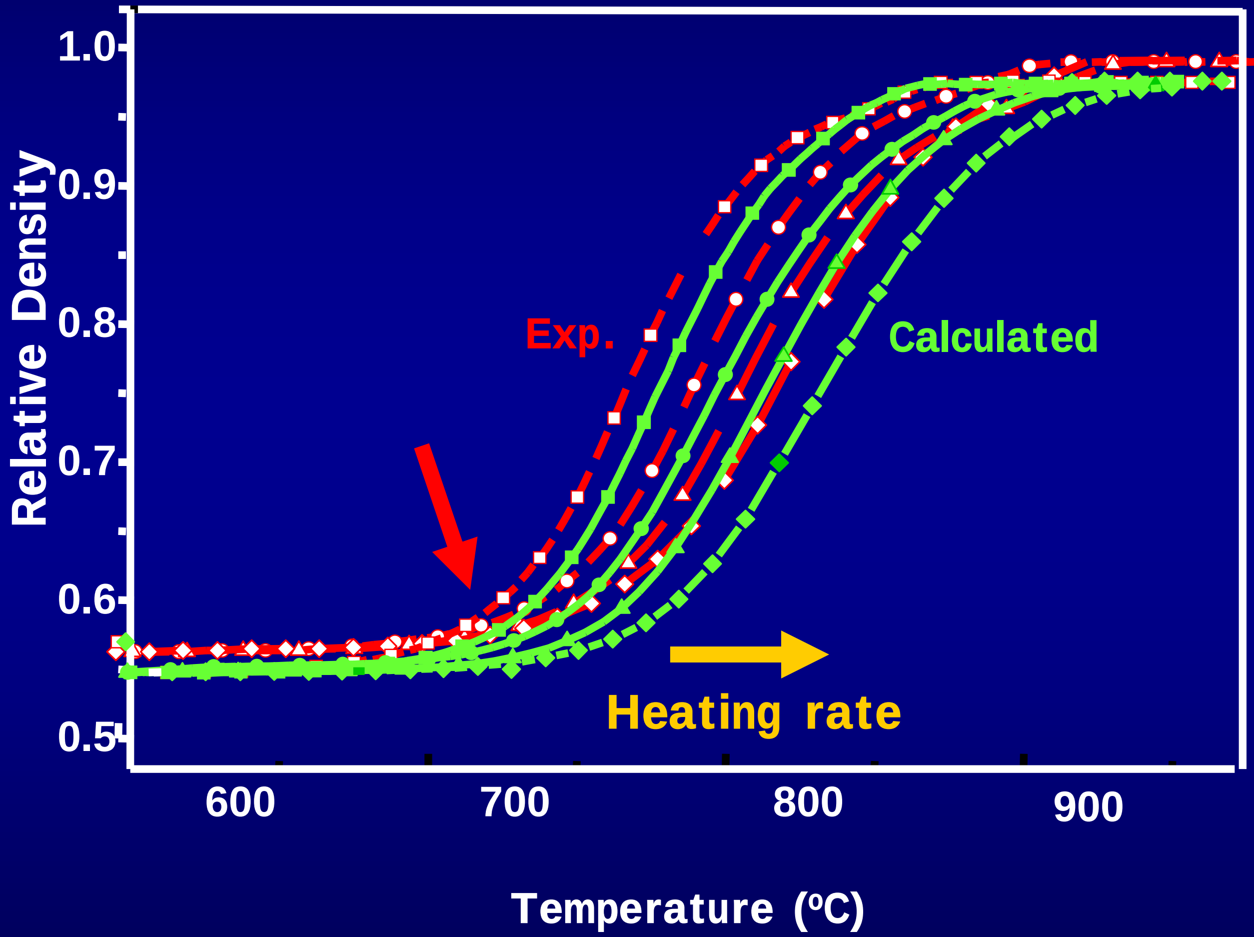
Al_2O_3
K = 10
Q = 10000
V_{Al2O3} =30-40%

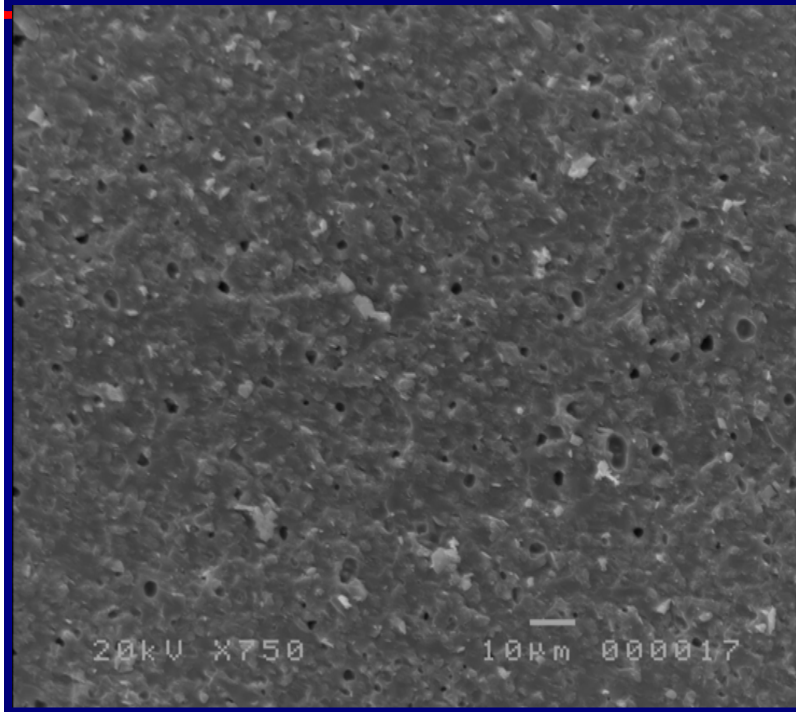
Dielectric Mixture

$$1/Q_m = (V/Q)_{glass} + (V/Q)_{alumina} \qquad Q_m = 200\text{-}300$$

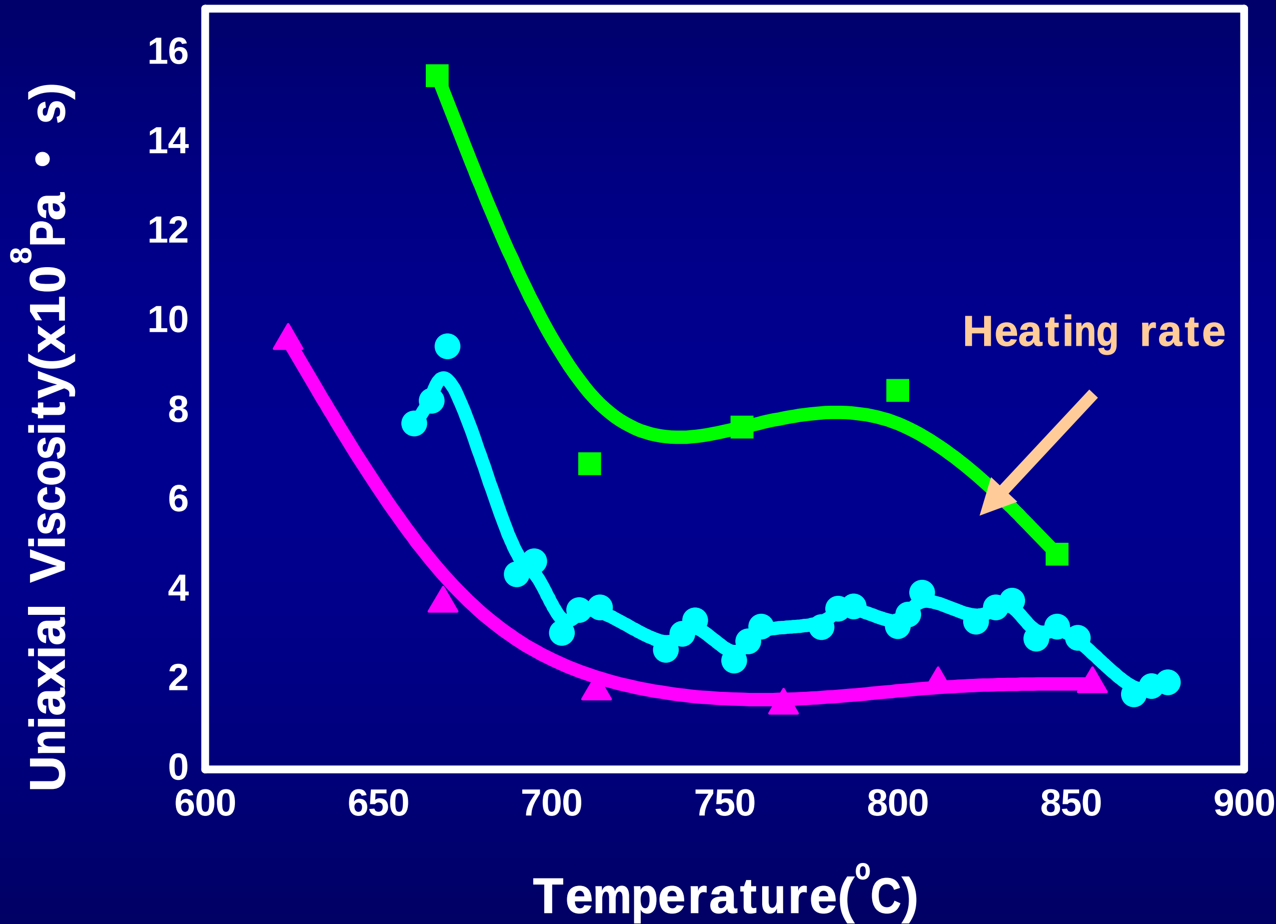
$$1/K_m = (V{*}K)_{glass} + (V{*}K)_{alumina} \qquad K_m = 4\text{-}8$$

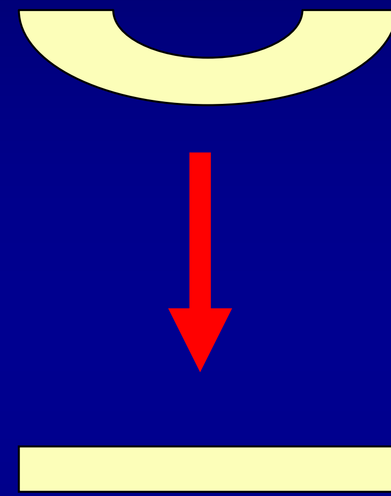
Densification of Glass+Ceramics





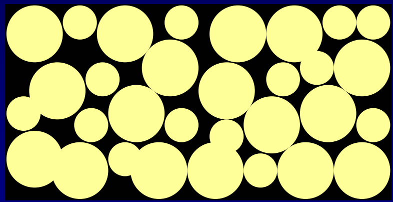
Uniaxial Viscosity (Ep)





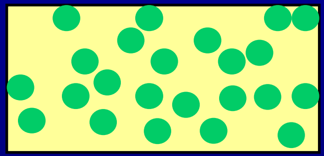
Processing robustness
--“Fool-Proof” systems

Type II: Glass-Ceramics



Glass: CaO, K_2O, B_2O_3, SiO_2
V_{glass} : 100%

Sintering
850~ 900 °C



Residual glass: B-rich
K=5-6
Q= 100-150
V_{glass}=20-40%

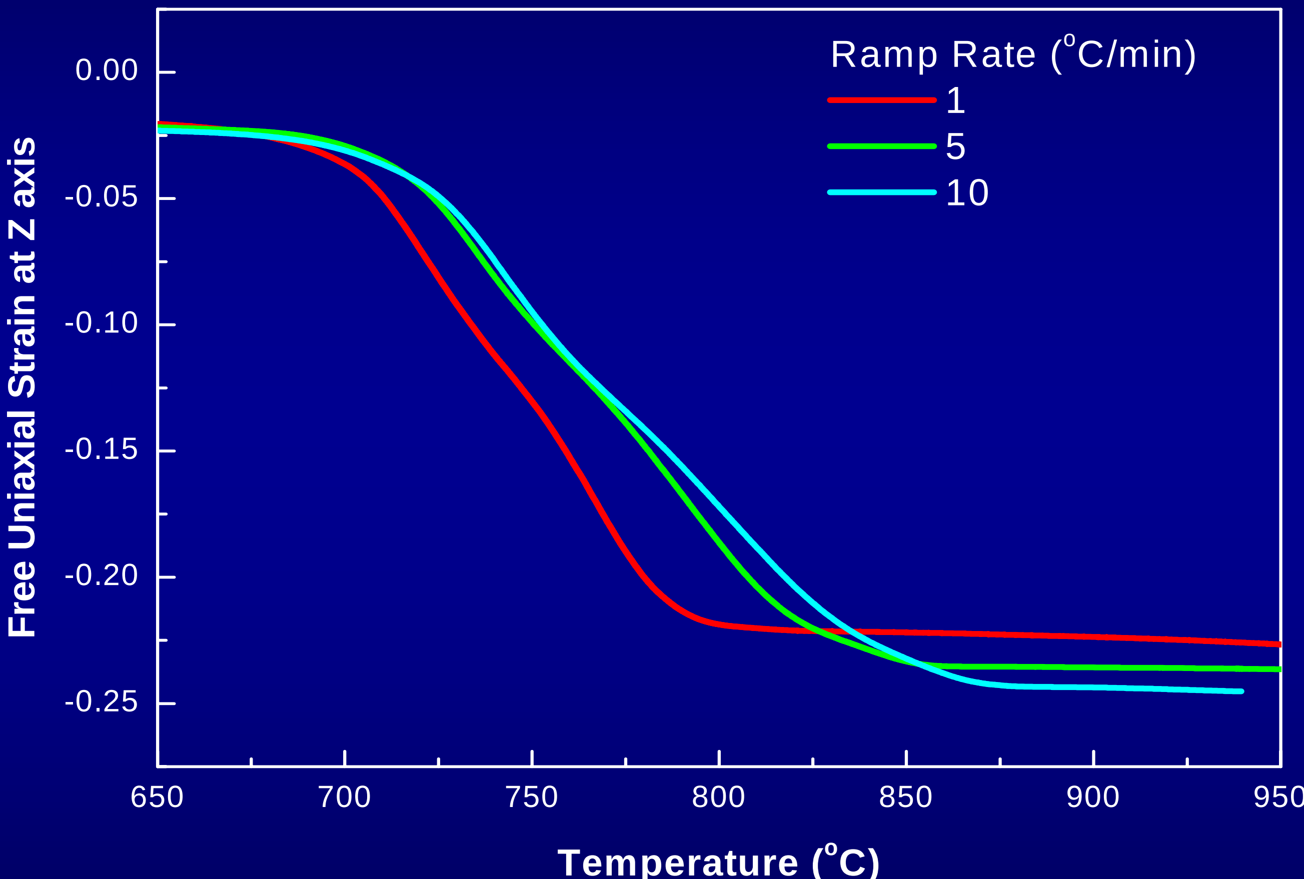
Wollastonite
K = 5-6
Q = 1000
V_{Al2O3} =60-80%

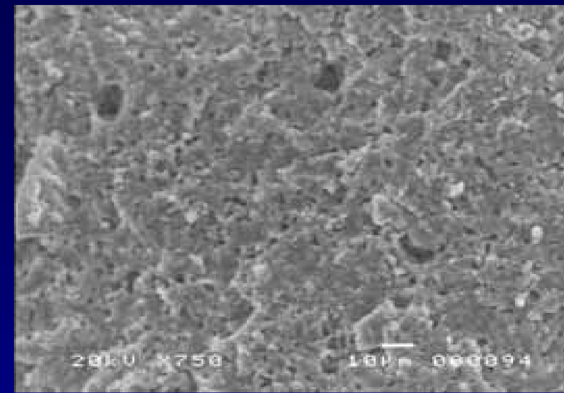
Dielectric Mixture

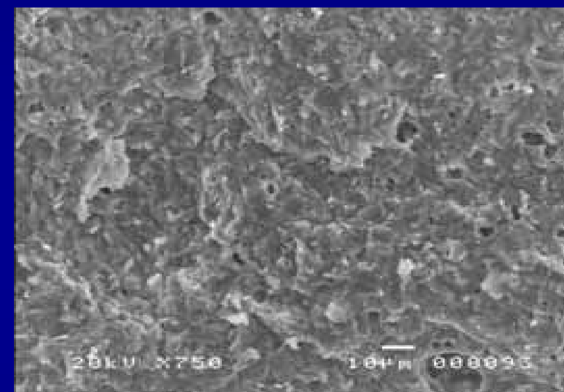
$$1/Q_m = (V/Q)_{glass} + (V/Q)_{alumina} \qquad \mathbf{Q_m = 500\text{-}700}$$

$$1/K_m = (V^*K)_{glass} + (V^*K)_{alumina} \qquad \mathbf{K_m = 5\text{-}6}$$

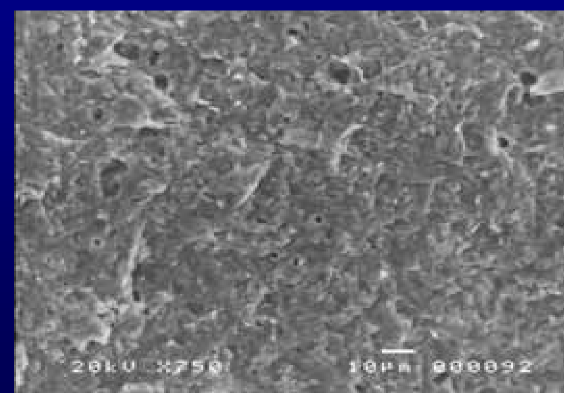
Effect of heating rate on densification



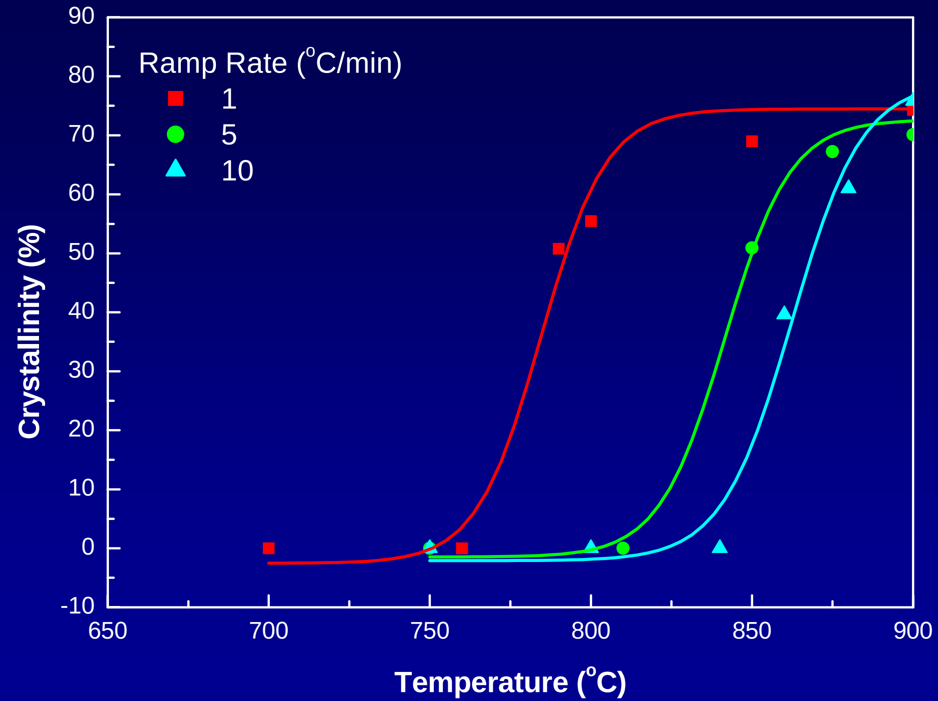


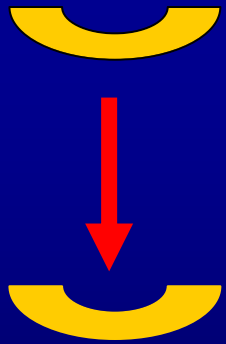


High

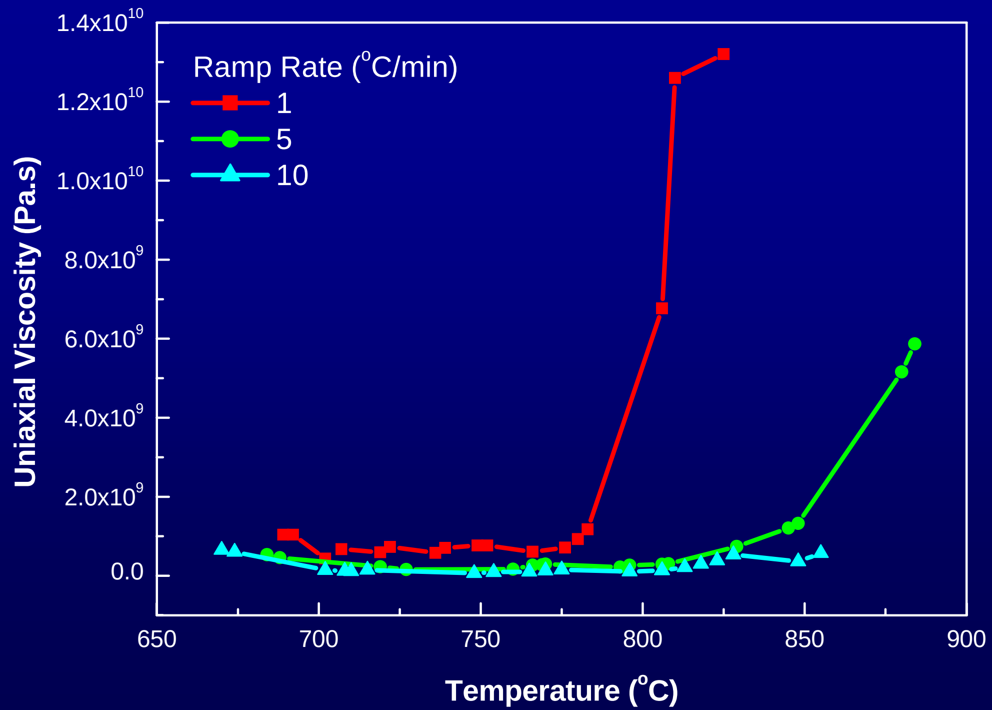


Effect of Crystallization on Viscosity & Densification

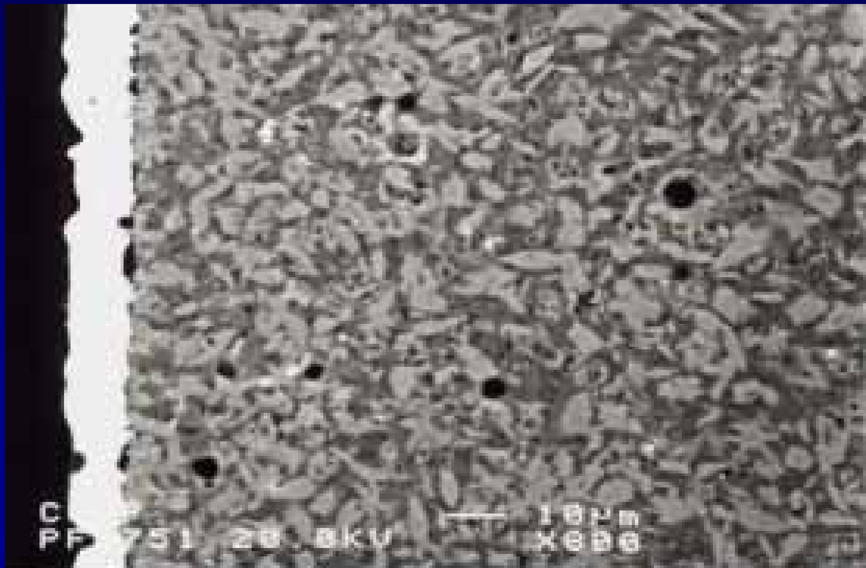


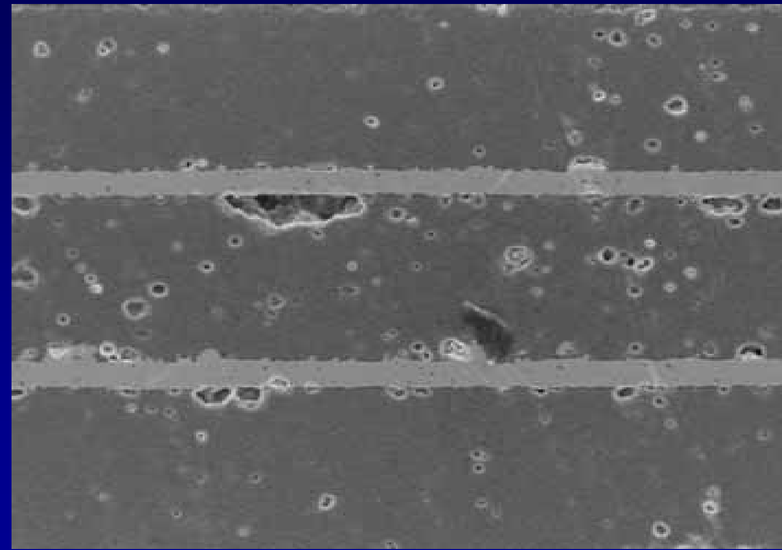


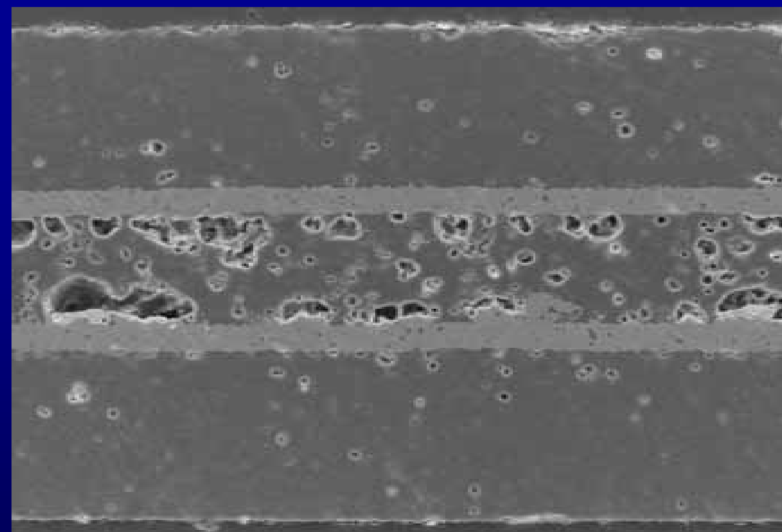
Smart System



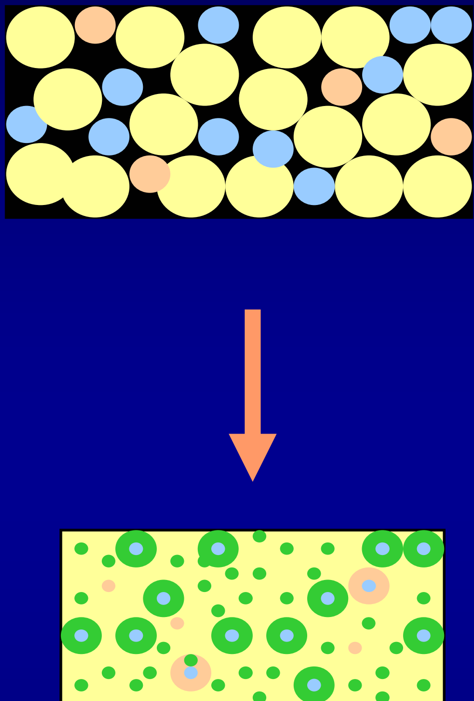
Interfacial Reaction between Ag and LTCC







Type III: Glass±Ceramics



Glass: K_2O, B_2O_3, SiO_2, CaO, SrO, BaO

Ceramic Filler Al_2O_3

T_f Adjuster TiO_2

Sintering 850~ 900 ˚C

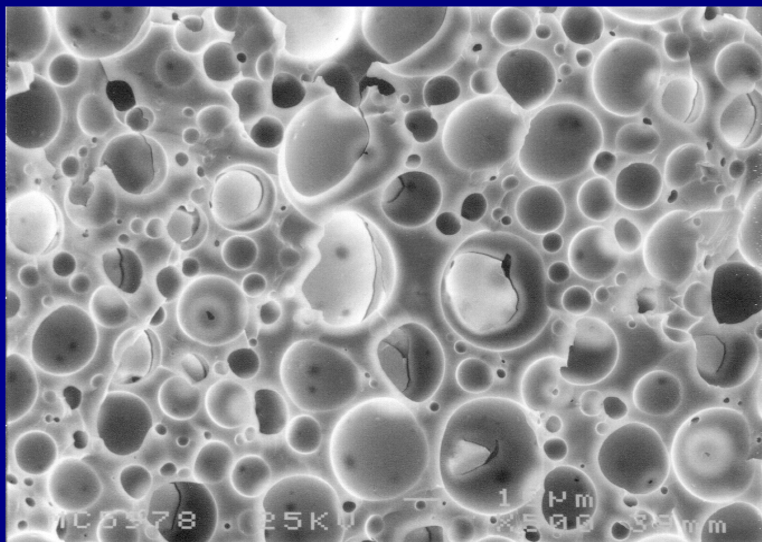
Residual Glass Q ~ 350 V_{glass}	$CaAl_2Si_2O_8$, Q=1300 $SrAl_2Si_2O_8$, Q=1300-10000 $BaAl_2Si_2O_8$, Q=10000 $V_{cryst.}$	Al_2O_3 Q = 10000 V_{Al2O3}	TiO_2

Dielectric Mixture

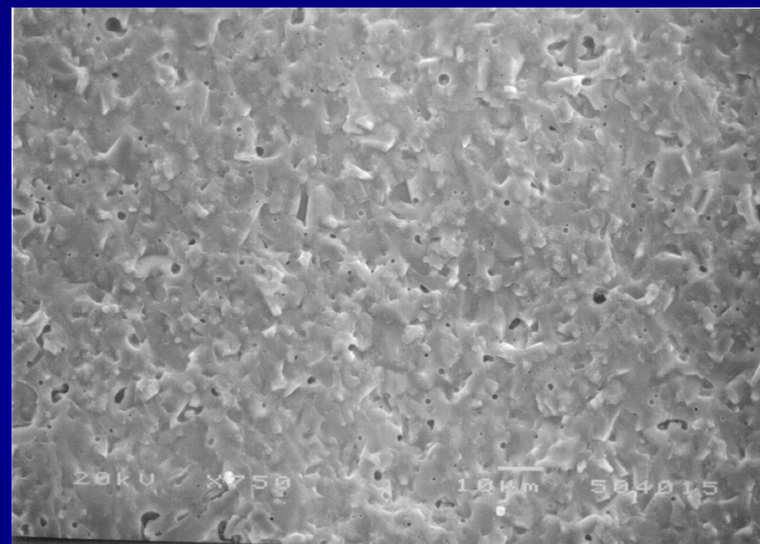
$$1/Q_m = (V/Q)_{glass} + (V/Q)_{alumina} \qquad \mathbf{Q_m = 900\text{-}1200}$$

$$1/K_m = (V^*K)_{glass} + (V^*K)_{alumina} \qquad \mathbf{K_m = 8\text{-}10}$$

Prevention of Bloating

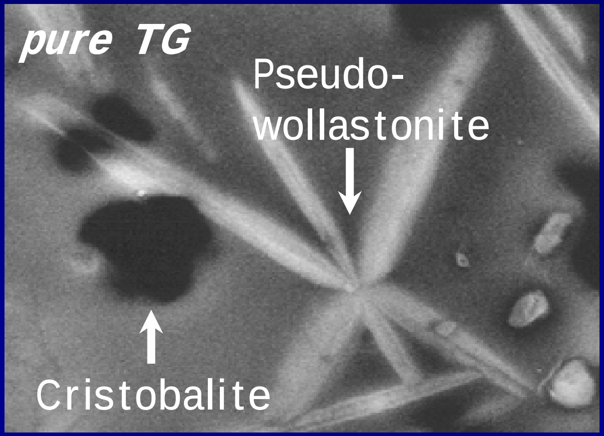


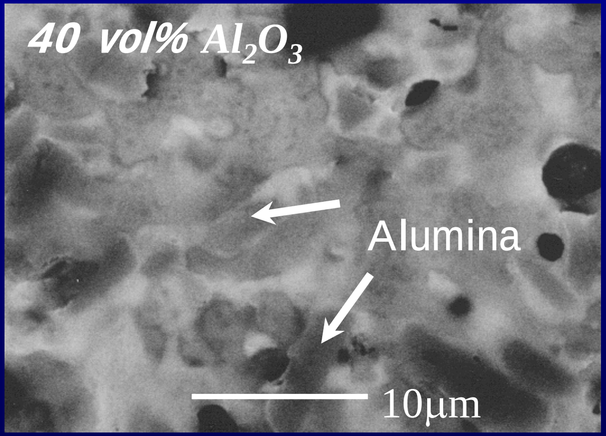
Pure glass

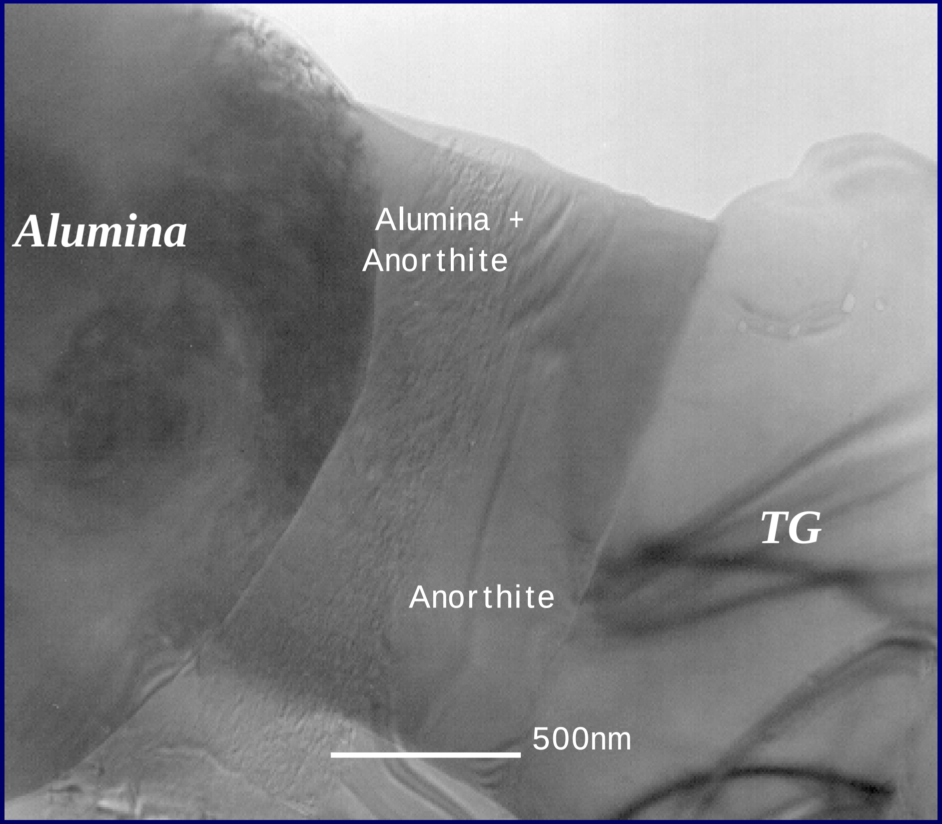


40 vol% Al_2O_3

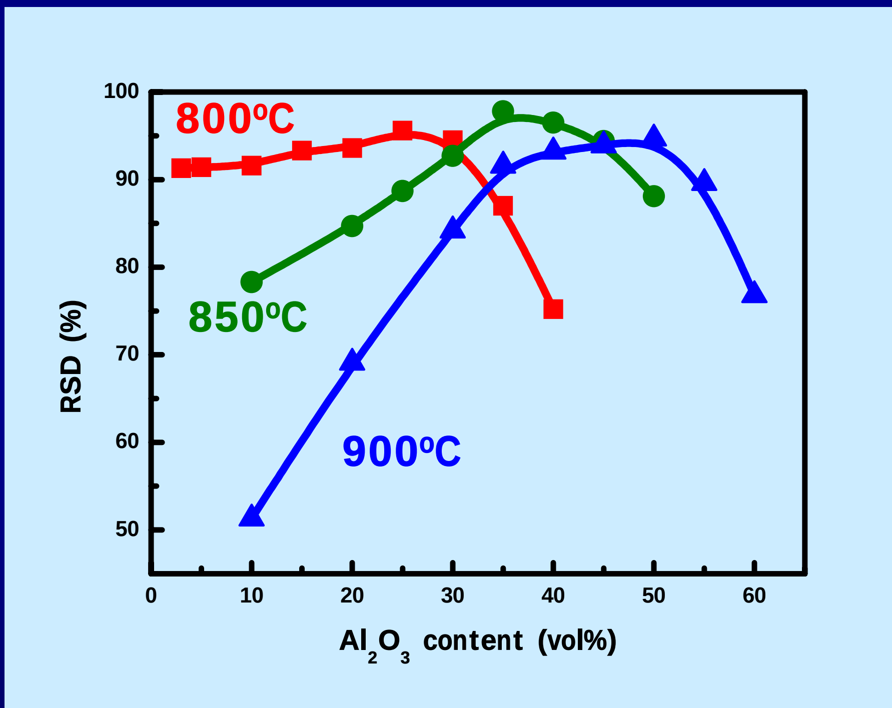
Effect of Al_2O_3 on Crystallization

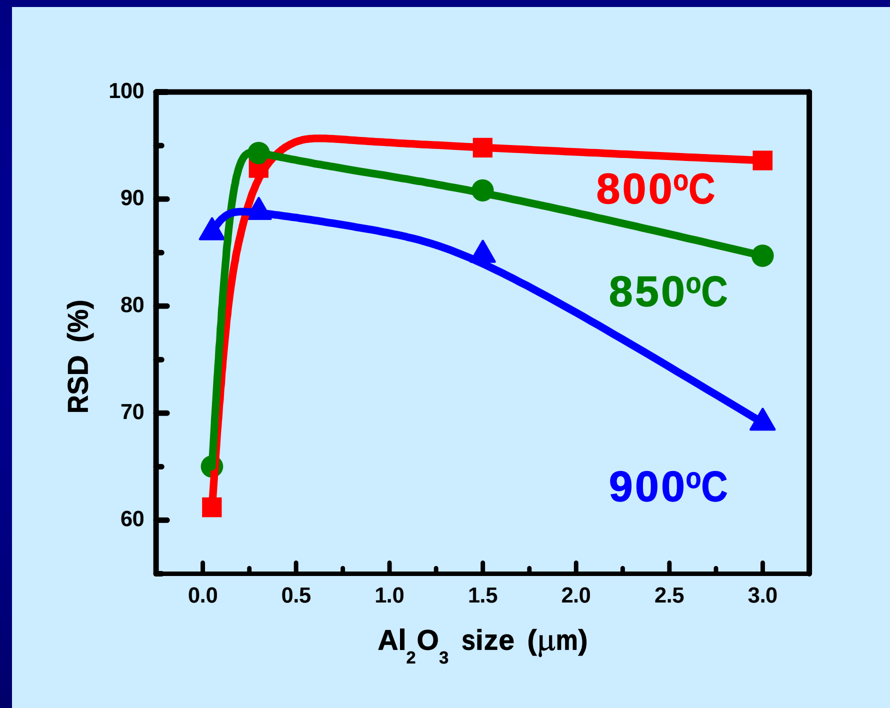






Effects of Alumina Content and Size on Densification





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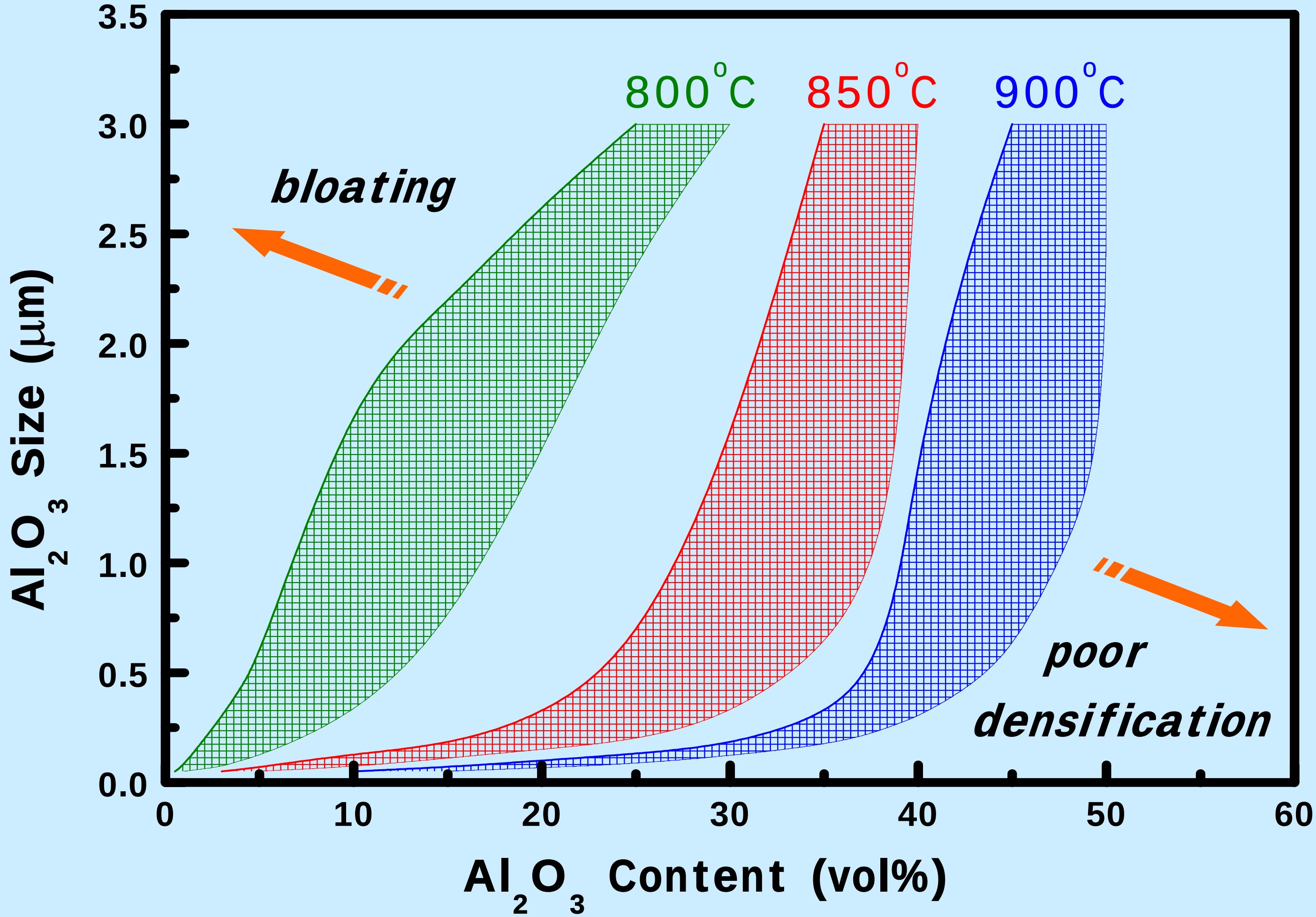
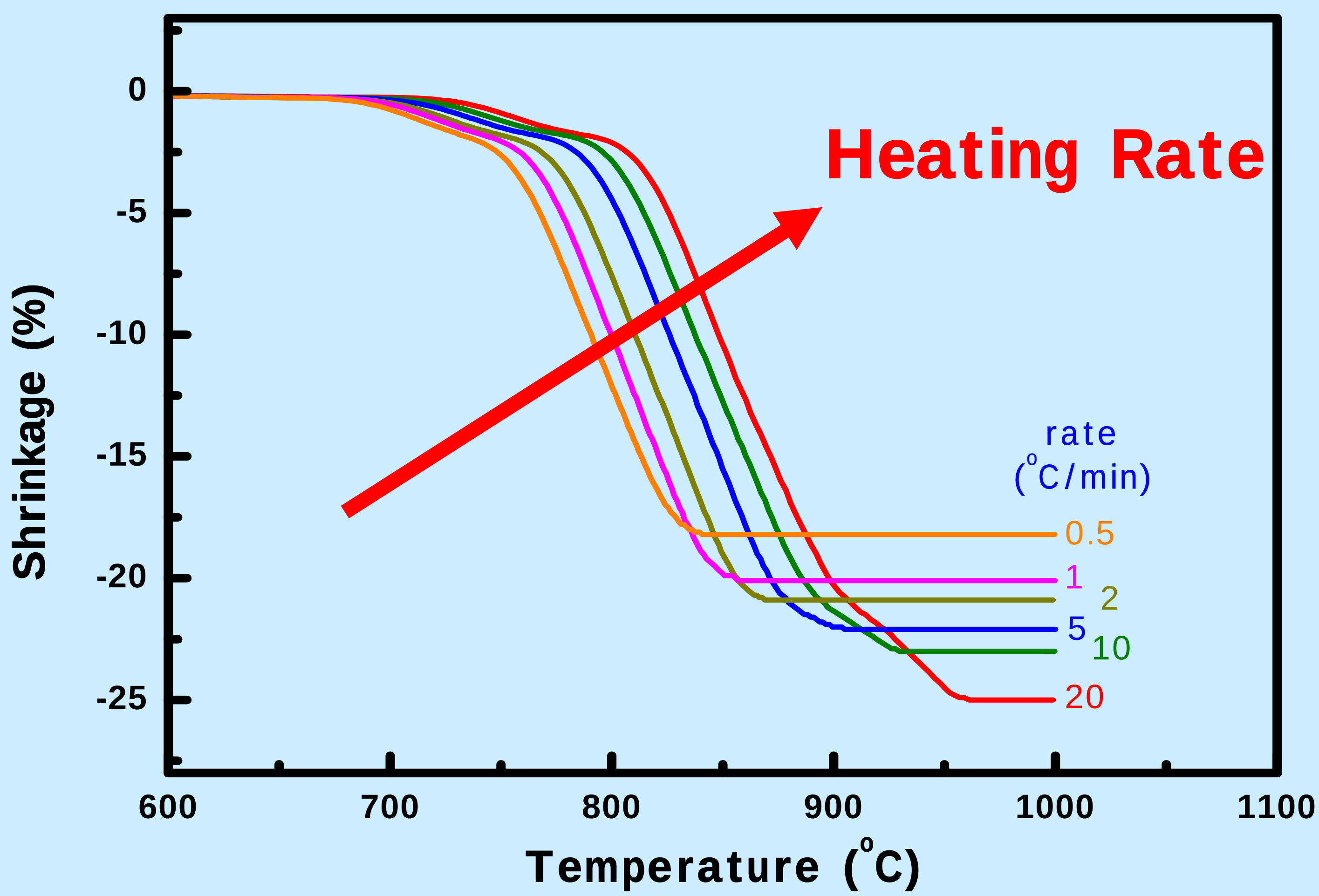
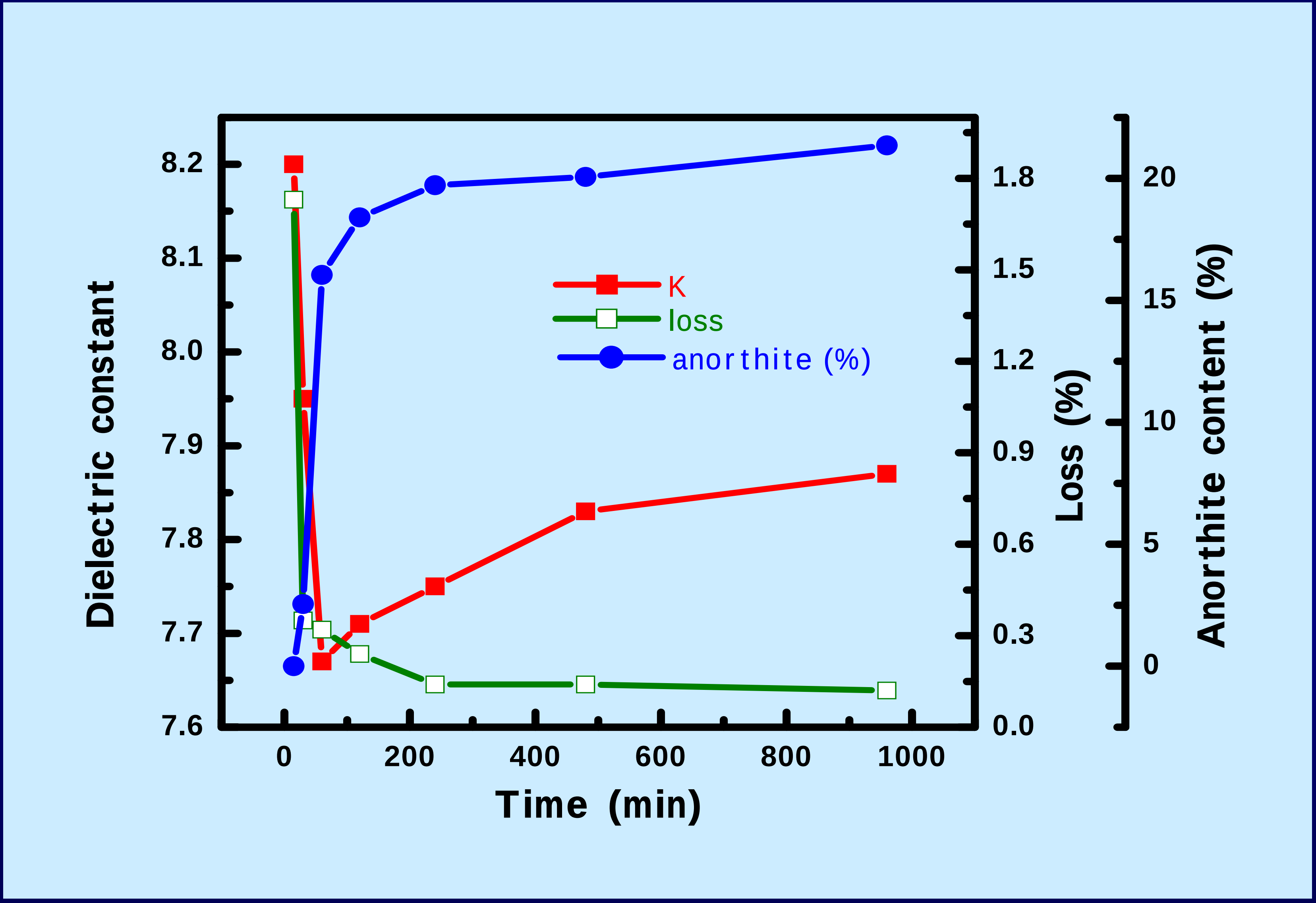


Effect of Heating Rate on Densification



Effect of Crystallization on Dielectric Properties



Glasses in LTCC

* K = 5-100
* Q > 1000
* Low-fire : 850-900C
* Non-crystallizable preferred
* Lead-free
* Insignificant reaction with Ag
* Excellent leaching resistance