National Polytechnic University of Armenia

The Effects of Ultrafast Irradiation on $Ba_xSr_{1-X}TiO_3$ Ferroelectric Thin Films

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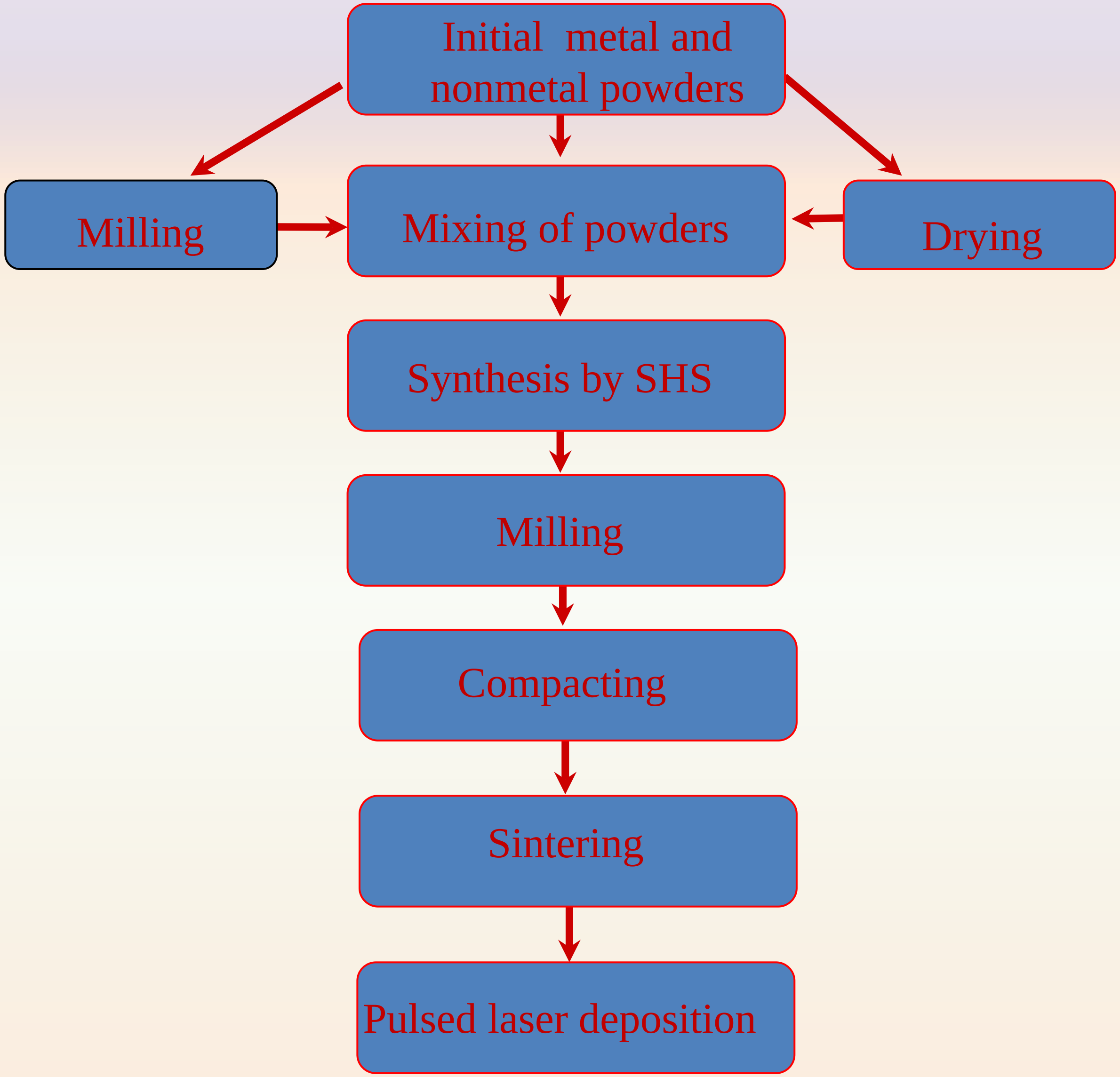
Content

- Nanostructure production, based on $\boldsymbol{Ba}_{\mathrm{x}}\boldsymbol{Sr}_{1\text{-}\mathrm{X}}\boldsymbol{TiO}_3$ ferroelectrics.

- Dielectric characteristics of nanofilm $Pt/Ba_xSr_{1-x}TiO_3/Pt$ structure under electron beam irradiation

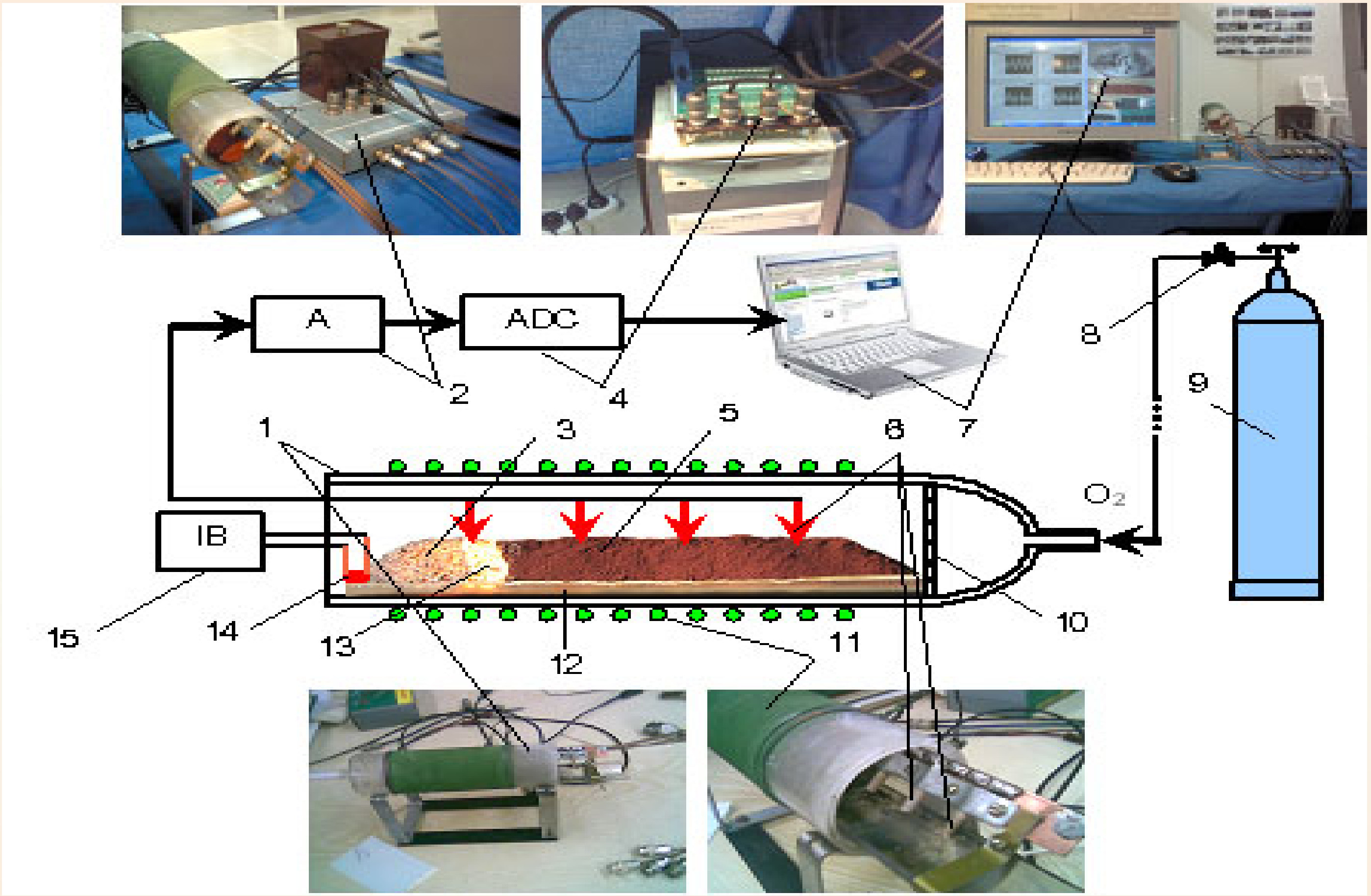
The technology of ferroelectric nanostructure production



Experimental SHS reactor

1. Quartz tube; 2. low noise amplifier; 3. end product; 4. analog-digital convector; 5. green mixture; 6. thermocouples; 7. PC; 8. oxygen flow controller; 9. oxygen; 10. quartz mesh; 11. heater; 12. thermoresistant boat; 13. combustion front; 14. wolfram ignitor;15. ignition block.

$$xBaO_2 + (1-k)TiO_2 + kTi + (1-x)SrCO_3 + O2 \rightarrow Ba_xSr_{1-x}TiO_3$$

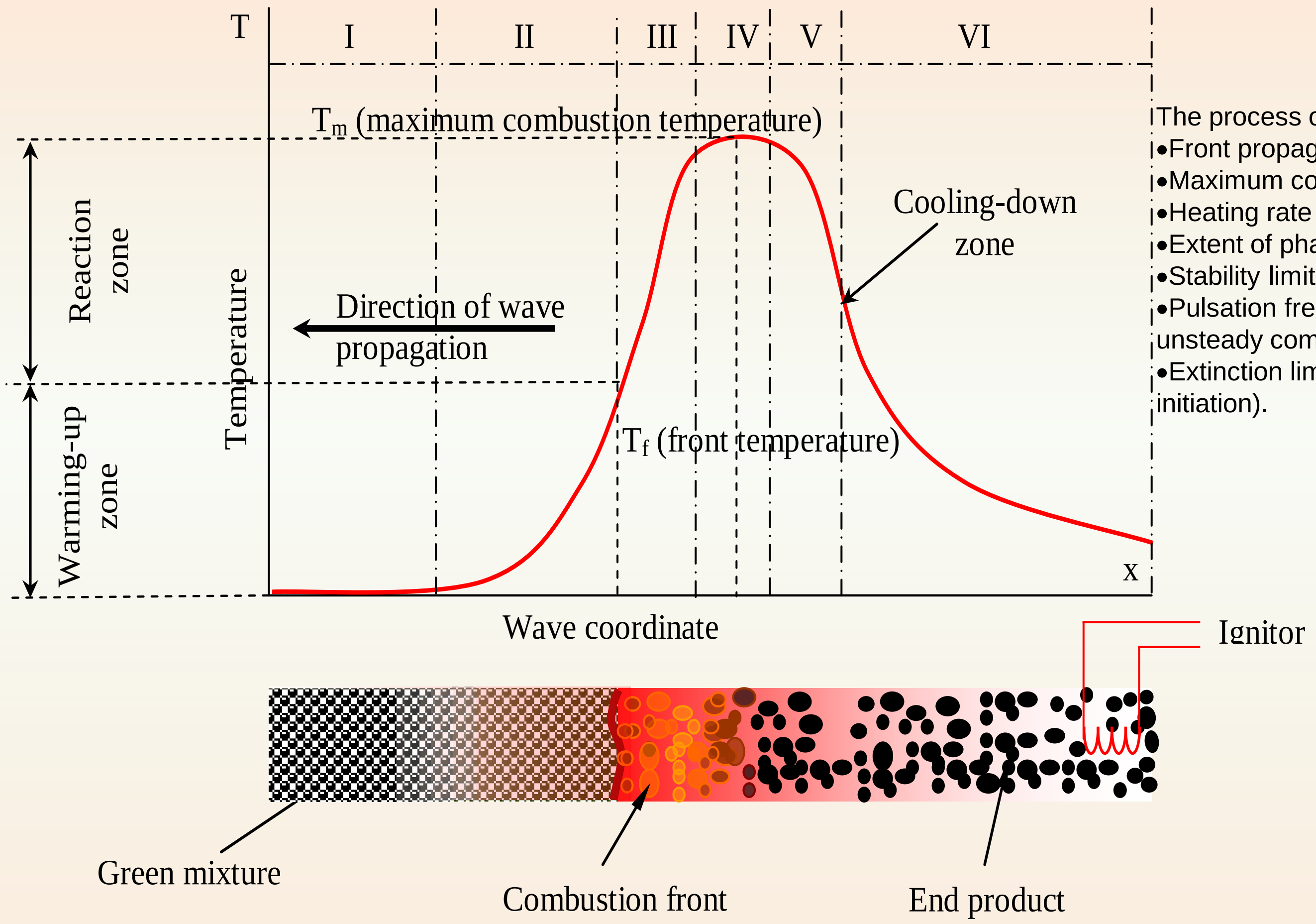


SHS technological types are characterized by the following features:

- low energy consumption (in most cases it is only necessary for initiating an SHS process);
- simple technological equipment, its high productive capacity and ecological;
- decreased number of technological stages in comparison with conventional technologies;
- feasibility of production lines adaptable to production of different materials and items and amenable to mechanization and automation;

Temperature distribution along combustion front propagation

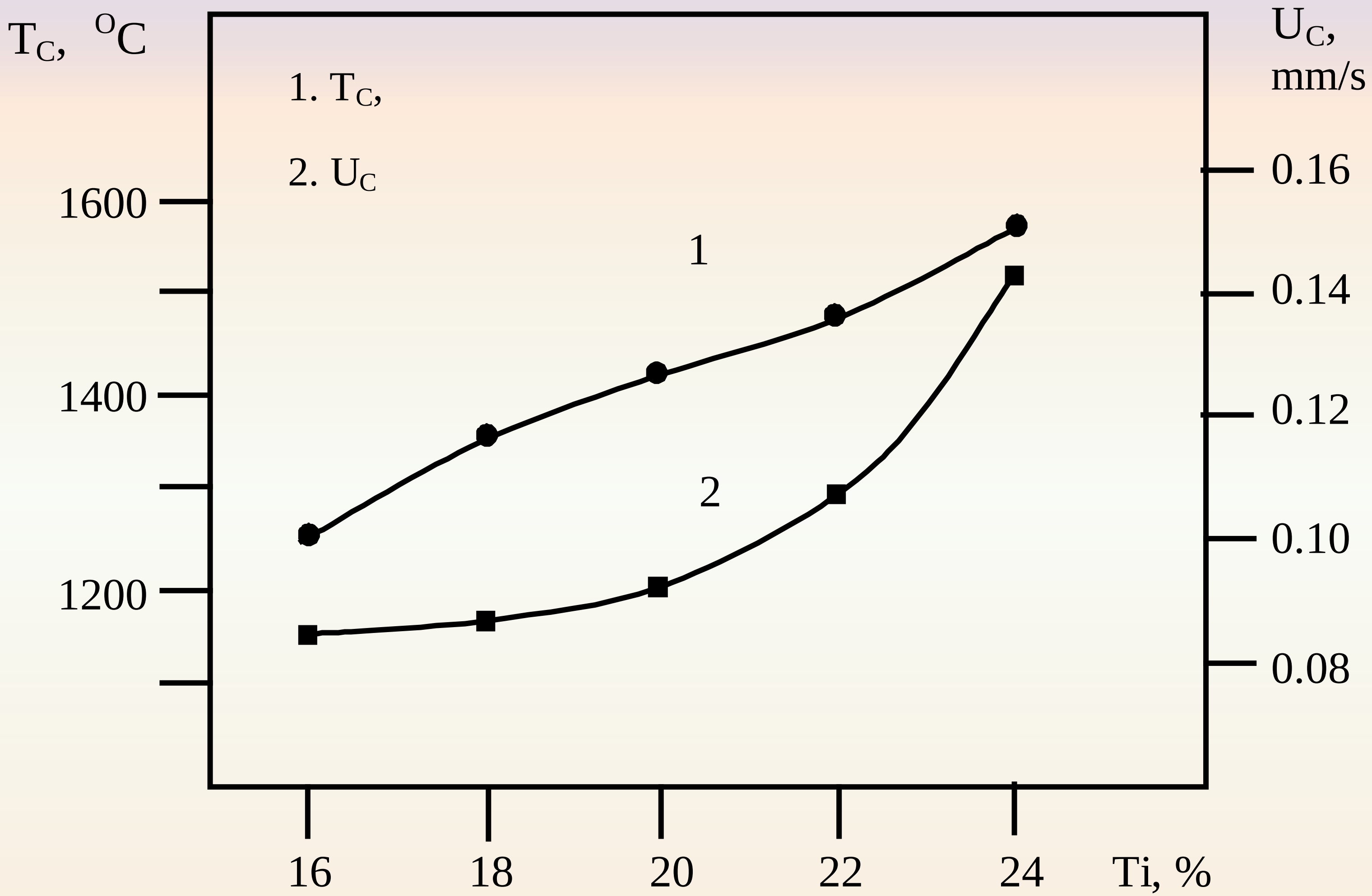
I-green mixture; II-warming-up zone; III-metal oxidation zone; IV-active oxidation of metal and formation of the intermediated; V-zone of secondary chemical interactions between intermediates and formation of final product; VI-cooling-down zone.



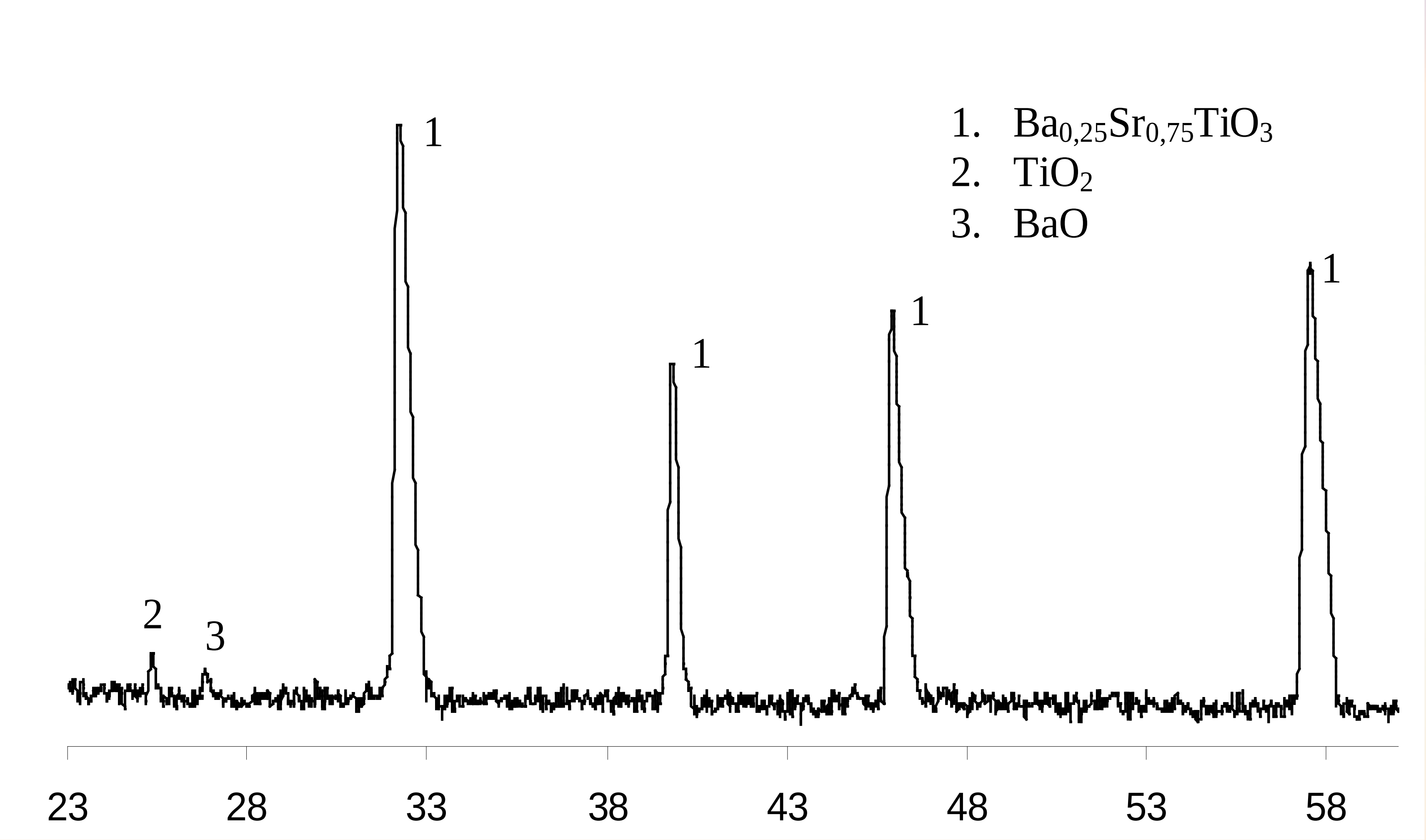
The process of wave propagation is characterized by:

- Front propagation (burning) velocity (0.1–0,4 cm/s).
- Maximum combustion temperature (1300–2000 K).
- Heating rate in the combustion front (10^3–10^6 K/s).
- Extent of phase/structure transformation.
- Stability limit (steady or unsteady wave propagation) .
- Pulsation frequency, hot spot velocity, etc. (in case of unsteady combustion).
- Extinction limit (no combustion even upon intense initiation).

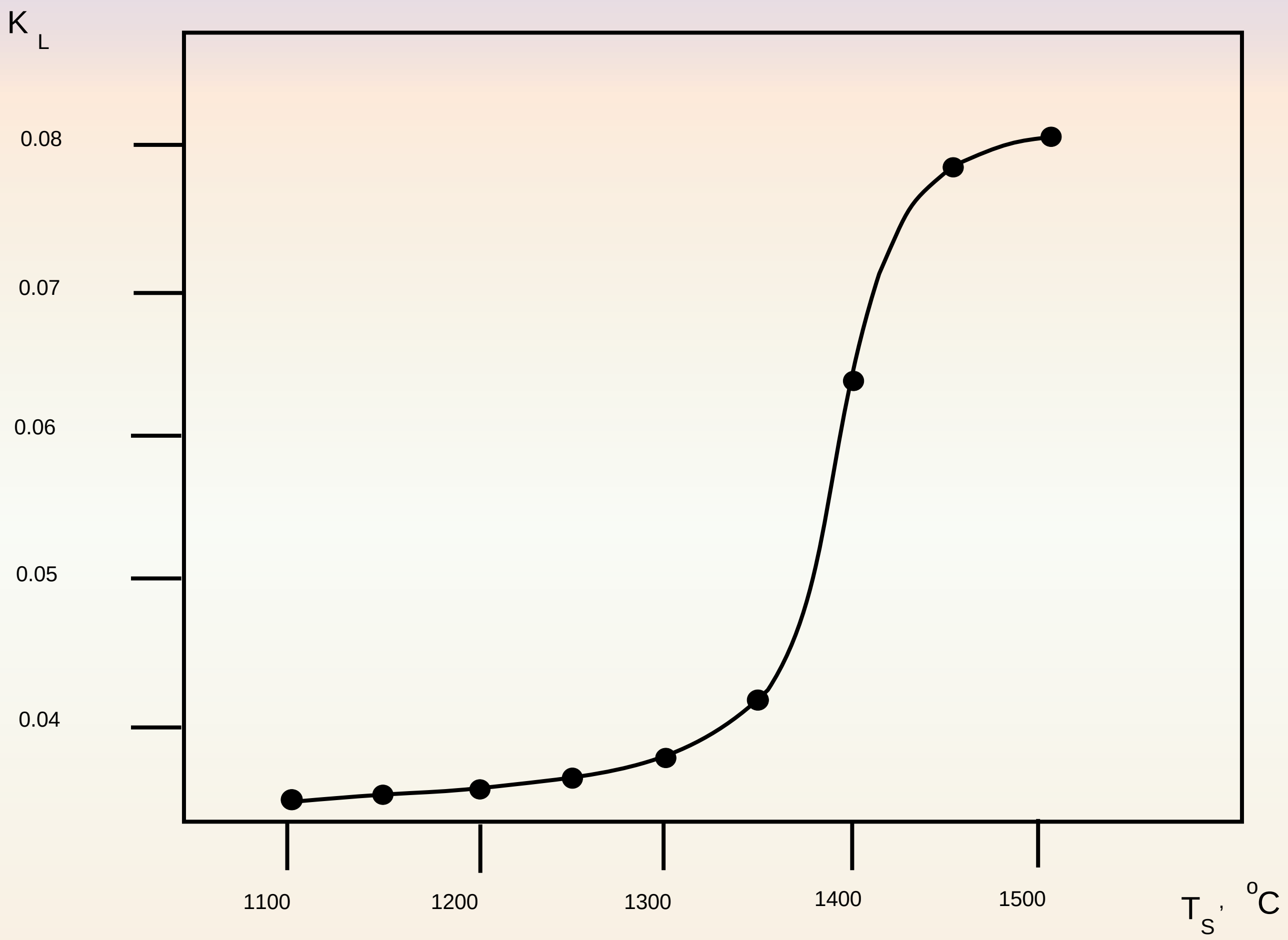
Combustion temperature (T_c) and velocity (U_c) *vs*. amount of combustible (Ti) in the initial mixture for $Ba_{0.25}Sr_{0.75}TiO_3$



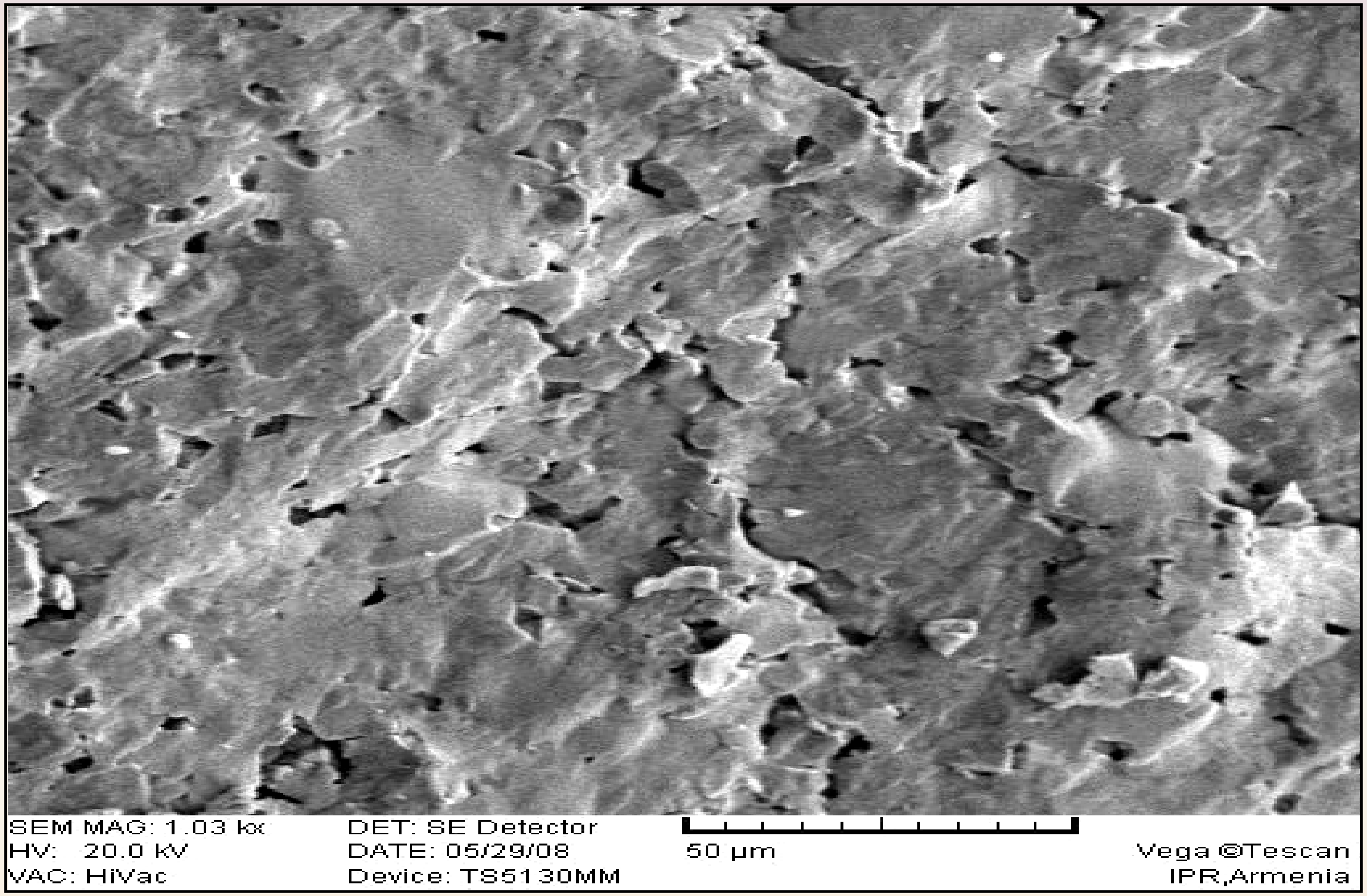
XRD patterns of $Ba_{0.25}Sr_{0.75}TiO_3$ powder



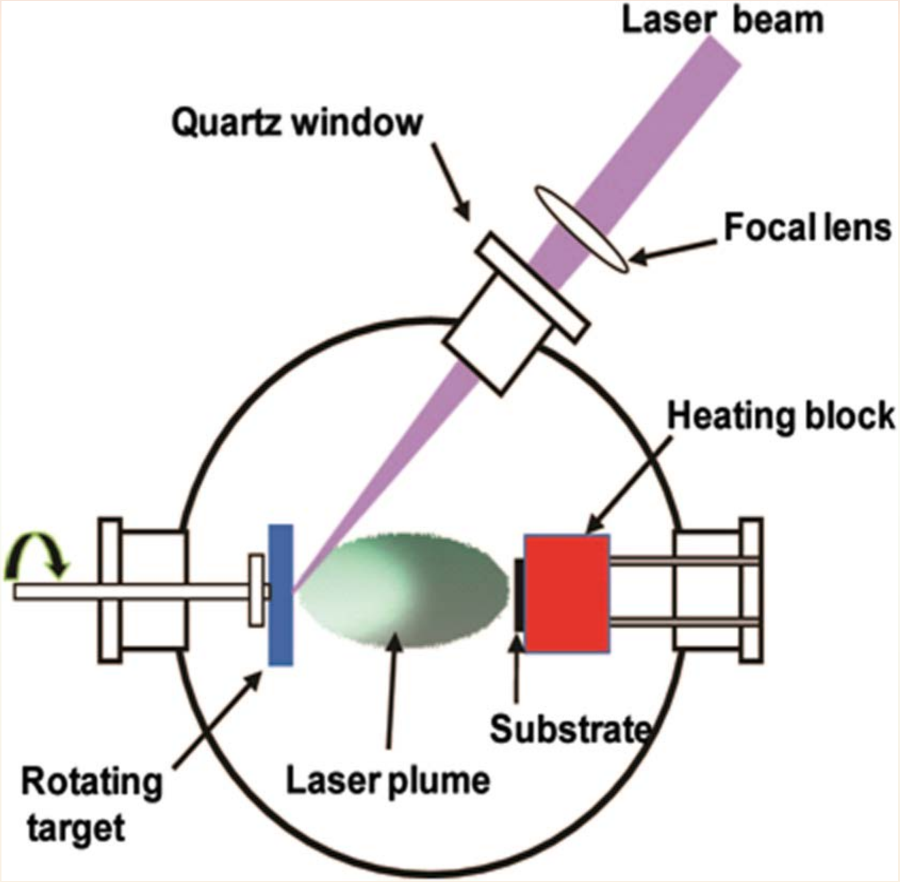
Linear shrinkage factor of ceramic samples vs. sintering temperature



SEM image of $Ba_{0.25}Sr_{0.75}TiO_3$



PLD of $Ba_{0.25}Sr_{0.75}TiO_3$ on a silicon substrate (p-Si, ρ = 1000 Ωcm)



- Oxygen flow 30 mL/min, pressure $2x10^{-3}$ mbar;
- KrF-excimer laser (Lambda LPX305) with a pulse width of 20ns ;
- Pulse energy of approximately 1J per pulse;
- Energy density of $2.5Jcm^{-2}$;
- Repetition rate of 10Hz;
- Deposition time of 100s.

PLD Condition

PLD Experiment 8038

Epi-Ba25Sr75TiO3 auf recl STO

Durchgeführt am: 07.07.2008 11:59:30 von Jürgen Schubert
Dauer des Experiments: 01:22:12
Basisdaten aus Experiment Nr. 8037

Substrat: \SrTiO3\SrTiO3(100) repolished 0.85mm (Dicke 0,85 mm Emissionsgrad 0,930)

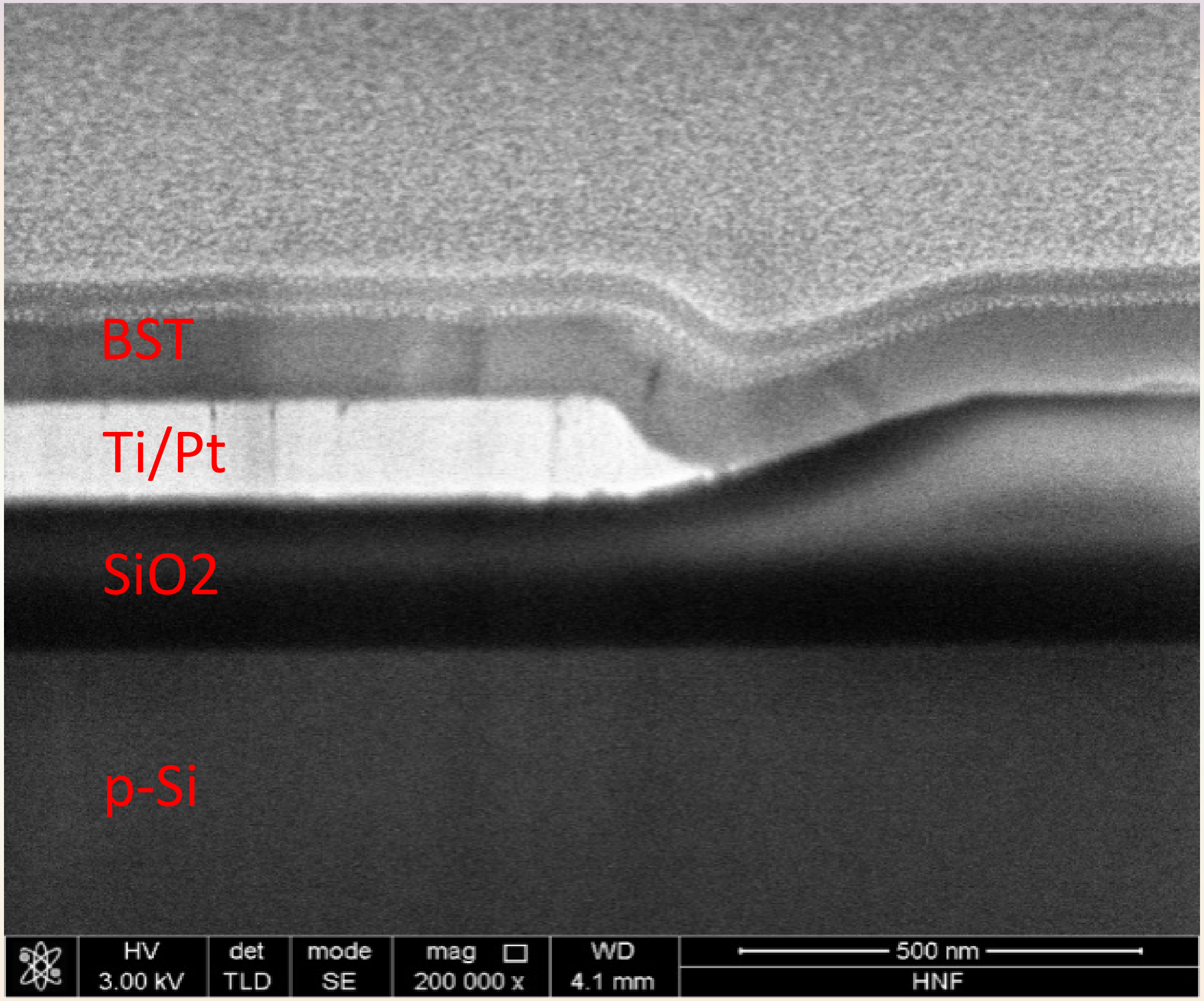
Belüftungsverzögerung: 15 Sekunden
Belüftungszeit: 30 Sekunden

Anzahl der Schichten und Temperschritte: 1

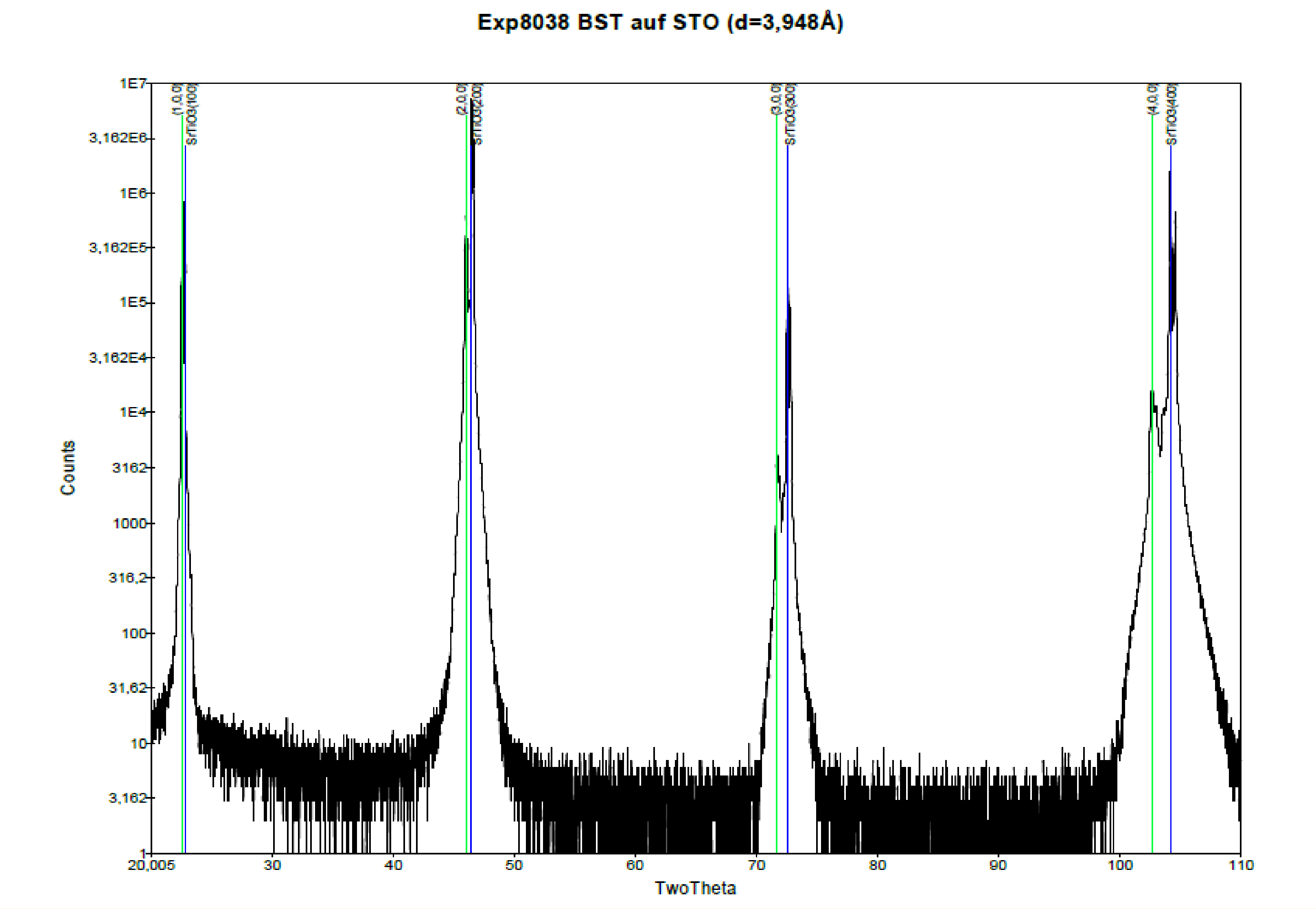
Herstellungsschritt 1: Ablation

Material: Ba25Sr75TiO3
(Fokus X = 4,00, Fokus Y = 5,00, Blende L = 3,50, Blende R = 3,50, Position = 56,50)
Laser: 100 Sekunden @ 10 Hz (constant high voltage mode, HV = 21,0 kV)
Heizen: 5,00 A für 12 min
Substratposition: x = 5,000 mm, y = 107,500 mm, Winkel = 36,0°
Sauerstoff-Fluß: 30,00 ml/min
Druckbereich: niedrig (während der Schichtherstellung mit Turbopumpe abpumpen)
Basisdruck: Vor Beginn dieser Schicht Kammer auf 8,00E-4 mbar evakuieren.

Cross-sectional SEM image showing the Si-SiO2-Ti-Pt-BST layer stack

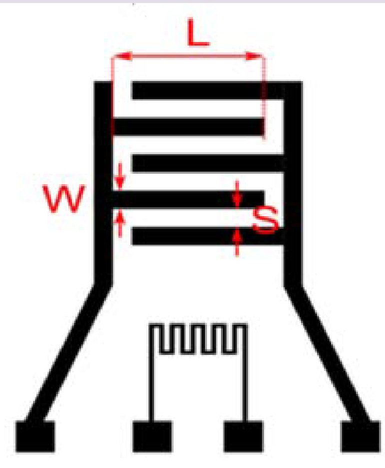


XRD patterns of $Ba_{0.25}Sr_{0.75}TiO_3$ nano-layer



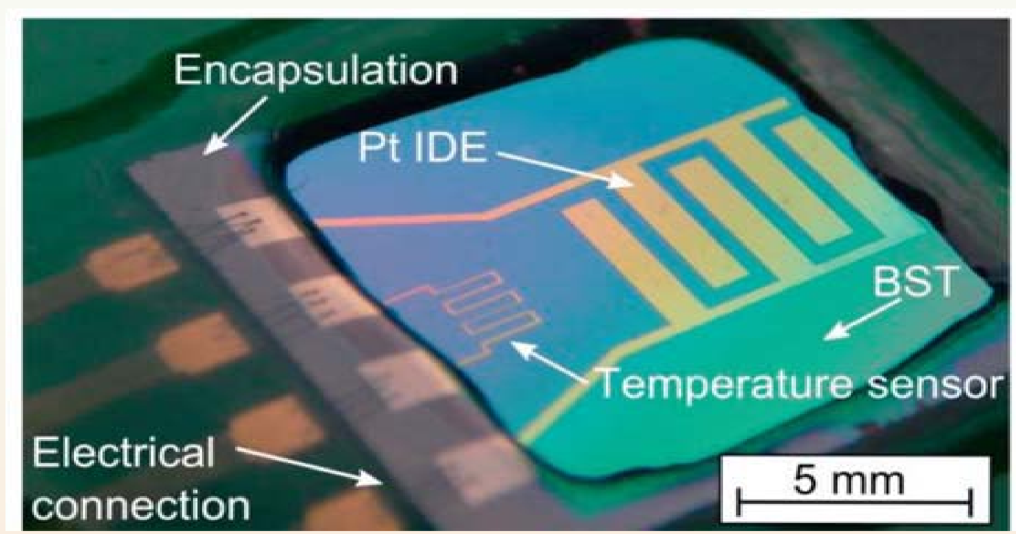
Photograph of a fabricated nano-layer structure chip - (b) and sizes of IDE geometry - (a)

a)



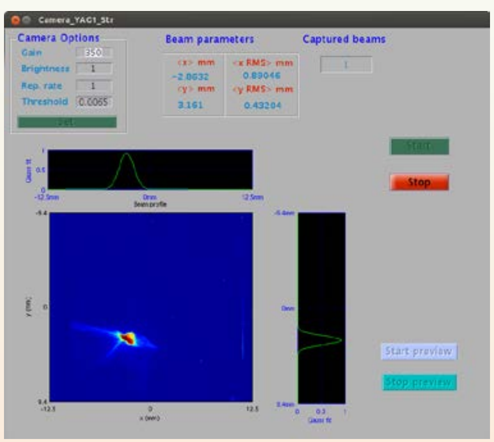
Finger number	50
Finger width W	600 µm
Finger spacing S	324 µm
Finger length L	2900 µm
Surface area A	0.087 µm
Substrate, SiO_2	500 µm
Ti / Pt	(20 / 200) nm
BST	485 nm

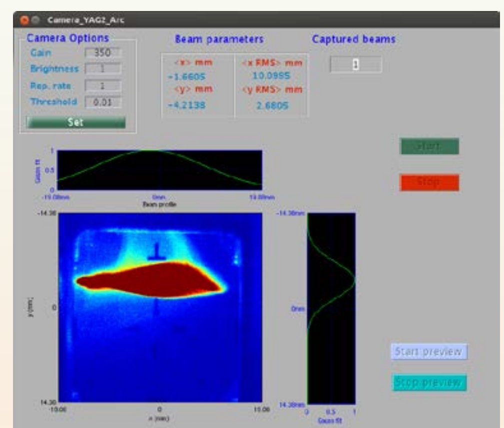
b)



AREAL machine parameters for Electron Beam Irradiation

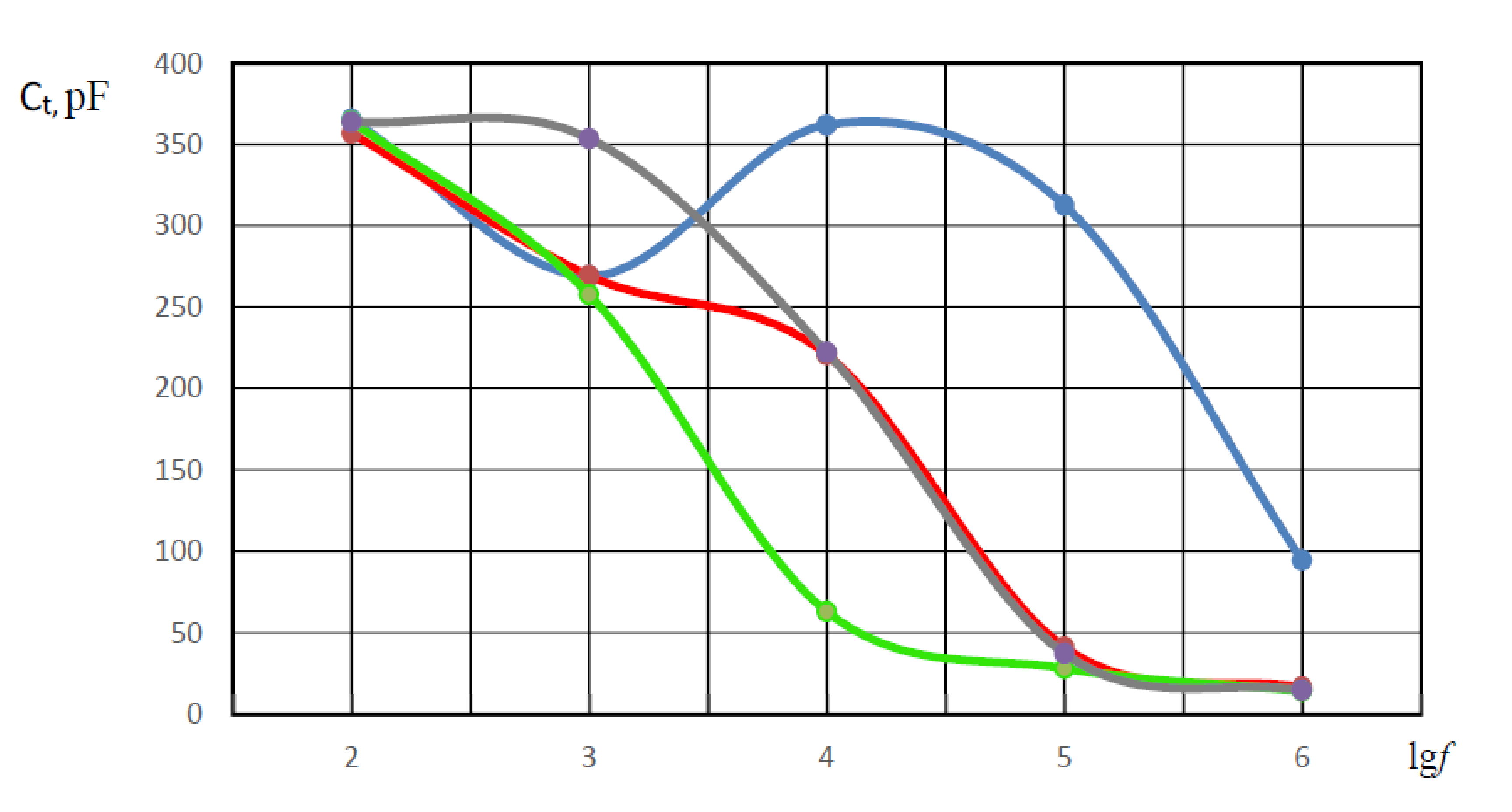
RF System			
RF High Voltage	[kV]	132	
RF High Voltage (Peak Power)	[dBm]	-4.02	Power meter on Gun
RF Phase	[deg]	-38	
Pulse Repetition Rate	[Hz]	12	
Magnets			
Solenoid Current	[A / V]	9.6/45	
Dipole Current	[A / V]	4.2/9	
Corrector Magnet (X | Y)	[A / V]	2.91/8	
Beam Parameters			
Beam Charge (FC-IN / FC-OUT)	[pC]	255/53	30 (absorbed by sample)
Beam Energy spectrometer	[MeV]	3.7	
Laser System			
Laser pulse duration	[ps]	0.5	
Time		1 hour	
Beam Profile @ YAG 1 (straight screen)		***Beam profile @ spectrometer E=3.7 MeV***	





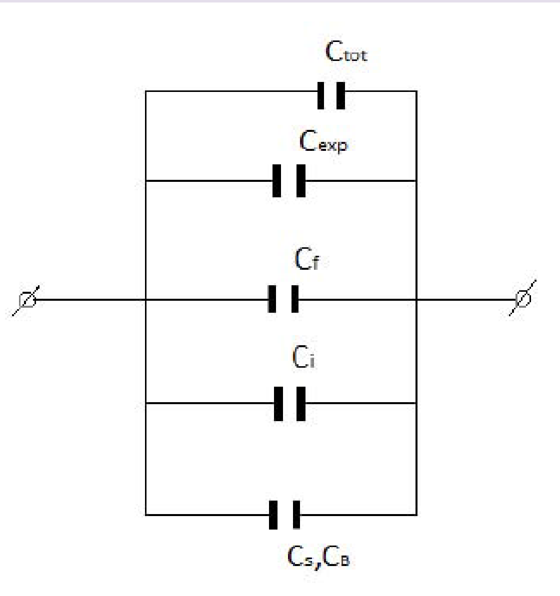
The C–f dependences of the examined structure

Before-blue line; after the first irradiation-red;
after the second irradiation-green; after the third irradiation-purple.



The calculation of ε_f *of the examined structures*

Equivalent circuits of the examined structures



The total (measured) capacitance of the structure:

$$C_{t_o t} = (n-1) l \cdot C_1$$

n is the amount of fingers, l is the length of the fingers.

$$C_1 = \frac{\varepsilon_o \varepsilon_f}{2} \cdot \frac{K[(1-k^2)^{1/2}]}{K(k)} = \frac{\varepsilon_o \varepsilon_f K(k^1)}{2 \cdot K(k)} ,$$

$K(k)$is the complete elliptic integral of the fins t kind with modules of k.

$$k = \cos\left(\frac{\pi}{2} \cdot \frac{w}{w+S}\right).$$

The capacitance of the equivalent circuit of structure:

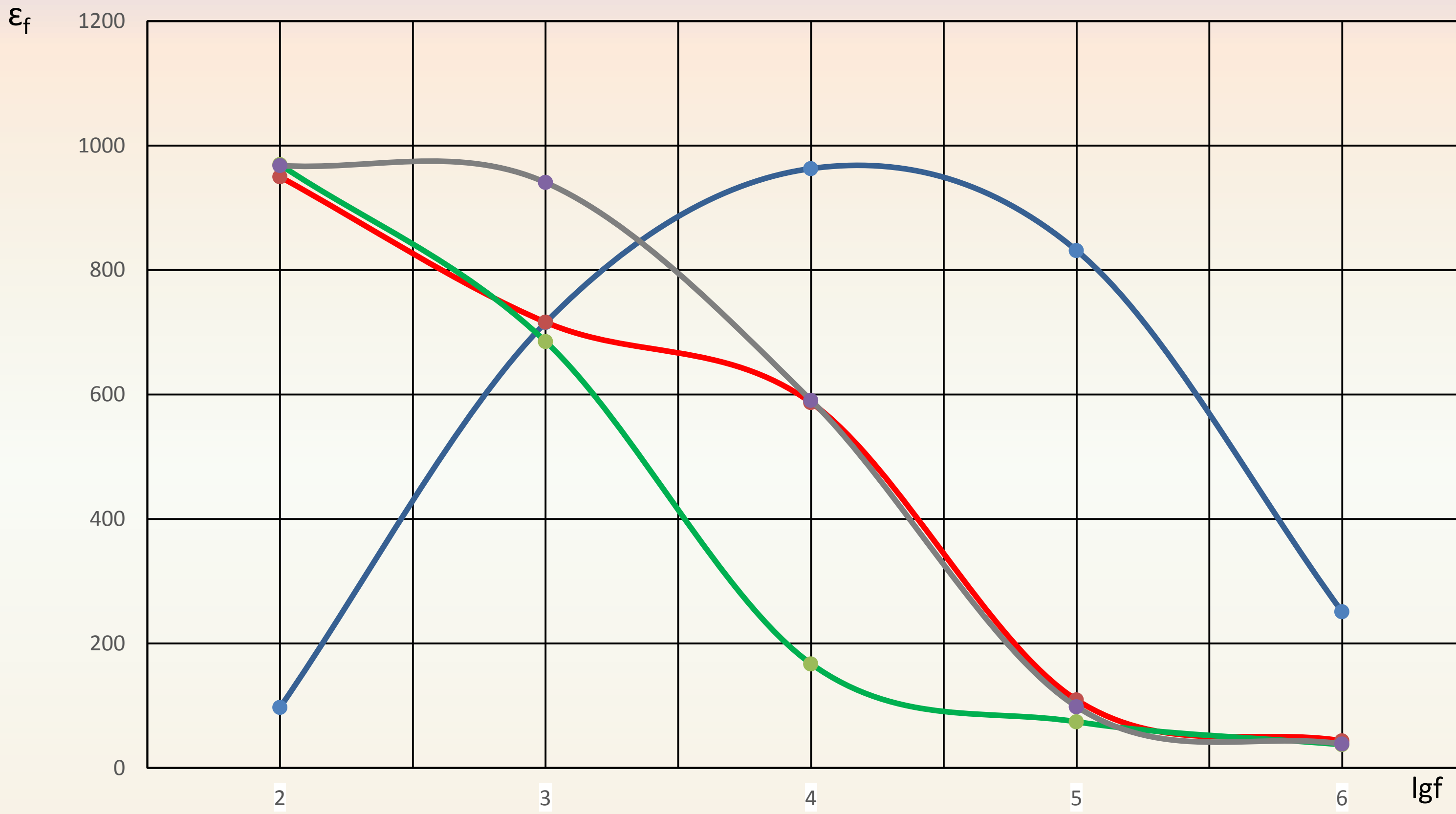
$C_{t_o t} = C_s + C_\beta + C_f + C_{exp} + C_i$,

where C_s is the capacitance of the substrate(pS_i), C_β is the parasitic capacitance between P_t electrodes (fingers), C_f is the capacitance of ferroelectric film, C_{exp} is the capacitance of the measurement set-up, C_i is the insulator lager (SiO_2) capacitance. The numerical calculations of C_i, C_β is shows, that its value about two order less than that the C_f and ignoring also the C_s , C_β and C_{exp}, we used the approximation of:

$$\varepsilon_f \cong \frac{2C_{t_o t}}{\varepsilon_o \cdot l \cdot (n-1)} \cdot \frac{K(k)}{K(k^1)}$$

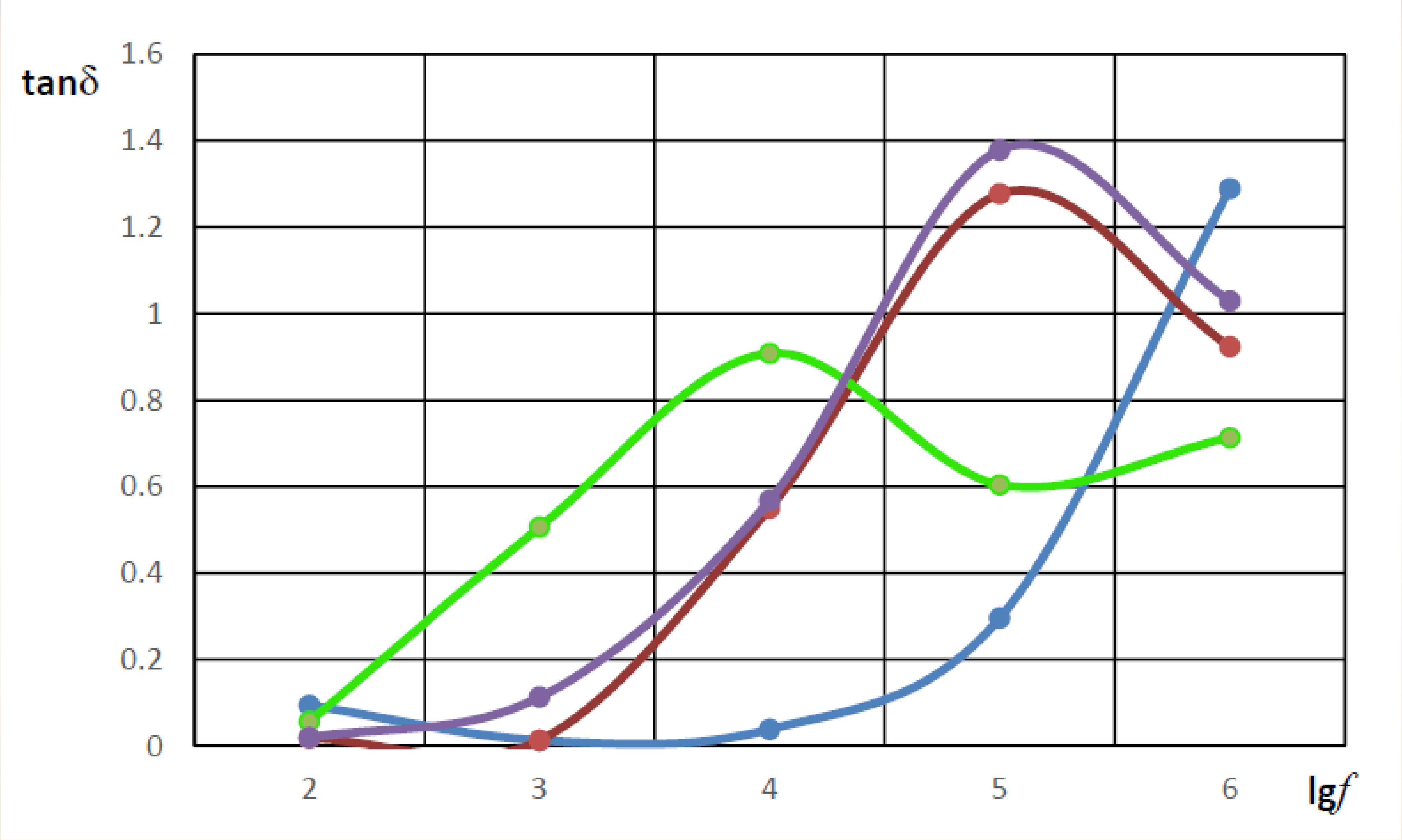
The ε_f –f dependences of the examined structures

Before-blue line; after the first irradiation-red; after the second irradiation-green; after the third irradiation-purple.



The tanδ–f dependences of the examined structures

Before-blue line; after the first irradiation-red;
after the second irradiation-green; after the third irradiation-purple.



Thank You