

Novel technique for monitoring of processing in nanoelectronics

P.V. Volkov, A.V. Goryunov, V.M. Daniltsev,
A.Yu. Luk'yanov, D.A. Pryakhin, A.D.
Tertyshnik,
O.I. Khrykin, and V.I. Shashkin



IPM RAS

Institute for Physics of Microstructures RAS,
Nizhny Novgorod, Russia

Motivation

In-situ monitoring of

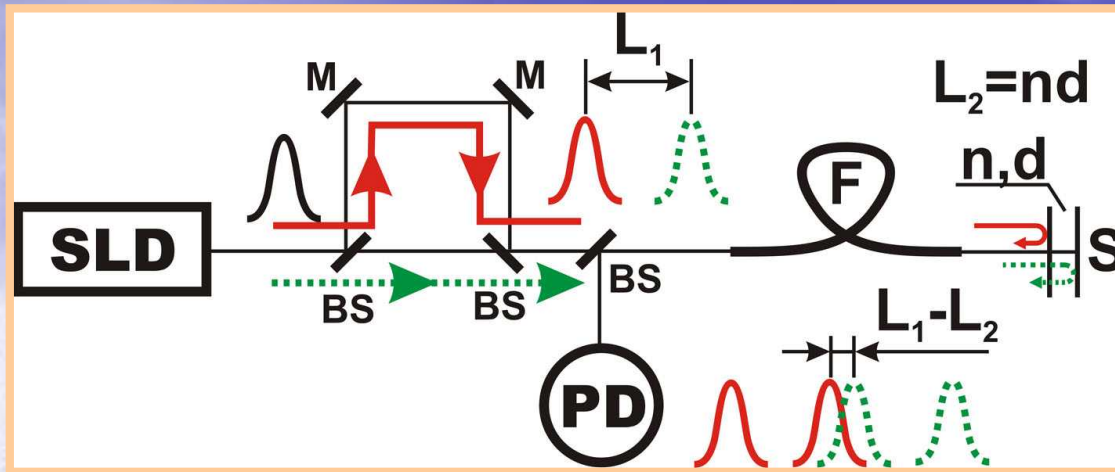
- growth parameters in MOVPE, MBE and PECVD reactors;
- microfabrication: laser ablation or dry etching in RIE reactor and ICP plasma.

Parameters:

- true temperature of substrate;
- thickness of semiconductor layer;
- substrate bowing.



Principle



SLD – superluminescent diode

F – fiber

BS – beam splitter

PD - photodiode

$L_{1,2}$ – optical path length in delay lines 1 and 2

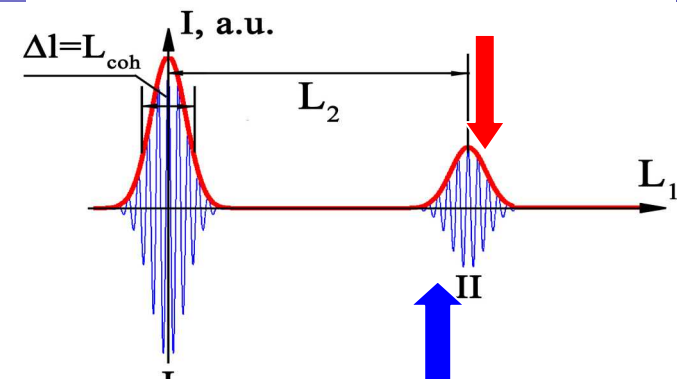
1 – reference delay line with swiped length

2 – delay line in substrate

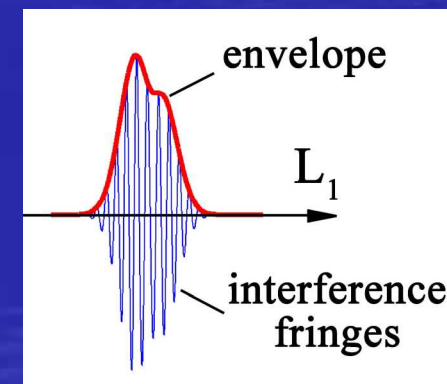
Interference will occur if difference

$|L_1 - L_2| < L_{\text{coh}}$ (coherence length)

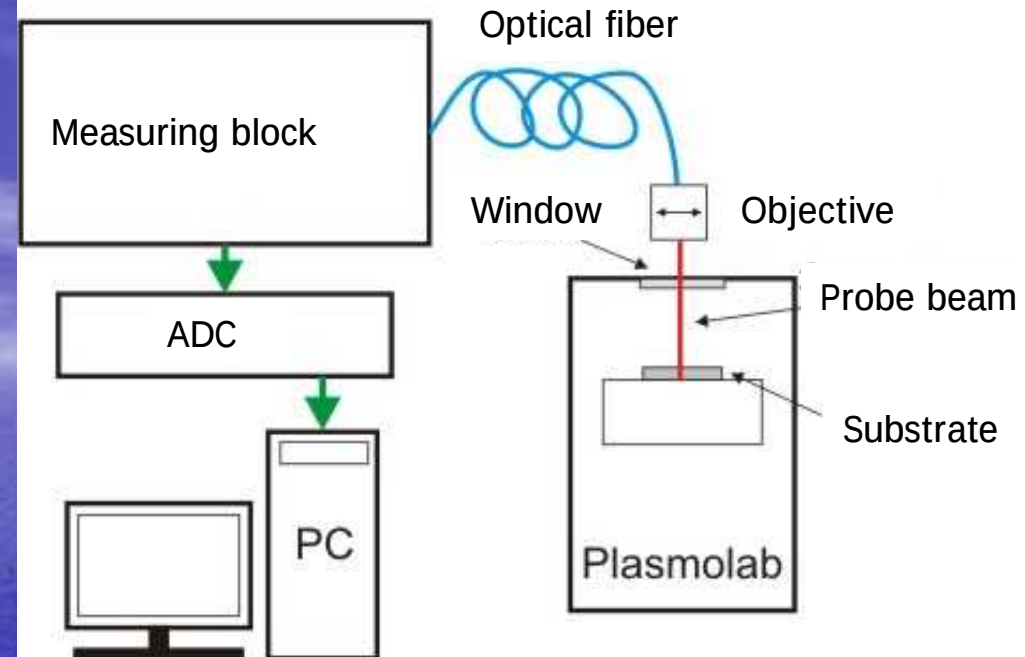
The optical thickness is registered as position of the envelope maximum.



Tiny changes in the optical thickness can be registered as a phase shift of interference fringes.



Methodology and Setup



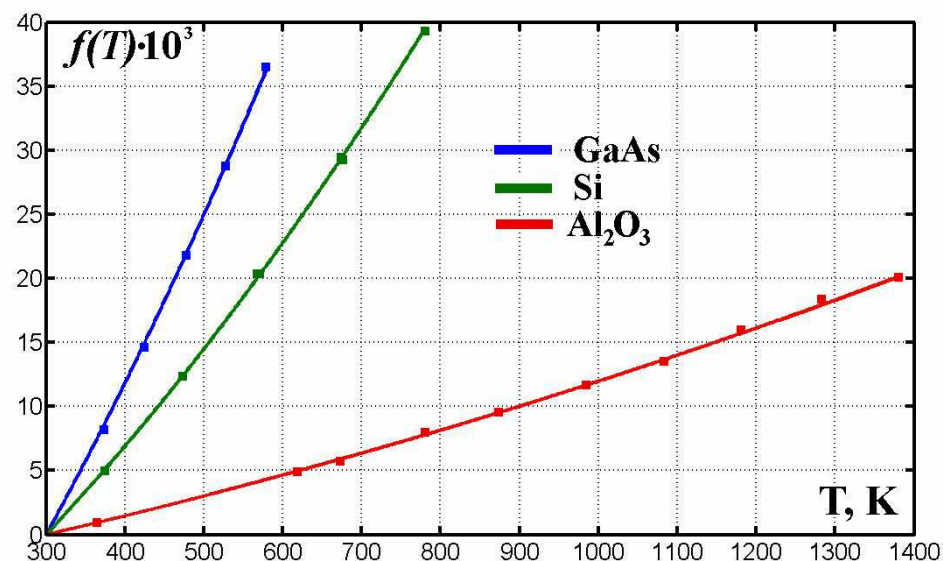
- Robustness and noise immunity, reliability in real conditions
- Multiple measurement channels
- Measurands: total optical thickness and everything convertible into it (temperature, real thickness, strain, pressure, etc.)



Calibration for measurements of temperature (along the envelope)

$$D(T) = n(T)d(T) = D_0(1 + f(T)),$$

D – optical thickness,
 n – index of refraction,
 d – thickness of substrate
 $D = D(T_0)$



$$f_{GaAs}(T) = 6.369 \cdot 10^{-8} \cdot T^2 + 7.407 \cdot 10^{-5} \cdot T - 2.795 \cdot 10^{-2}$$

$$T_0 = 300 \text{ K}, l = 1.3 \text{ mm}$$

$$f_{Si}(T) = 3.486 \cdot 10^{-8} \cdot T^2 + 4.455 \cdot 10^{-5} \cdot T - 1.65 \cdot 10^{-2}$$

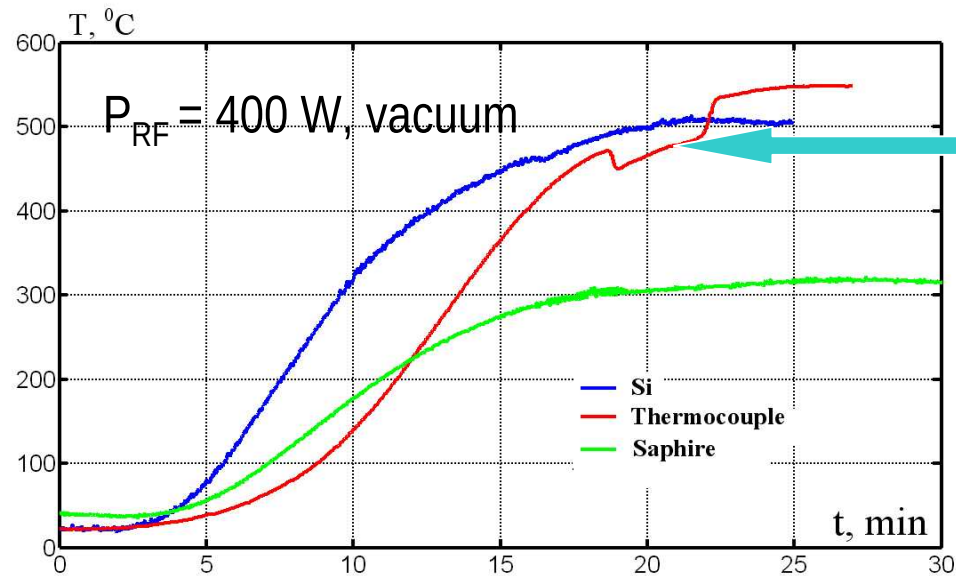
$$T_0 = 300 \text{ K}, l = 1.55 \text{ mm}$$

$$f_{Al_2O_3}(T) = 4.08 \cdot 10^{-9} \cdot T^2 + 1.178 \cdot 10^{-5} \cdot T - 3.903 \cdot 10^{-3}$$

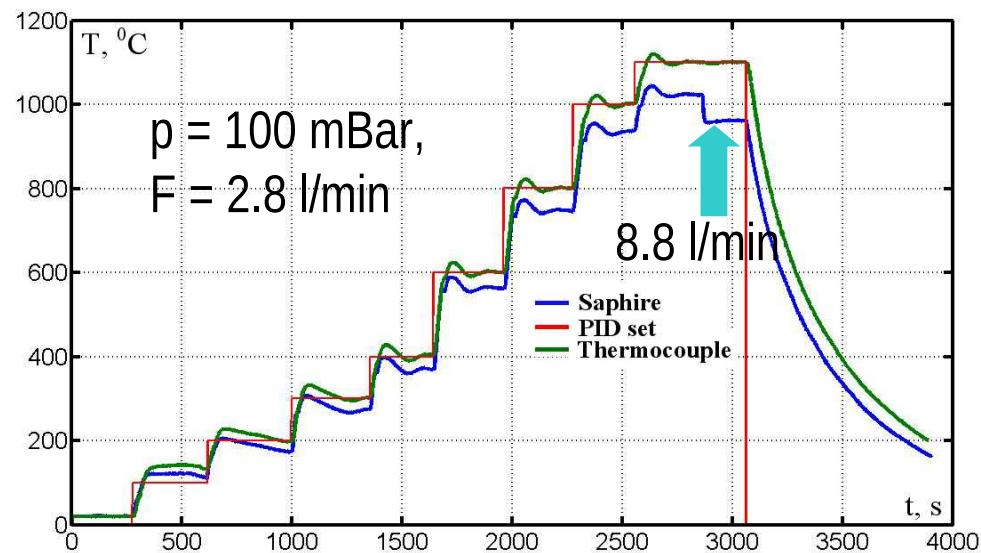
$$T_0 = 300 \text{ K}, l = 1.55 \text{ mm}$$

Calibration accuracy in thermostatic oven $\pm 1^\circ\text{C}$

Heating of sapphire substrates

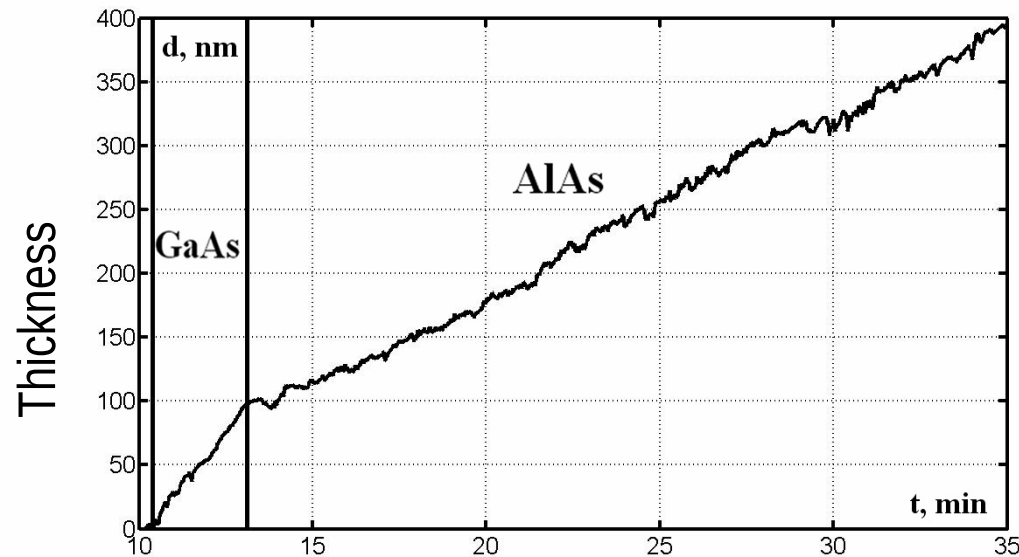


Unstable
thermocouple
reading

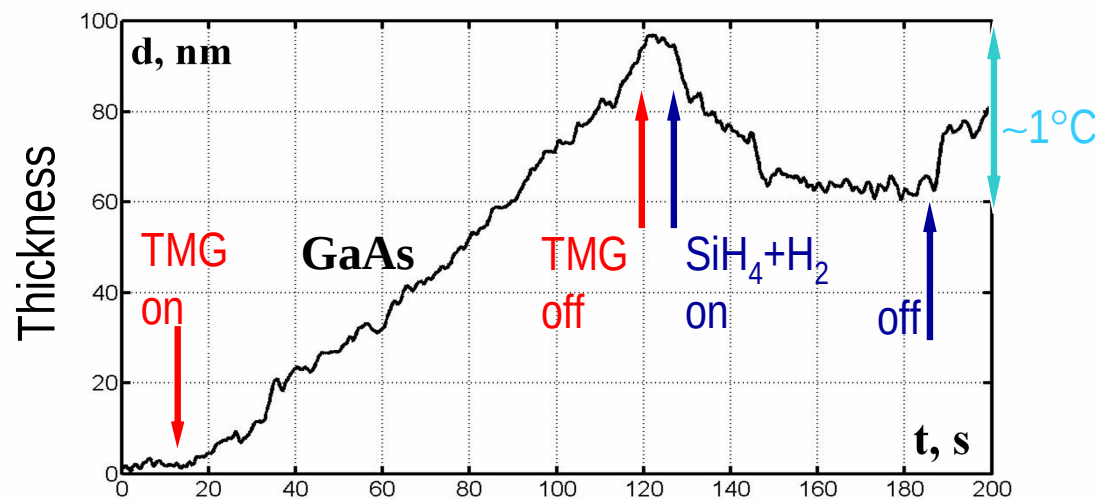


**Absolute
precision of
temperature
measurements
reaches $\pm 1^{\circ}\text{C}$**

Monitoring of thickness (along the phase)



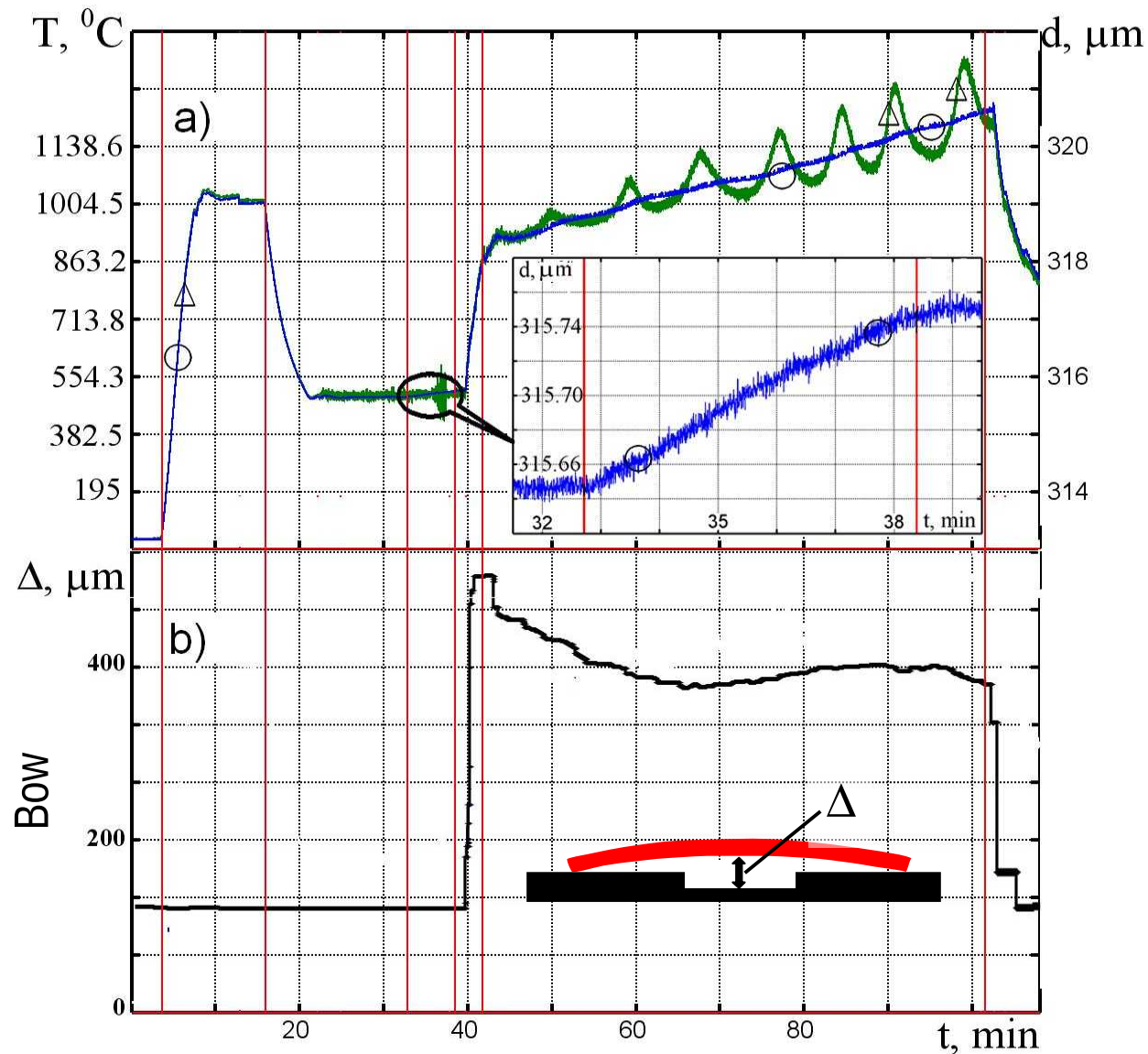
GaAs/AlAs
heterostructures



GaAs-d(Si)-GaAs
structures

The accuracy is
equal to ± 2 nm

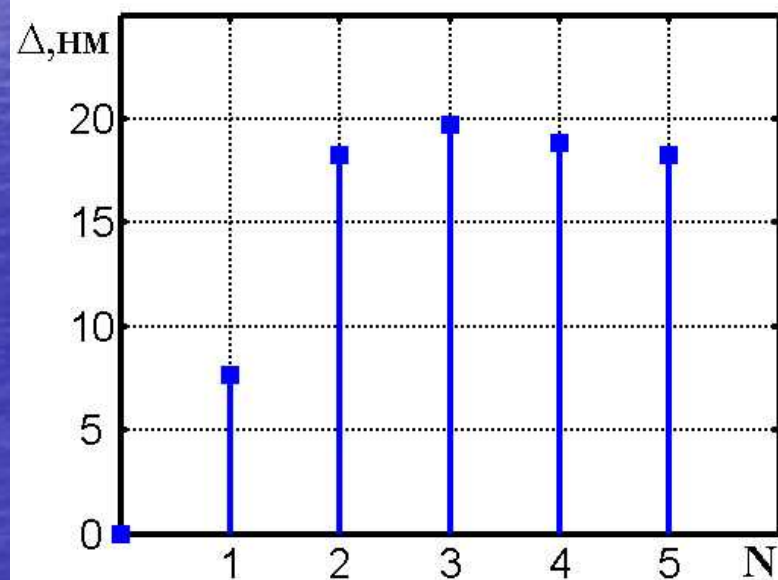
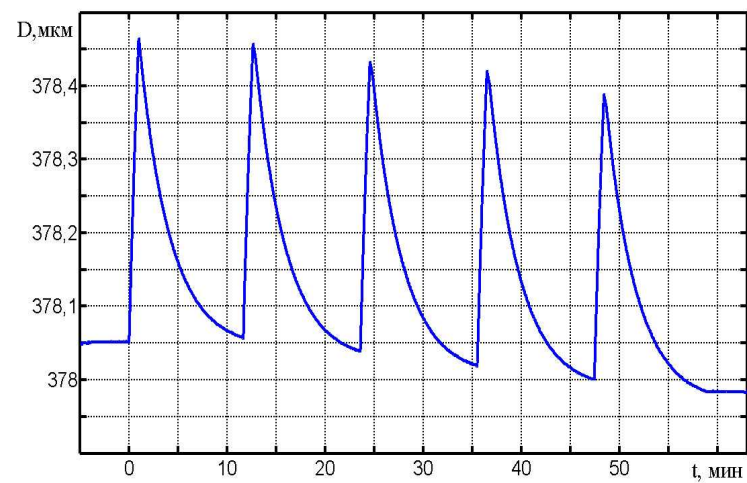
Monitoring of the GaN growth



Along the phase
Along the envelope

Accuracy:
temperature - $\pm 1^{\circ}\text{C}$;
thickness - $\pm 2 \text{ nm}$;
bow - $\pm 3 \text{ mm}$

Etching of Si



Etching of Si : SiO₂ : Si

Коэффициент отражения.
(Влияют изменения
геометрической толщины).

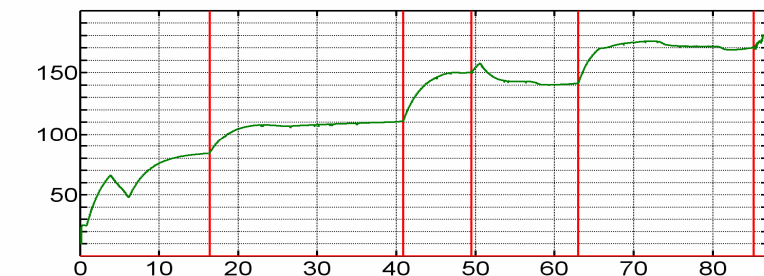
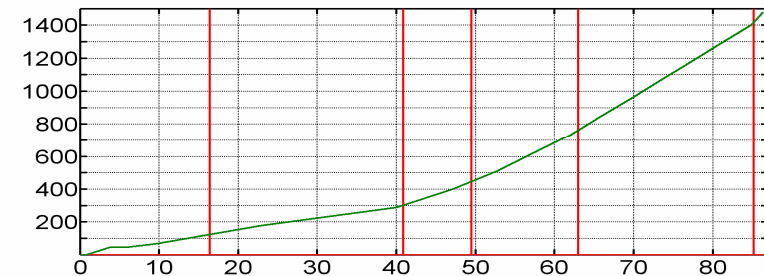
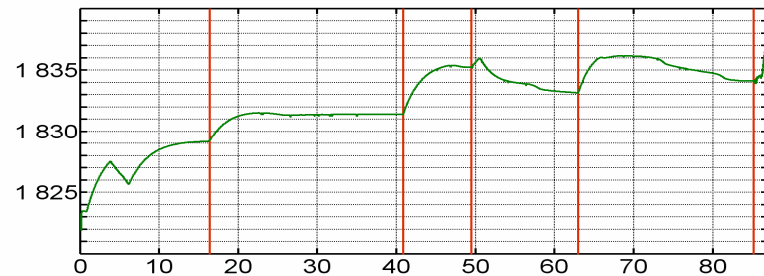
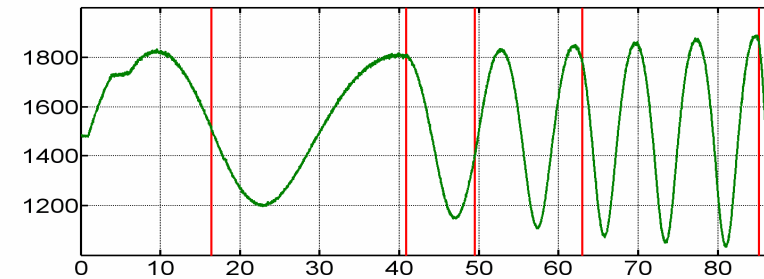
Изменение оптической толщины
всей структуры (Влияют
изменения температуры и
геометрической толщины).

Толщина стравливаемого слоя.
Получена из обработки
коэффициента отражения.

Температура подложки.
Получена из измерений
оптической толщины подложки
и толщины стравливаемого слоя.

Индукционно связанный разряд, мощность, W,

Емкостной разряд, мощность, W,



0	0	50	100	300
100	150	150	150	300

View of monitoring system



Thank you for attention !