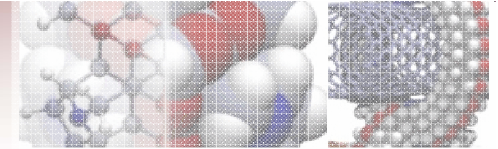


Metode Moderne de Analiza si Control Nedistructiv cu Radiatii X: Conditii, Limite, Perspective

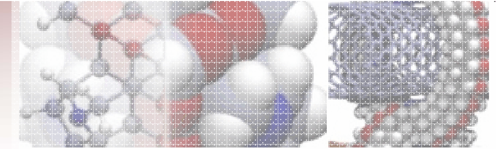
Aplicatii in studiul materialelor nanostructurate si Metrologia Nanotehnologiilor Aplicate

Mihai Danila, Mihaela Miu, Monica Simion, Adina Bragaru

(mihai.danila@imt.ro)

IMT Bucuresti

126A, Erou Iancu Nicolae Street, R-077190 , Bucharest, ROMANIA
PO-BOX 38-160, 023573, Bucharest, ROMANIA



A. Microstructura fizica (faze cristaline) – XRD (WA, IP, GI) ->

Transmisie +/Reflexie, Topografie

A1. Materiale Policristaline

Filme subtiri, pulberi, suspensii, probe de volum

Nanomateriale (faze cristaline slab difractante, cantitati mici)

A2. Materiale Monocristaline

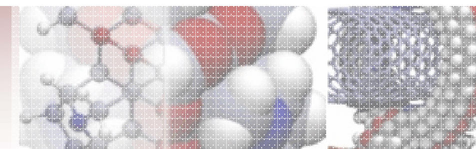
Plachete- probe de volum/grosime mare, filme epitaxiale, QD&(M)QW

Straturi poroase PS-Si

B. Determinarea grosimii, rugozitatii, densitate, largimea interfetei filmelor subtiri depuse pe substrat – XRR (Reflectivitate de raze X)

(Indiferent de tipul materialului probei/compozitia de faze – cristalin si/sau amorf)

Conditii / Limitari / Perspective impuse/determinate de:



1. Caracteristicile fascicolului de raze X incident pe proba:

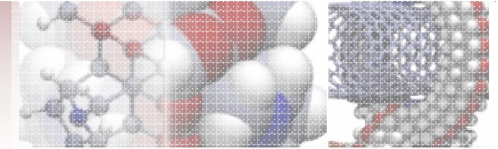
- lungimea de unda/energia fotonului X 1A/1-15 keV,
- fluenta si intensitatea fascicolului pe proba 1-10^{6} -10^{9} cps,
- durata pulsului,
- tipul fascicolului: paralel sau divergent,
- divergenta fascicolului.

2. Caracteristicile goniometrului & sistemului de detectie:

- numarul de axe independente de rotatie ale probei – uniax (pulberi & policristale),
- uniax, axa dubla sau tripla.

3. Caracteristicile probei

- Faza slab difractantata – volum/cantitate mica, amestec faza cristalina/amorfa
- Nanomateriale: dimensiunea medie de cristalit 1nm <D < 5nm;
- Limita pentru faza cristalina este de 1nm!



Aplicatii:

1. Difracție pe pulberi (policristale) > X-Ray Powder Diffraction

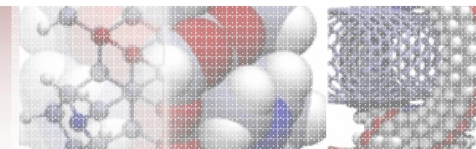
- Compoziție de faze
- % cristalinitate (analiza cantitativă&calitativă)
- Dimensiune de cristalit
- Incidență razantă GIXRD- grazing incident small angle X-ray diffraction
- Rafinarea parametrului de retea cristalina
- Deformari si tensiuni reziduale
- Microdifracție & Mapare parametri fizici pe proba
- Textură

2. Analiza filmelor subțiri

- GIXRD glancing incident angle diffraction
- IPXRD in-plane XRD
- Măsurători de reflectivitate de raze X – X - ray reflectivity XRR
- Filme epitaxiale (grosimi, tensiuni, compoziție, deformari)
- Rocking curves – analiza perfecțiunii de monocristal

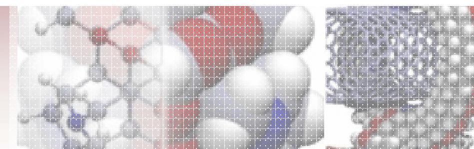
3. Analiza semiconductorilor de volum (monocristal > placheta)

- UHRXRD Difractie de Ultra Inalta rezolutie- determinarea absoluta a parametrului de retea
- RSM Reciprocal Space Map
- Determinarea dopajului
- Rocking curves – analiza perfecțiunii de monocristal



Difractometrul de inalta rezolutie cu anod rotitor 9 kW cu axa tripla Rigaku SmartLab instalat in IMT

Conditii



Metodele moderne de metrologie si control nedistructiv cu radiatii X presupun:

1. Proceduri automate de aliniere (modulelor optice, fascicol, proba) si achizitie date

2. Viteza mare de achizitie a datelor

3. Intensitate maxima a fascicolului pe proba

4. Repetabilitatea si fiabiliatatea mare a datelor experimentale (fara artefacte)

5. Proceduri software adecvate de Analiza si Prelucrare a Datelor Eperimentale (automate sau nu)

6. Stabilirea adecavata a metodei si configuratiei de analiza experimentala

7. Utilizarea uzuala de standarde, referinte si (re)calibrari uzuale

Limite: **1.** Probe slab difractante, predominant amorfe, volum mic de faza cristalina (cazul nanomaterialelor)

2. Metode statistice – valorile masurate sunt mediate pe multe celule elementare/cristalite/arie mare

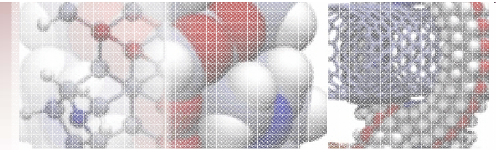
3. Dimensiuni/ modificari/ influente la nivel de celula elementara Dd/d = 10^{-3} - 10^{-7}

Rugozitati maxime de 4 -5 nm (XRR), grosimi maxime de 1000-2000 nm

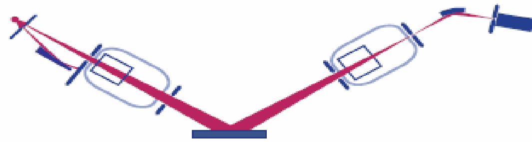
Perspectivele sunt determinate de limitele actuale

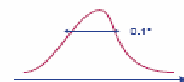
1. Durata pulsului RX -> micsorare

2. Intensitatea/Brilianta fascicolului (pe proba) -> crescuta cu ordine de marime

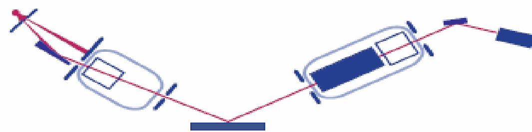


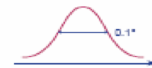
Optics



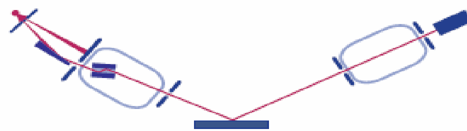


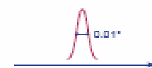
Bragg-Brentano focusing
Phase id, crystal structure, etc.
for powders



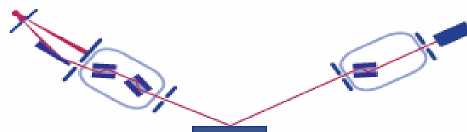


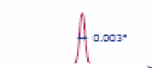
Parallel beam
Phase id, crystal structure, etc.
for thin films



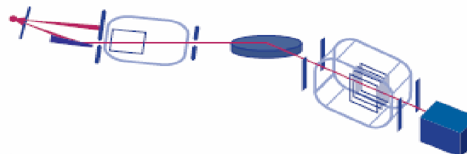


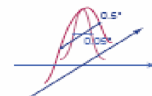
Ge 2-bounce
Crystal structure, film thickness, etc.
for imperfect crystals



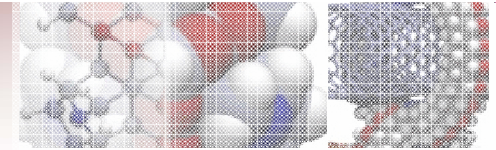


High resolution / triple-axis
Crystal structure, film thickness, etc.
for highly perfect crystals

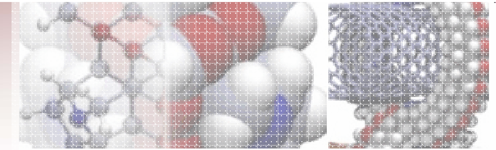




In-plane geometry
Depth controlled phase id, etc.
for ultra thin films

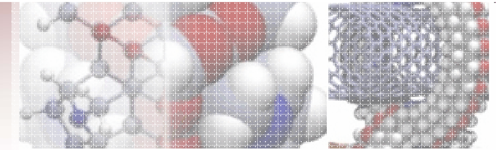


- Tunable for the best performance (just following the guidance software)

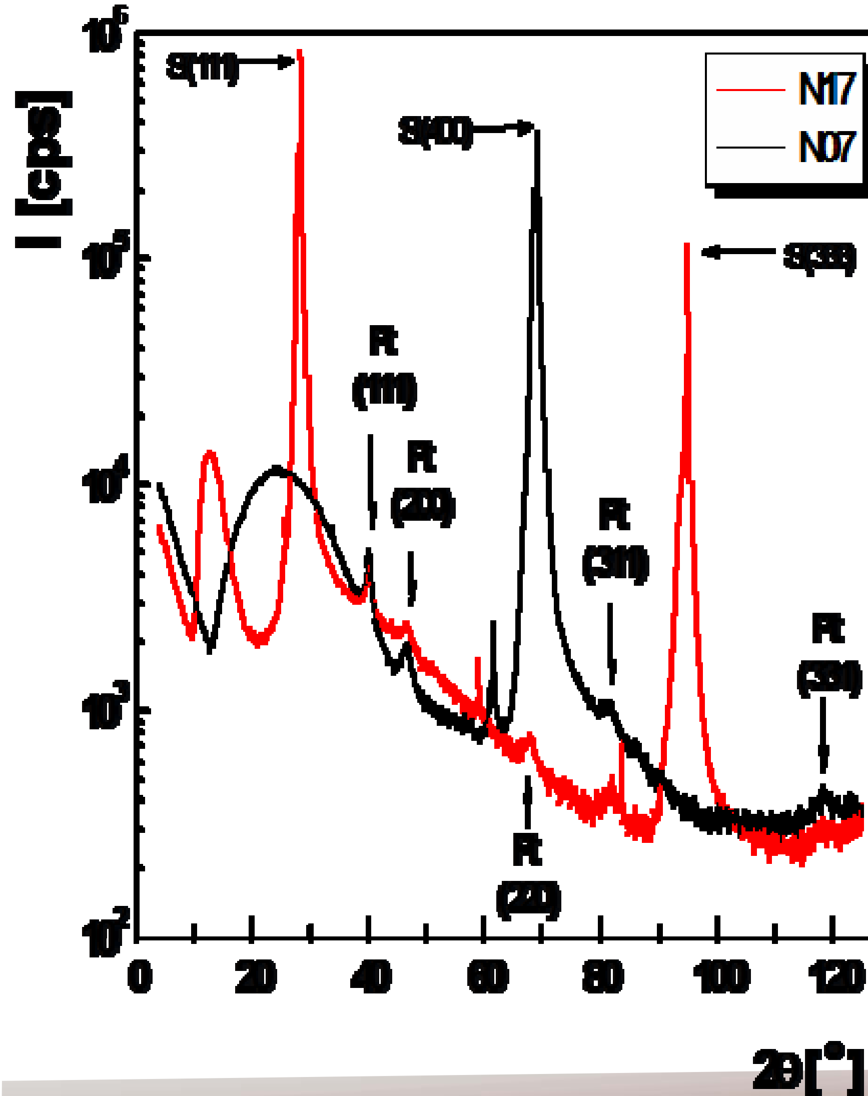


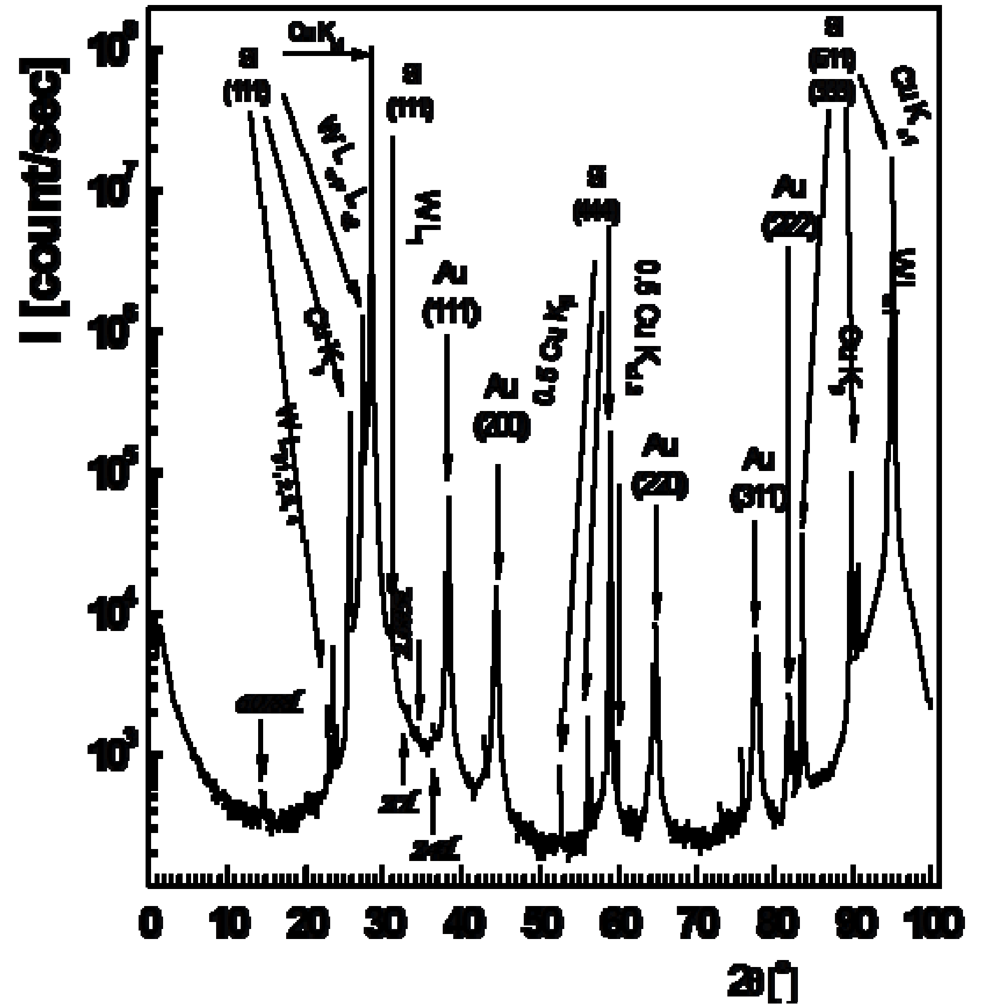
Appendix : Angular Resolution of Optical System

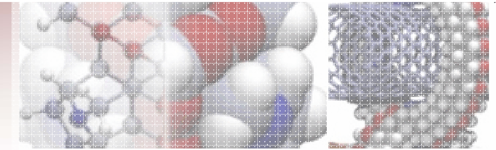
Exemple



1. Metoda A1, A2 > Microstructura filme Pt (Au) in PS – Si (400)







I [cps]

150
125
100
75
50
25

Pt(111)

Pt(220)

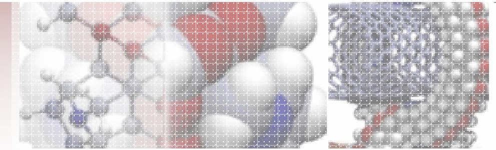
Pt(311)

Pt NP/PS Si(004)

40
50
60
70
80

2θ [°]

9/8/2008 1:22:30 PM | HV 30.00 kV | mag 60 000 x | WD 9.4 mm | det ETD | tilt 1 ° | 2 µm



2. Metoda A1 > Microstructura PVA cu factor de biodegradare marit

Transmisie, Fascicol paralel nemonocromatizat

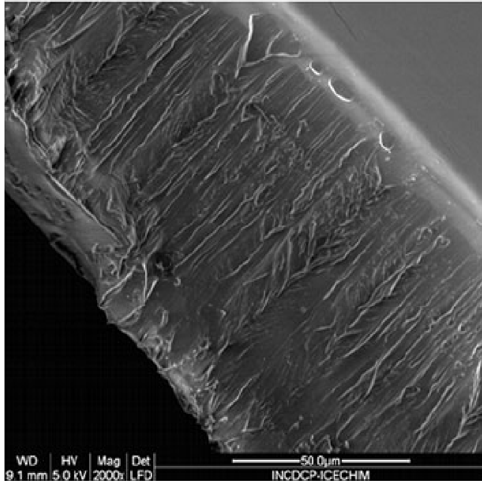
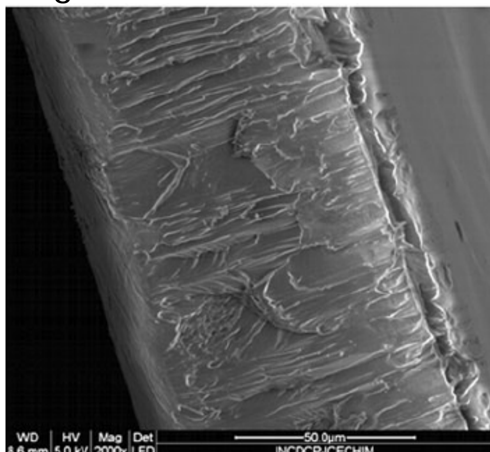
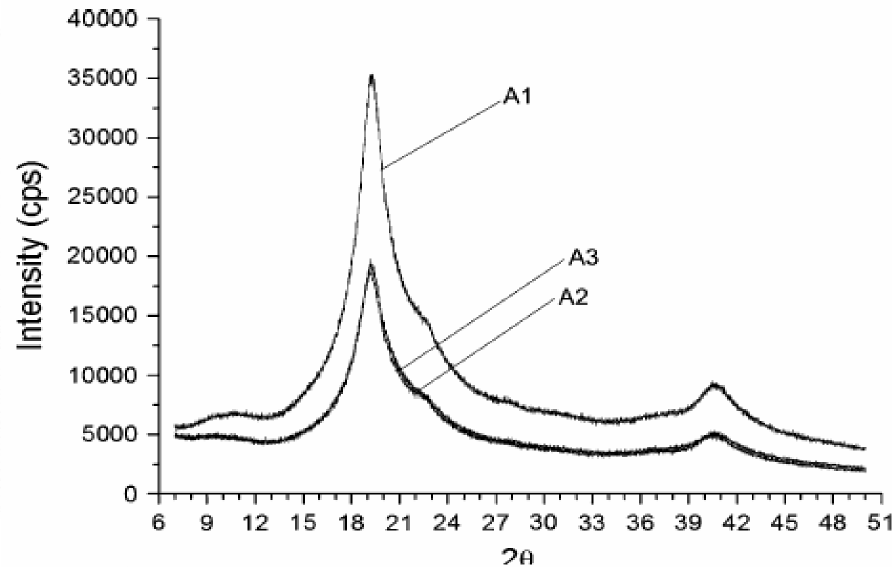
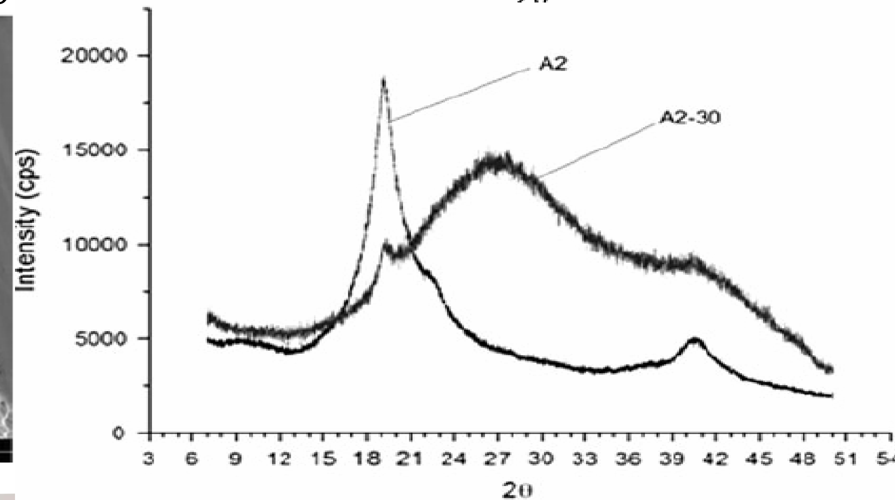


Fig 1 a, b. SEM, PVA Inainte







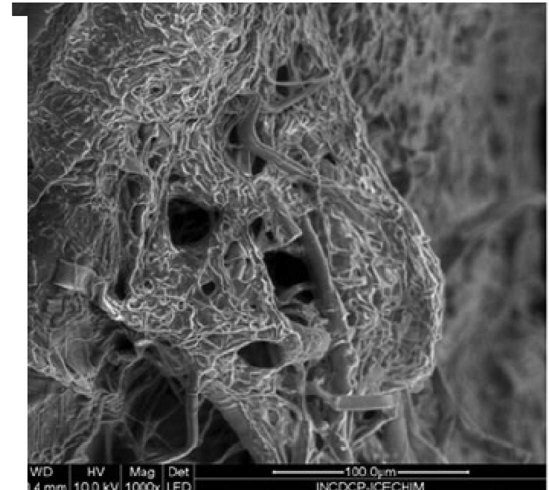
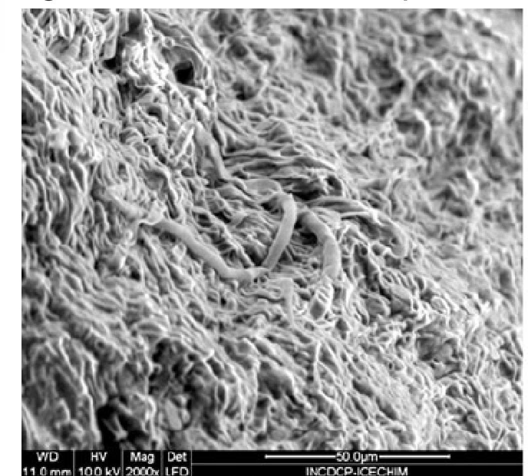
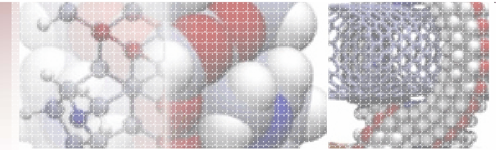


Fig 2 a, b. SEM, PVA dupa atac





Reflexie, Fascicol paralel ne/monocromatizat

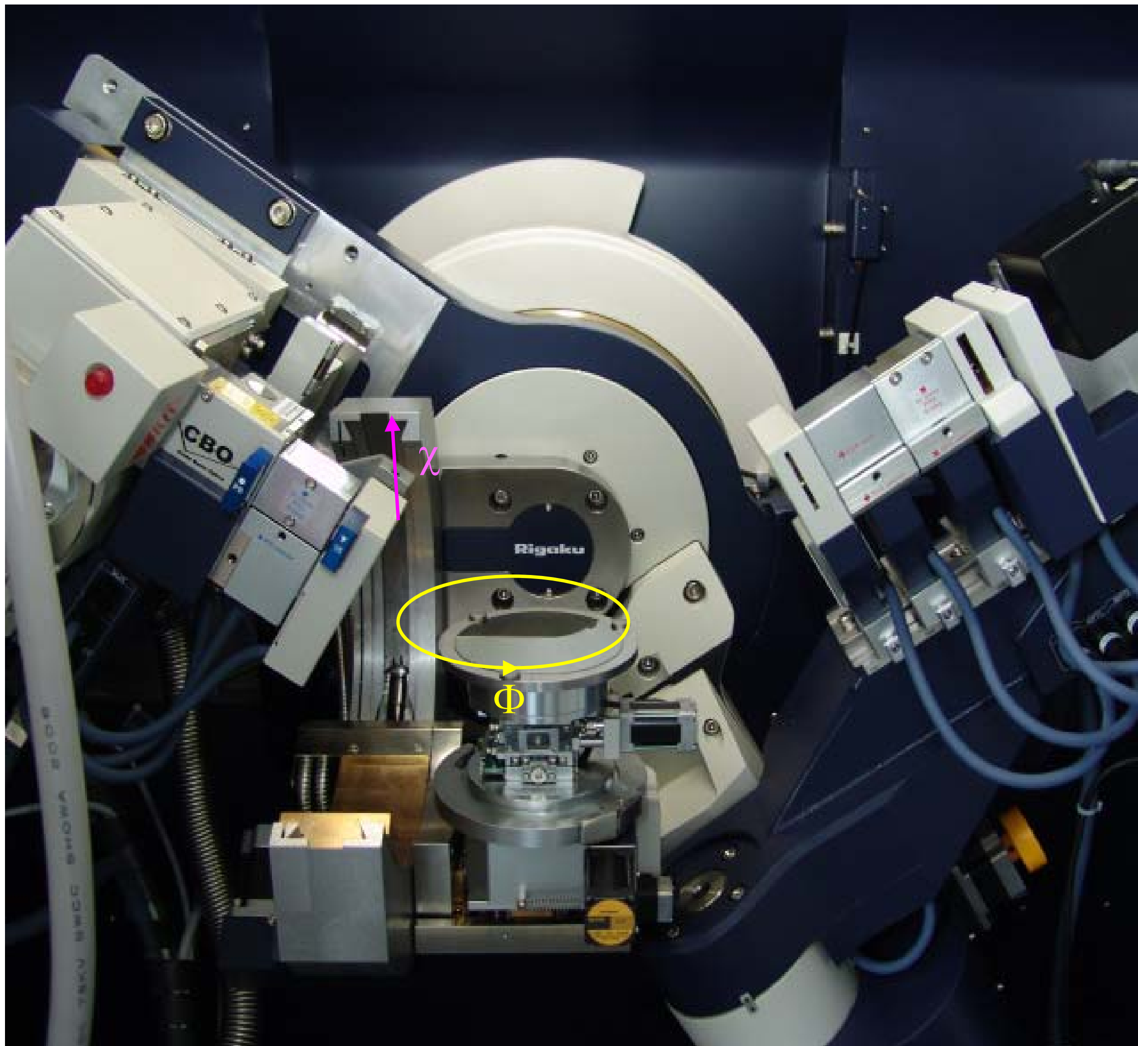
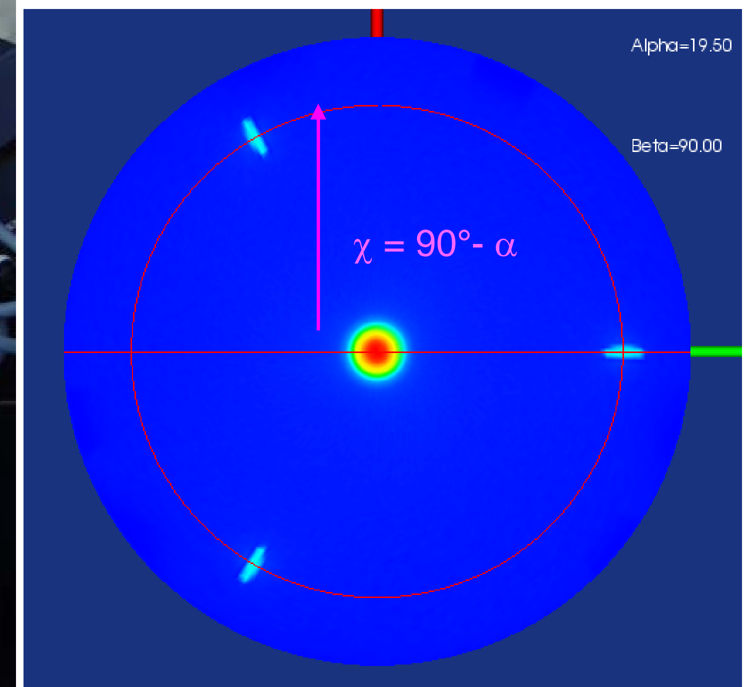


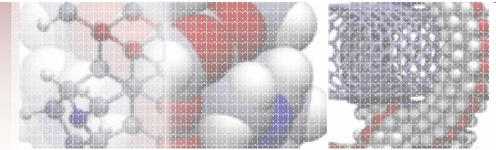
Figura de poli Si (111)

Φ – **sample rotation**

χ – **sample inclination**

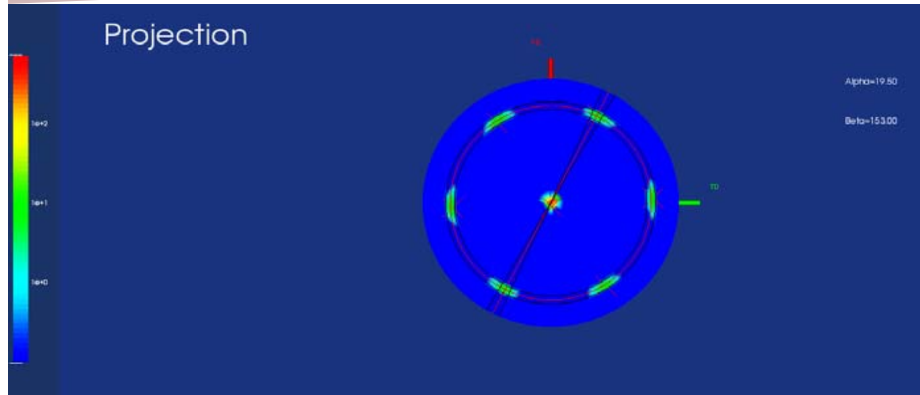


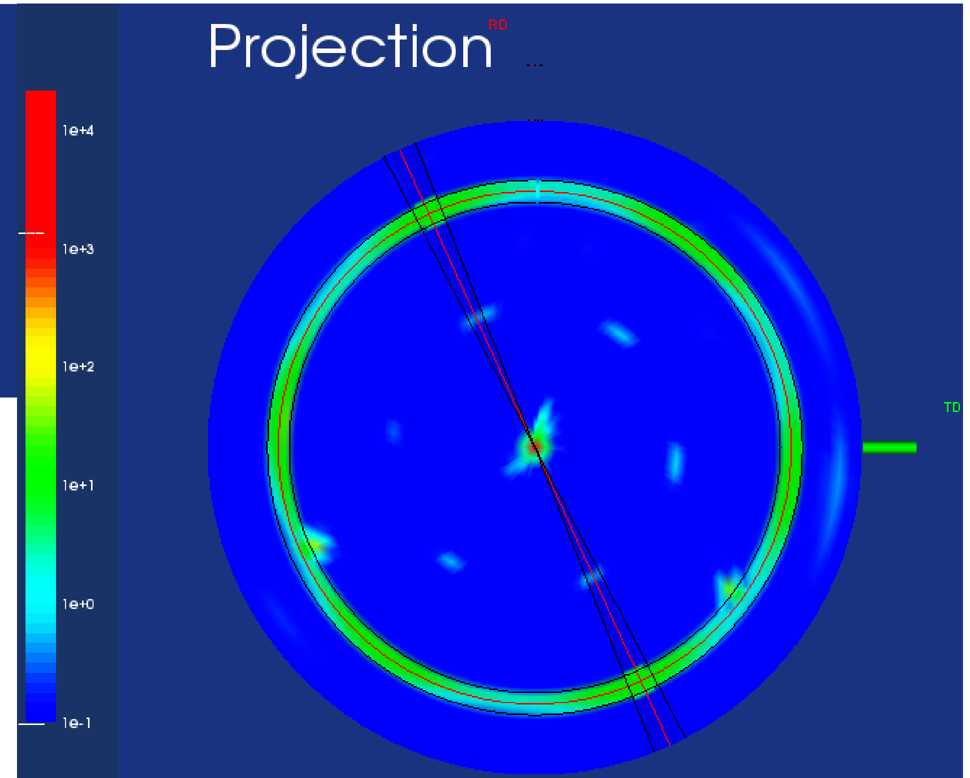
3.a. Metoda A1,2 >Textura, figuri de poli

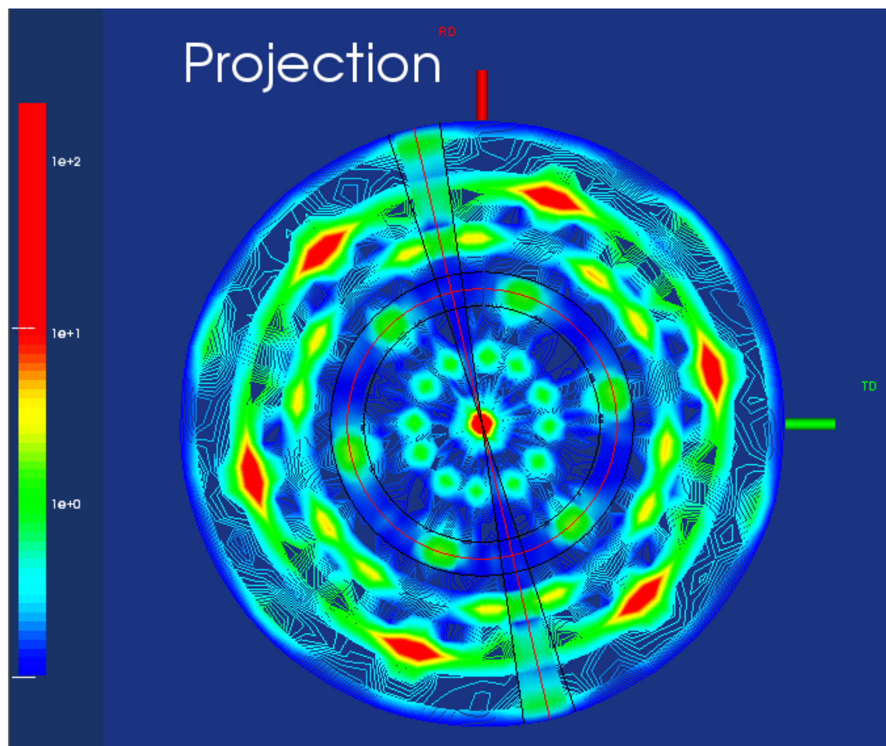


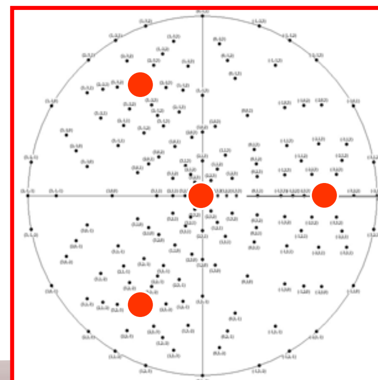
a. Monocristal Au(111) cu defecte (twining)

b. Monocristal Au(111) cu defecte (twining+dislocatii la 60°) si texturarea suprafatei

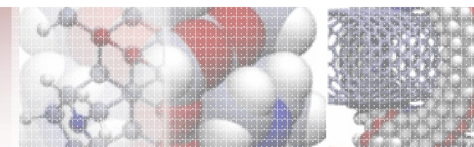






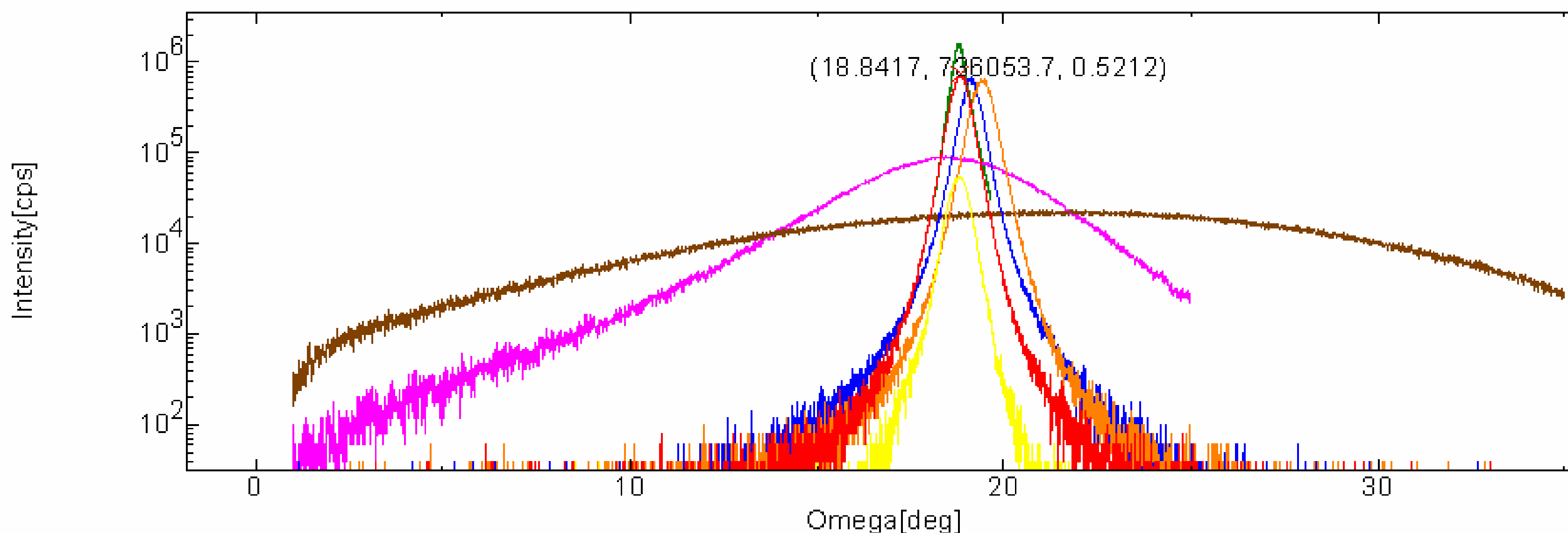


c. Textura Au(111) + blocuri monocristaline

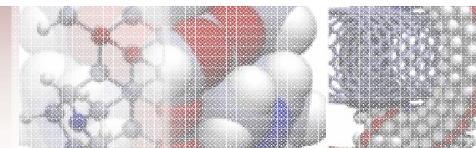


Comparatie Au111_cu IMT_2xmica.ras / Collected Data-4

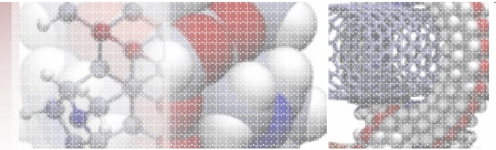
Sample Name	: None	Scan Mode	: CONTINUOUS	CBO selection slit	: PB
Comment	: Height alignment	Scan Speed	: 12.0000 deg/min	Incident parallel slit	: Soller_slit_5.0deg
		Scan Step	: 0.0100 deg	Incident slit	: 1.000mm
Date	: 11/19/09 12:19:06	Scan Axis	: Omega	Length limiting slit	: 0.5mm
Operator	: Admin	Scan Range	: 1.0001 - 35.0001 deg	Receiving slit # 1	: 1.000mm
X-Ray	: 40 kV , 80 mA	2-Theta	: 38.2276 deg	Filter	: None
Wavelength	: CuKa / 1.541867 A	Omega	: 0.9951 deg	Receiving optical device	: PSA_open
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg	Receiving parallel slit	: Soller_slit_5.0deg
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg	Receiving slit # 2	: 1.000mm
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg	Attenuator	: Open
Detector	: SC-70			Diffracted beam mono.	: Flat
Memo	: None			Monochromator slit	: None
Optics Attribute	: Medium resolution parallel beam/RS				



SmartLab Guidance(TM) Admin(System Manager) May-17-2011 18:54:35 Page-1



A. Reflexie, Fascicol paralel ne/monocromatizat, WAXRD



B. Metoda A1, GIXRD

RX3

GIXRD, PB + DBM

($\omega = 0.35^{o}$)

(9.3 sec/step, step 0.094^{o})

$D_{hkl} = 4.44$nm

Au(111)

Au(200)

Au(220)

Au(311)

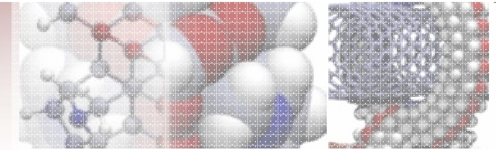
Au(222)

I [counts]

0
1000
2000
3000
4000
5000
6000
7000

20
30
40
50
60
70
80
90

2θ [^{o}]

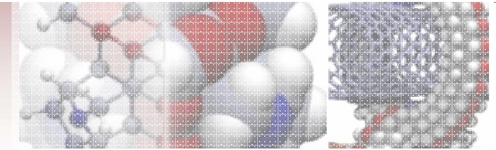


Metoda B. XRR Determinarea grosimii filmelor pe substrat (3)

REFLECTIVITY PROFILE

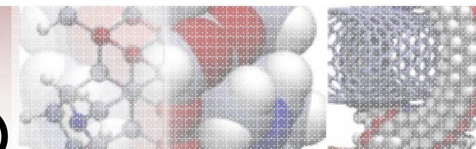
No.	Layer Name	Thickness (nm)	Density (g/cm3)	Roughness (nm)	Period	Func.
2	Au	11.26(6)	19.30000[--]	2.16(3)		Const.
1	Cr	6.24(2)	5.30000[--]	0.581(4)		Const.
0	GLASS	0.000[--]	2.21000[--]	0.580(12)		Const.

5. Metoda B, XRR, film Au fara strat de aderenta de Cr



REFLECTIVITY PROFILE

1. Au t = 41.968(3)nm ρ = 19.3g/cm3 σ = 1.028(2)nm
2. Glass - ρ = 2.213g/cm3 σ = 0.6nm

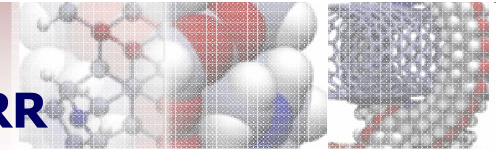


6. XRR, Oxid SiO2 nativ amorf (poros, densitate < val. Teoretica)

REFLECTIVITY PROFILE

No.	Layer Name	Thickness (nm)	Density (g/cm3)	Roughness (nm)	Period	Func.
2	SiO2	1.026(6)	1.826(6)	0.5292(19)		Linear
1	SiO2	3.559(7)	1.608(7)	0.654(11)		Linear
0	Si	0.000[--]	2.33000[--]	0.642(5)		Const.

7. Metoda B, DLC (diamond like Carbon)/SiO2 nativ/Si, XRR



3/30/2011 , 8:14:12 PM , Exp. Curve: DLC1 XRR A2_2-Theta_Omega.asc

Layer Structure : C/SiO2//Si

Layer	Material	Thickness [nm]	rel. Density	Roughness [nm]
1	C	132.62 ± 0.76	0.65 ± 0.04	1.55 ± 0.21
2	SiO2	4.65 ± 0.59	0.93 ± 0.06	0.31 ± 0.00
Sub.	Si	------------------	1.00 fix	0.16 ± -----

Io : 2.1533E6 ± 24.71%   Iu : 3.326 ± -----

S1 : 0.26609   Delta : -0.0251 ± -----

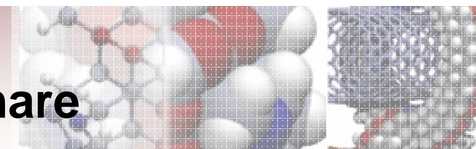
Intensity

10^6 10^5 10^4 10^3 10^2 10^1

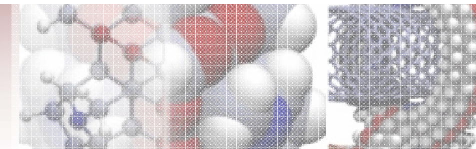
0 0.40 0.80 1.20 1.60 2.00 2.40

2Theta [degree]

8. HRMRXRD Straturi PS-Si (Si poros) cu gradient de deformare



	SAXS	SEM	SEM	
	Particle Size [nm]	Pore Size [nm]	Grosime PS [μm]	Densitate pori [%]
X1 10mA/cm^2	4,20	4,7	5,83	52,81
X2 25mA/cm^2	3,70	6,6	10,82	64,08
X3 40mA/cm^2	3,32	8,5-10,0	15,70	75,08



I [cps]

10^6

10^5

10^4

10^3

10^2

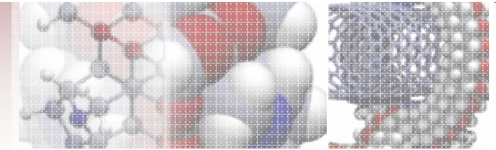
X3

X2

X1

68,90 69,00 69,10 69,20 69,30

2θ [°]



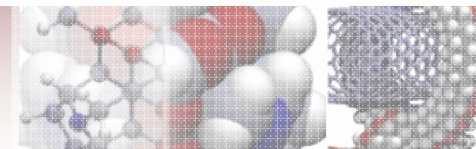
I [cps]

10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0

X2_etched
X1_etched
X3_etched

68,80
69,00
69,20
69,40

2θ [°]



10^7
10^6
10^5
10^4
10^3
10^2

I [cps]

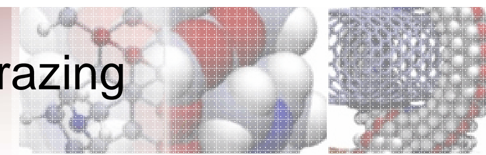
X2_etched
X2

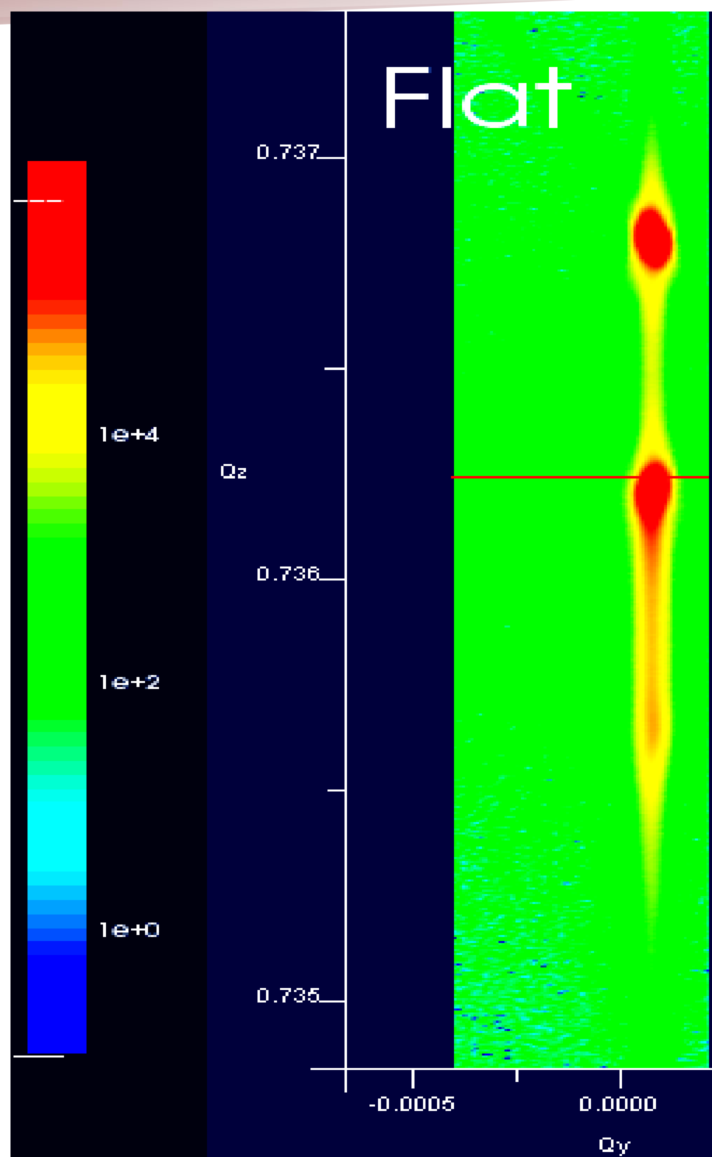
68,80
69,00
69,20

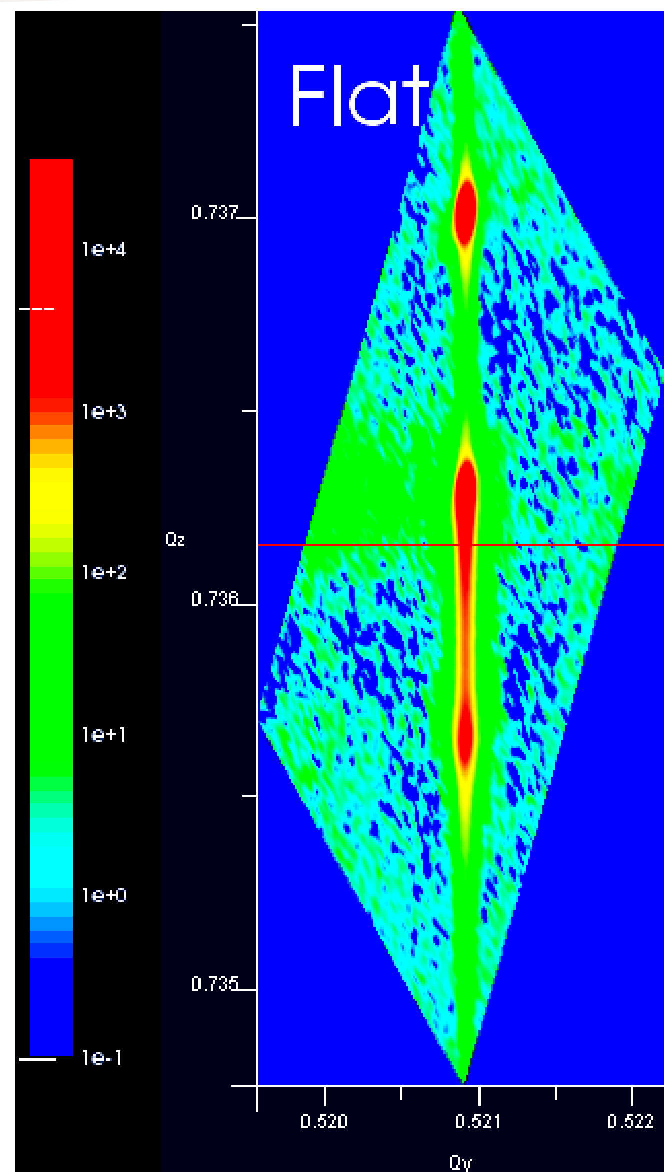
2θ [°]

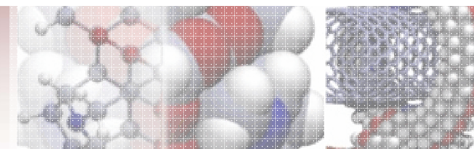
RSM symmetric space map **Si(004)**, X2 before etch

RSM asymmetric space map, grazing exit, **Si(224)**, X3 before etch









9. HRMRXRD Laser structures, Superlattices + QD + MQW, InGaAs/GaAs AlGaAs Buffer on GaAs (004)

(66.0704, 1815600.3, 0.0068)

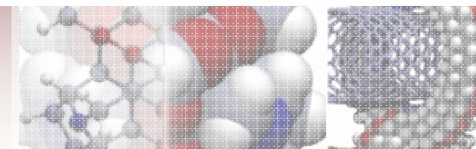
Intensity[cps]

10^1 10^2 10^3 10^4 10^5 10^6

62 63 64 65 66 67

Theta/2-Theta[deg]

Inset: Intensity[cps] — 10^1 10^2 — 63 64 — Theta/2-Theta[deg]



(66.0704, 1815600.3, 0.0068)

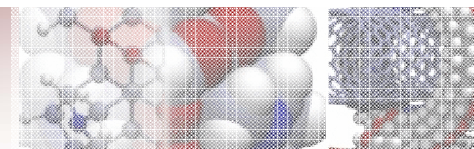
Intensity[cps]

10^6
10^5
10^4
10^3
10^2
10^1

65.6 65.8 66.0 66.2 66.4

Theta/2-Theta[deg]

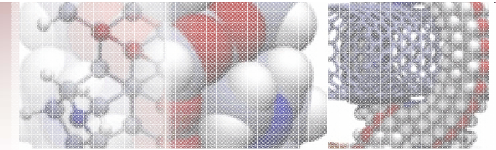
Structura fitata



Layer	Thickness	Repetition
InGaAs	1.2nm	
GaAs	15.0nm	
:		20 Period
AlGaAs	2.0nm	20 Period
GaAs	1.3nm	20 Period
AlGaAs	100.0nm	
:		20 Period
GaAs	1.3nm	20 Period
AlGaAs	2.0nm	20 Period
GaAs	15.0nm	
InGaAs	1.2nm	
GaAs	15.0nm	
:		20 Period
AlGaAs	2.0nm	20 Period
GaAs	1.3nm	20 Period
AlGaAs	100.0nm	
SUBSTRATE : GaAs (0 0 1 , 0 0 4)		

Layer	Thickness	Repetition
InGaAs	8.0nm	
GaAs	17.0nm	
:		20 Period
AlGaAs	2.6nm	20 Period
GaAs	1.5nm	20 Period
AlGaAs	106.8nm	
:		20 Period
GaAs	1.4nm	20 Period
AlGaAs	1.9nm	20 Period
GaAs	15.1nm	
InGaAs	6.9nm	
GaAs	14.3nm	
:		20 Period
AlGaAs	2.5nm	20 Period
GaAs	1.1nm	20 Period
~~GaAs~~	~~1.3nm~~	20 Period
AlGaAs	101.6nm	
SUBSTRATE : GaAs (0 0 1 , 0 0 4)		

RSM InGaAs/GaAs



Flat

1e+4
1e+2
1e+0

0.630
0.625
0.620
0.615
Qz

-0.254
-0.252
-0.250
-0.248
Qy

Topo

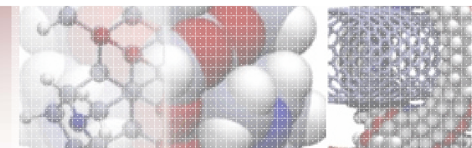
1e+4
1e+2
1e+0

Intensity
1e+4
1e+2
1e+0

Qz
0.53
0.52

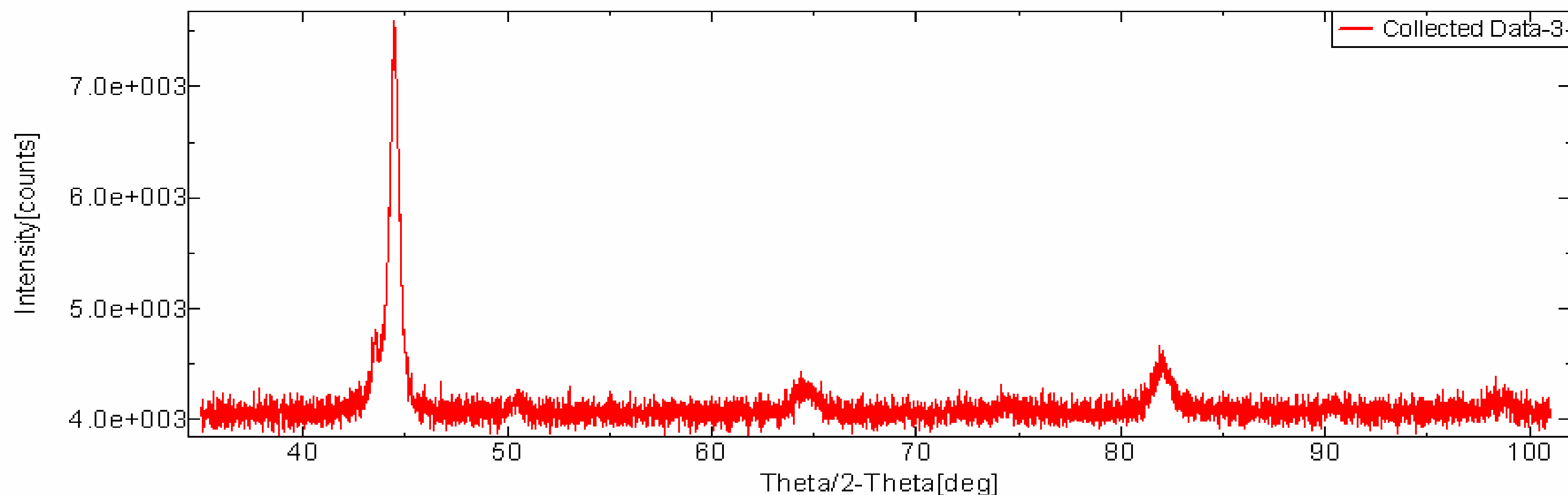
Qy
-0.255
-0.250
-0.245

10. Determinarea continutului de Austenita reziduala (oteluri)

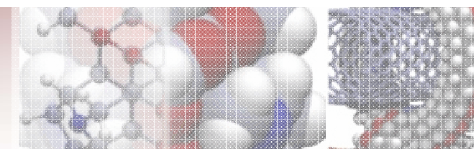


V1517_PB.ras / Collected Data-3

Sample Name	: V1517	Scan Mode	: CONTINUOUS	CBO selection slit	: PB
Comment	: None	Scan Speed	: 6.0000 deg/min	Incident parallel slit	: Soller_slit_5.0deg
		Scan Step	: 0.0100 deg	Incident slit	: 1.000mm
Date	: 05/03/11 14:29:14	Scan Axis	: Theta/2-Theta	Length limiting slit	: 15.0mm
Operator	: Admin	Scan Range	: 35.0000 - 101.0000 deg	Receiving slit # 1	: 1.000mm
X-Ray	: 45 kV , 200 mA	2-Theta	: 34.9950 deg	Filter	: None
Wavelength	: CuKa / 1.541867 A	Omega	: 17.4975 deg	Receiving optical device	: PSA_open
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg	Receiving parallel slit	: Soller_slit_5.0deg
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg	Receiving slit # 2	: 1.000mm
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg	Attenuator	: 1/10000
Detector	: SC-70			Diffracted beam mono.	: None
Memo	: Austenita reziduala			Monochromator slit	: None
Optics Attribute	: Medium resolution parallel beam/RS				

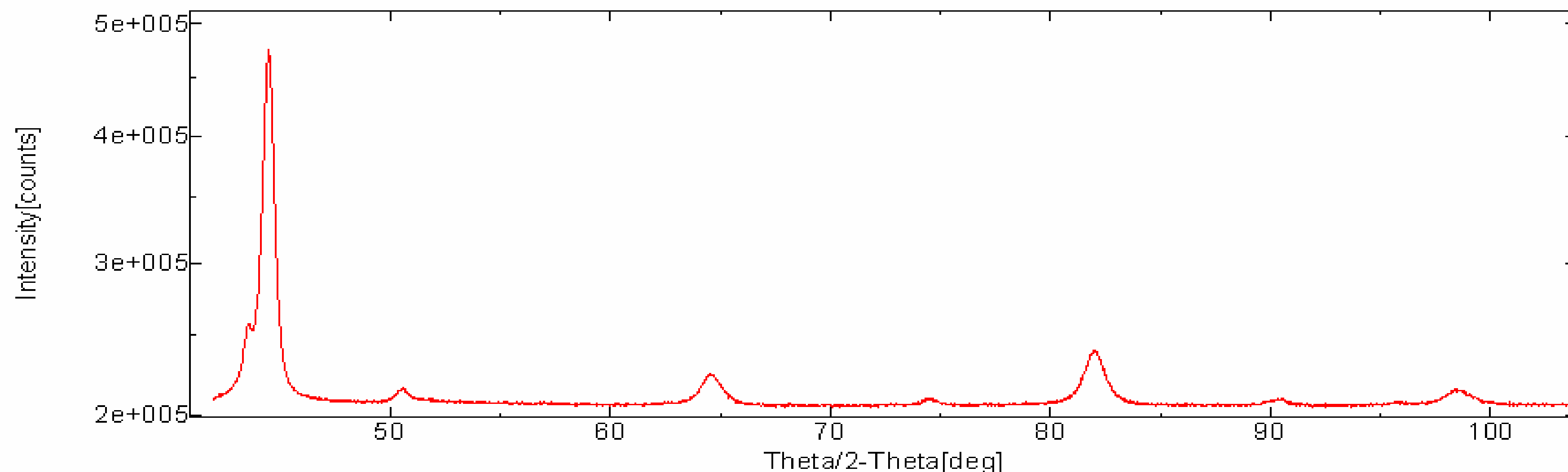


SmartLab Guidance(TM) Admin(System Manager) May-17-2011 15:13:22 Page-1

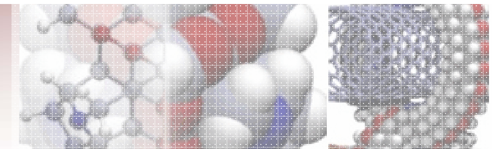


V1517_BB_L.ras / Collected Data-4

Sample Name	: V1517_BB	Scan Mode	: CONTINUOUS	CBO selection slit	: BB
Comment	: austenita rez	Scan Speed	: 2.0000 deg/min	Incident parallel slit	: Soller_slit_5.0deg
		Scan Step	: 0.0200 deg	Incident slit	: 2/3deg
Date	: 05/03/11 16:15:38	Scan Axis	: Theta/2-Theta	Length limiting slit	: 15.0mm
Operator	: Admin	Scan Range	: 42.0000 - 104.0000 deg	Receiving slit # 1	: 4.000deg
X-Ray	: 45 kV , 200 mA	2-Theta	: 0.0000 deg	Filter	: None
Wavelength	: CuKa / 1.541867 A	Omega	: 0.0000 deg	Receiving parallel slit	: Soller_slit_5.0deg
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg	Receiving slit # 2	: 13.000mm
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg	Attenuator	: Open
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg	Diffracted beam mono.	: No_unit
Detector	: D/teX Ultra			Monochromator slit	: None
Memo	: AUSTENITA, BB				
Optics Attribute	: Bragg-Brentano focusing				

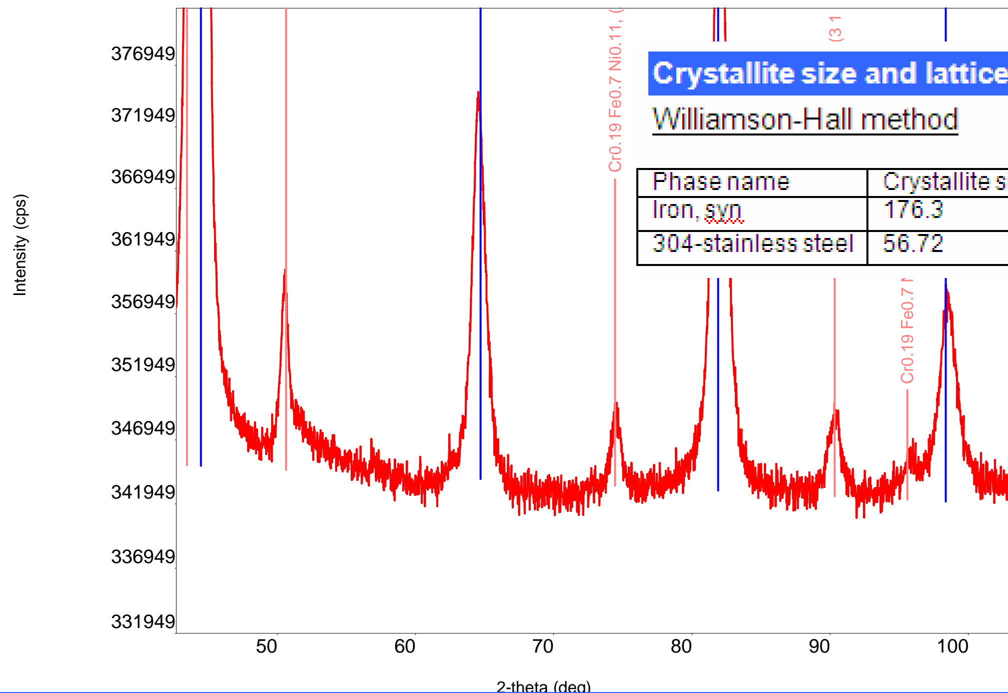


SmartLab Guidance(TM) Admin(System Manager) May-17-2011 15:15:05 Page-1



Qualitative analysis results

Phase name	Formula	Figure of merit	Phase reg. detail	DB card number
Iron, syn	Fe	0.283	ICDD (PDF2.DAT)	00-006-0696
304-stainless steel	Cr0.19 Fe0.7 Ni0.11	0.492	ICDD (PDF2.DAT)	00-033-0397



Crystallite size and lattice strain

Williamson-Hall method

Phase name	Crystallite size(A)	Strain (%)
Iron, syn	176.3	0.00463(5)
304-stainless steel	56.72	0.000000e+000

Target phase: 304-stainless steel

No.	2-theta (deg)	Int. W (deg)
1	43.482(4)	0.597(17)
3	50.46(3)	1.62(5)
5	74.40(5)	0.75(7)
7	90.27(5)	1.05(8)
8	95.9239	1.587582

Width correction

- No correction
- Use external standard
- Use internal standard

Internal standard: Iron, syn

Analyze: Lattice strain and crystallite size

Method: Halder-Wagner method

Formula: Y=0.028X-0.0005

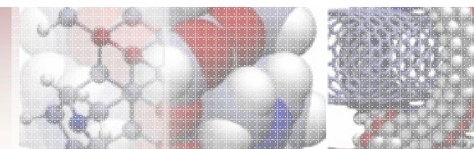
Crystallite size(ang.): 59(10)

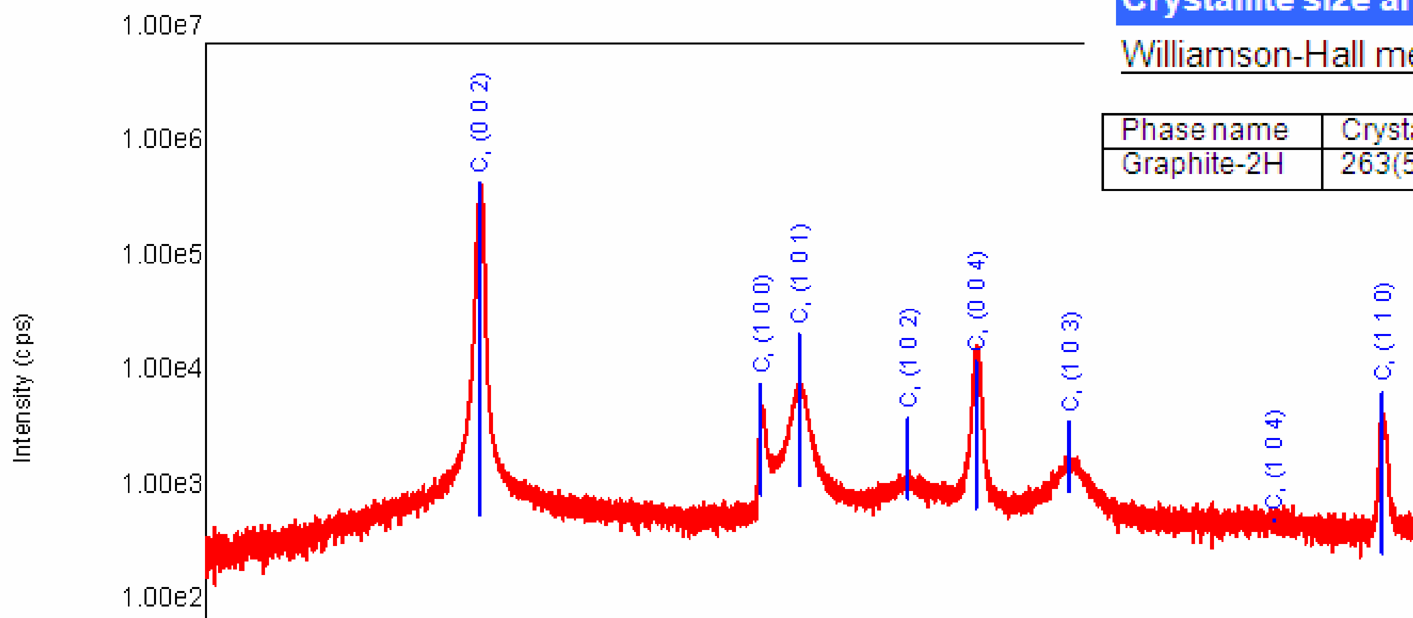
Lattice strain(%): 0.000000e+000

Measurement conditions

X-Ray	45 kV , 200 mA	Scan speed / Duration time	2.0000 deg./min.
Goniometer		Step width	0.0200 deg.
Attachment	-	Scan axis	2theta/theta
Filter		Scan range	42.0000 - 104.0000 deg.
CBO selection slit	-	Incident slit	2/3deg
Diffrected beam mono.	No_unit	Length limiting slit	-
Detector	D/teX Ultra	Receiving slit #1	4.000deg
Scan mode	CONTINUOUS	Receiving slit #2	13.000mm

11. Pulbere Grafit de puritate spectrala (Cehia), D=26nm





Crystallite size and lattice strain

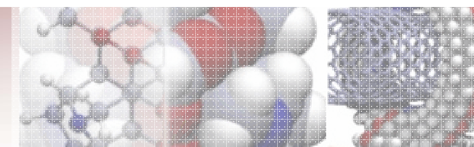
Williamson-Hall method

Phase name	Crystallite size(A)	Strain (%)
Graphite-2H	263(54)	0.14(19)

Measurement conditions

X-Ray	45 kV , 200 mA	Scan speed / Duration time	6.0000 deg./min.
Goniometer		Step width	0.0100 deg.
Attachment	-	Scan axis	2theta/theta
Filter		Scan range	11.0000 - 80.0000 deg.
CBO selection slit	-	Incident slit	1.000mm
Diffrected beam mono.	No_unit	Length limiting slit	-
Detector	SC-70	Receiving slit #1	1.000mm
Scan mode	CONTINUOUS	Receiving slit #2	1.000mm

12. Film grafene multilayer (Si, Sticla) D=6.7nm



EG_NMP_0702_D.ras / Collected Data-9

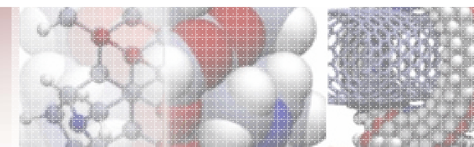
Sample Name	: None	Scan Mode	: CONTINUOUS	CBO selection slit	: PB
Comment	: None	Scan Speed	: 12.0000 deg/min	Incident parallel slit	: Soller_slit_5.0deg
		Scan Step	: 0.0100 deg	Incident slit	: 1.000mm
Date	: 04/19/11 17:10:00	Scan Axis	: Theta/2-Theta	Length limiting slit	: 10.0mm
Operator	: Admin	Scan Range	: 10.0000 - 62.0000 deg	Receiving slit # 1	: 1.000mm
X-Ray	: 45 kV , 200 mA	2-Theta	: 9.9950 deg	Filter	: None
Wavelength	: CuKa / 1.541867 A	Omega	: 4.9975 deg	Receiving optical device	: None
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg	Receiving parallel slit	: Soller_slit_5.0deg
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg	Receiving slit # 2	: 1.000mm
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg	Attenuator	: 1/10000
Detector	: SC-70			Diffracted beam mono.	: None
Memo	: transfer pe sticla			Monochromator slit	: None
Optics Attribute	: Medium resolution parallel beam/RS				

SmartLab Guidance(TM) Admin(System Manager)

Crystallite size and lattice strain

Williamson-Hall method

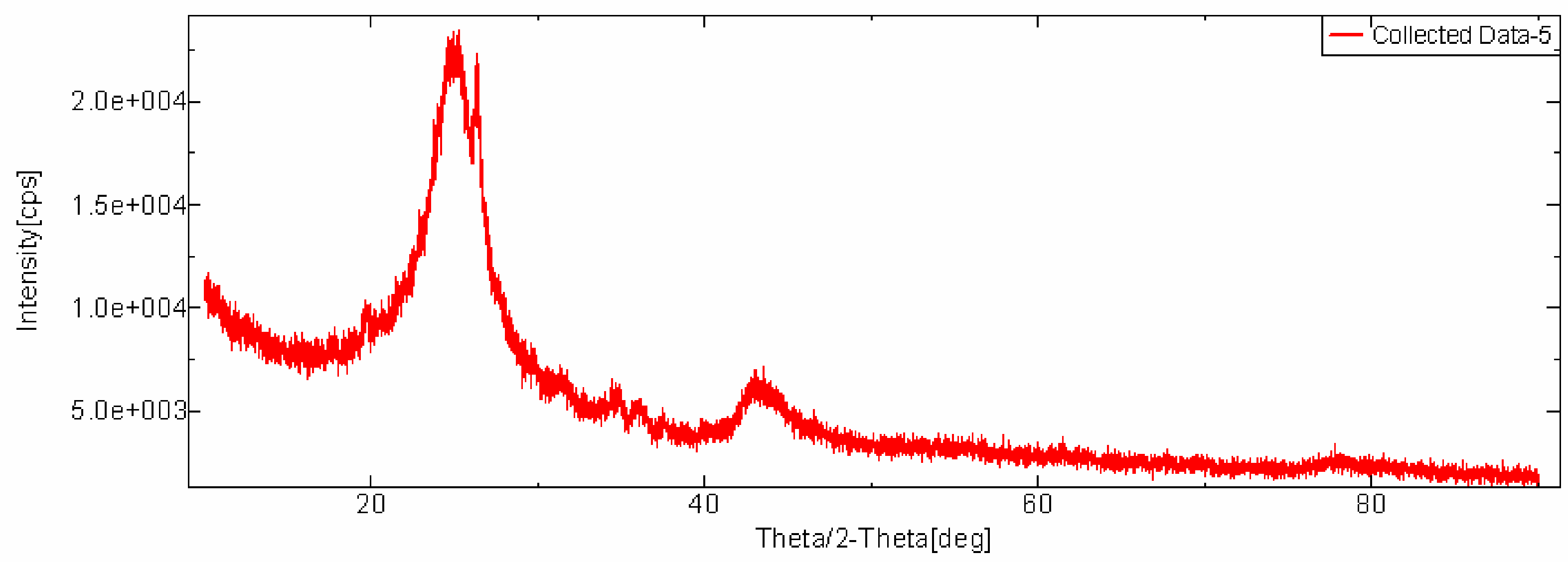
Phase name	Crystallite size(A)	Strain (%)
Graphite-2H	67.962393	0.000000e+000
Unknown	0.0000	0.0000



13. Film carbon (GO – oxid de grafit), strat C redus

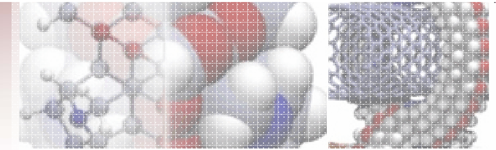
r-GOX SCW_T.ras / Collected Data-5

Sample Name	: None	Scan Mode	: CONTINUOUS	CBO selection slit	: PB
Comment	: None	Scan Speed	: 12.0000 deg/min	Incident parallel slit	: Soller_slit_5.0deg
		Scan Step	: 0.0100 deg	Incident slit	: 1.000mm
Date	: 04/12/11 12:54:20	Scan Axis	: Theta/2-Theta	Length limiting slit	: 10.0mm
Operator	: Admin	Scan Range	: 10.0000 - 90.0000 deg	Receiving slit # 1	: 1.000mm
X-Ray	: 45 kV , 200 mA	2-Theta	: 9.9950 deg	Filter	: None
Wavelength	: CuKa1 / 1.540593 A	Omega	: 4.9975 deg	Receiving optical device	: PSA_open
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg	Receiving parallel slit	: Soller_slit_5.0deg
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg	Receiving slit # 2	: 1.000mm
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg	Attenuator	: 1/10000
Detector	: SC-70			Diffracted beam mono.	: None
Memo	: None			Monochromator slit	: None
Optics Attribute	: Medium resolution parallel beam/RS				



SmartLab Guidance(TM) Admin(System Manager)

May-17-2011 15:34:17 Page-1



14. Filme PbS texturate, GIXRD, XRR

P54

12/9/2010 , 5:19:27 PM , Exp. Curve: P56_PBS_XRR_pre_2-Theta_Omec

Layer Structure : PbS//QuartzGlass

Layer	Material	Thickness [nm]	rel. Density	Roughness [nm]
1	PbS	13.55 ± 0.18	0.59 ± 0.00	3.85 ± 0.05
Sub.	QuartzGlass	-------------------	1.00 fix	-0.64 ± -----

Io : 8.8014E8 ± 2.99% Iu : 38.987 ± 0.826

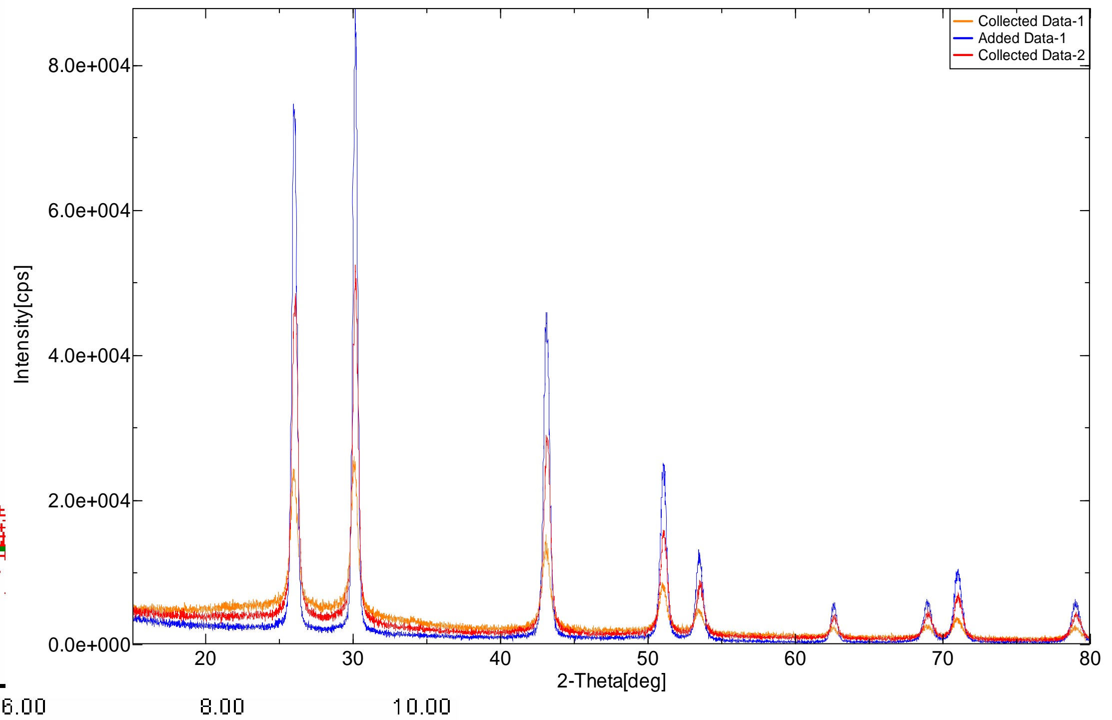
S1 : 0.29838 Delta : -0.0028 ± -----

Intensity

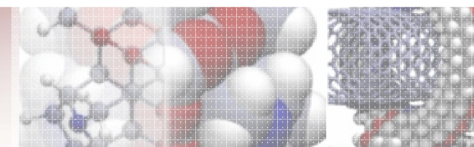
10^9 10^8 10^7 10^6 10^5 10^4 10^3 10^2 10^1

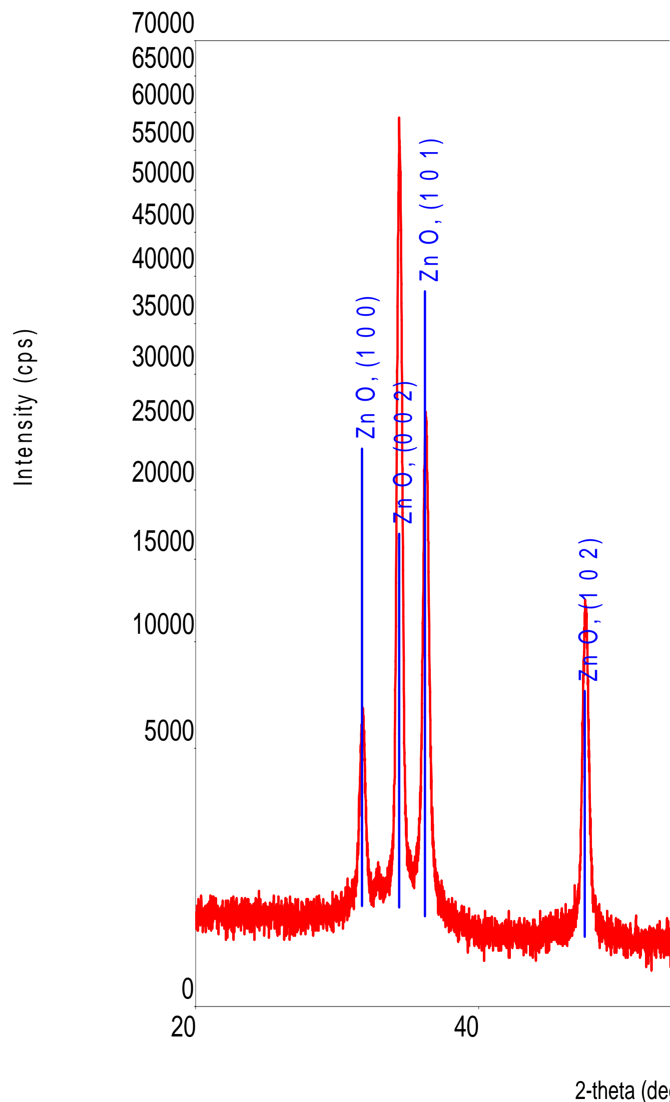
0 2.00 4.00 6.00 8.00 10.00

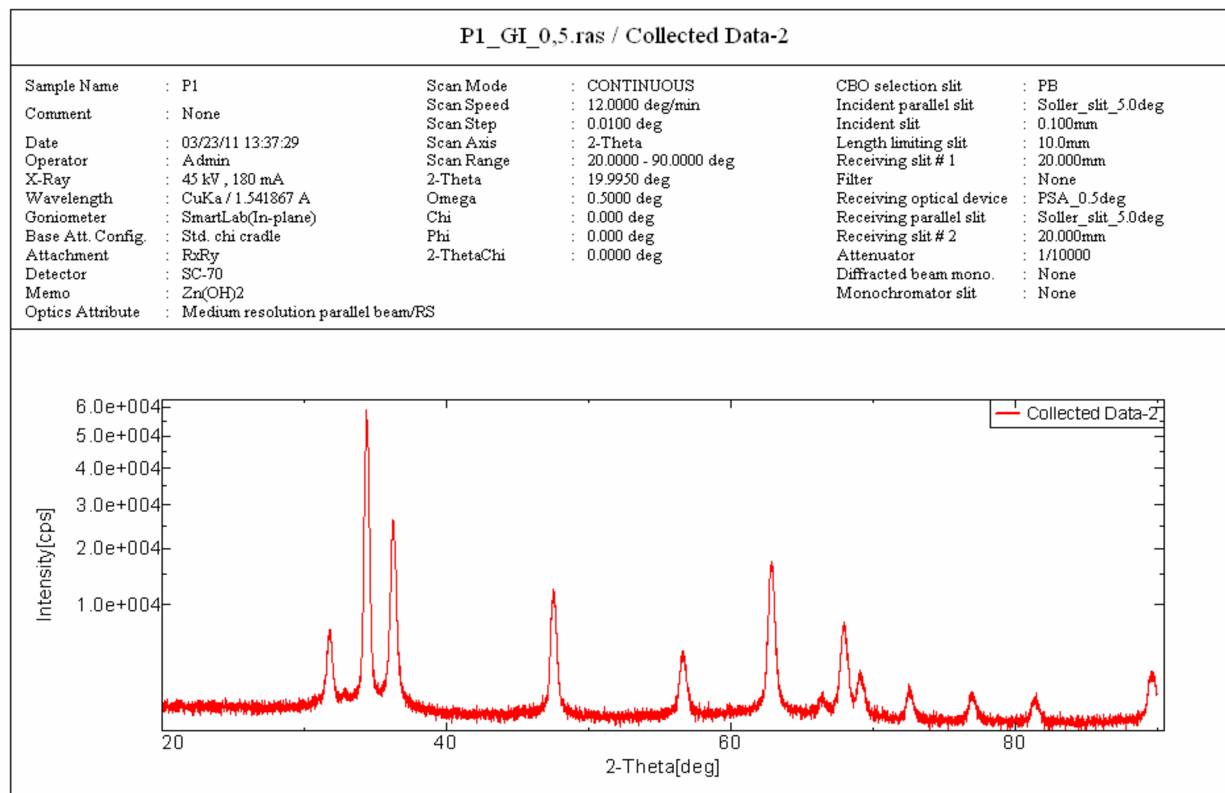
2Theta [degree]



15. Film ZnO, GIXRD



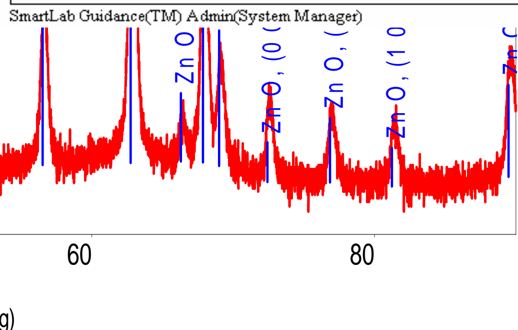




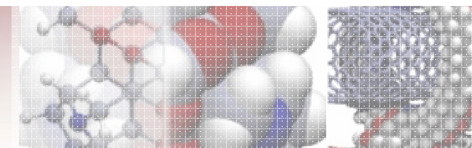
P1_GI_0,5.ras / Collected Data-2

Sample Name	: P1	Scan Mode	: CONTINUOUS	CBO selection slit	: PB
Comment	: None	Scan Speed	: 12.0000 deg/min	Incident parallel slit	: Soller_slit_5.0deg
		Scan Step	: 0.0100 deg	Incident slit	: 0.100mm
Date	: 03/23/11 13:37:29	Scan Axis	: 2-Theta	Length limiting slit	: 10.0mm
Operator	: Admin	Scan Range	: 20.0000 - 90.0000 deg	Receiving slit # 1	: 20.000mm
X-Ray	: 45 kV , 180 mA	2-Theta	: 19.9950 deg	Filter	: None
Wavelength	: CuKa / 1.541867 A	Omega	: 0.5000 deg	Receiving optical device	: PSA_0.5deg
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg	Receiving parallel slit	: Soller_slit_5.0deg
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg	Receiving slit # 2	: 20.000mm
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg	Attenuator	: 1/10000
Detector	: SC-70			Diffracted beam mono.	: None
Memo	: Zn(OH)2			Monochromator slit	: None
Optics Attribute	: Medium resolution parallel beam/RS				

SmartLab Guidance(TM) Admin(System Manager) May-17-2011 15:46:24 Page-1

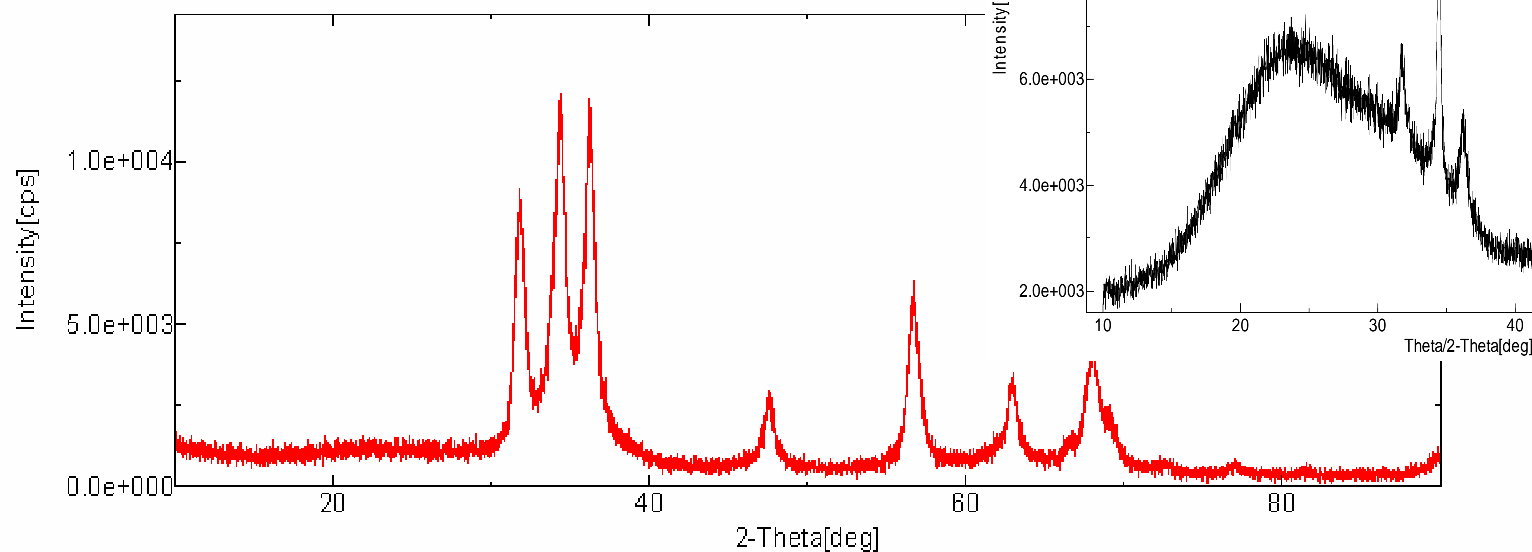


17. Nanofire de ZnO/Sticla, GIXRD+ WAXRD



P5_PB_GI.ras / Collected Data-1

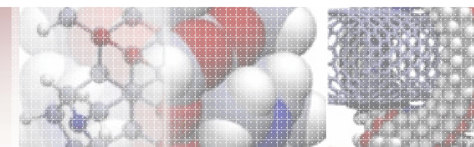
Sample Name	: P5	Scan Mode	: CONTINUOUS	CBO selection slit	: PB
Comment	: None	Scan Speed	: 12.0000 deg/min	Incident parallel slit	: Soller_slit_5.0deg
		Scan Step	: 0.0100 deg	Incident slit	: 0.100mm
Date	: 04/13/11 14:19:13	Scan Axis	: 2-Theta	Length limiting slit	: 10.0mm
Operator	: Admin	Scan Range	: 10.0000 - 90.0000 deg	Receiving slit # 1	: 20.000mm
X-Ray	: 45 kV , 200 mA	2-Theta	: 9.9950 deg		
Wavelength	: CuKa1 / 1.540593 A	Omega	: 0.5000 deg		
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg		
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg		
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg		
Detector	: SC-70				
Memo	: None				
Optics Attribute	: Medium resolution parallel beam/RS				



SmartLab Guidance(TM) Admin(System Manager) May-17-2011 15:48:48 Page-1

18. Pulbere ZnO, Proiect FP7 Nanosustain (D= 8.7nm)

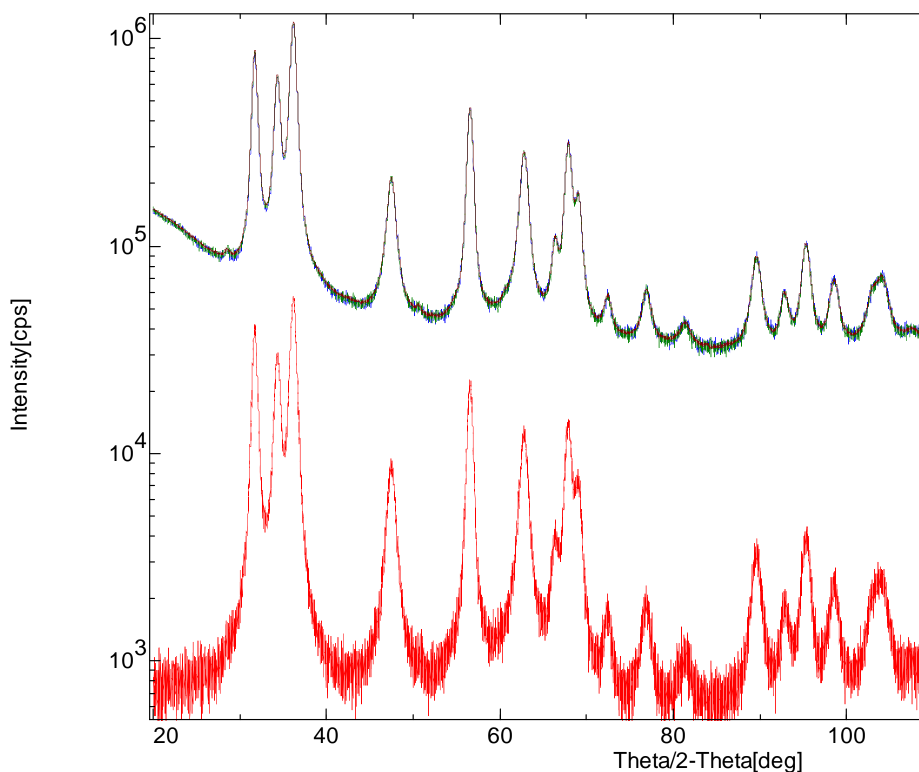
Comparatie detector 0D NaI (SC70) cu 1D (Dtex)



Crystallite size and lattice strain

Williamson-Hall method

Phase name	Crystallite size(A)	Strain (%)
Zinc Oxide	87(6)	0.20(19)

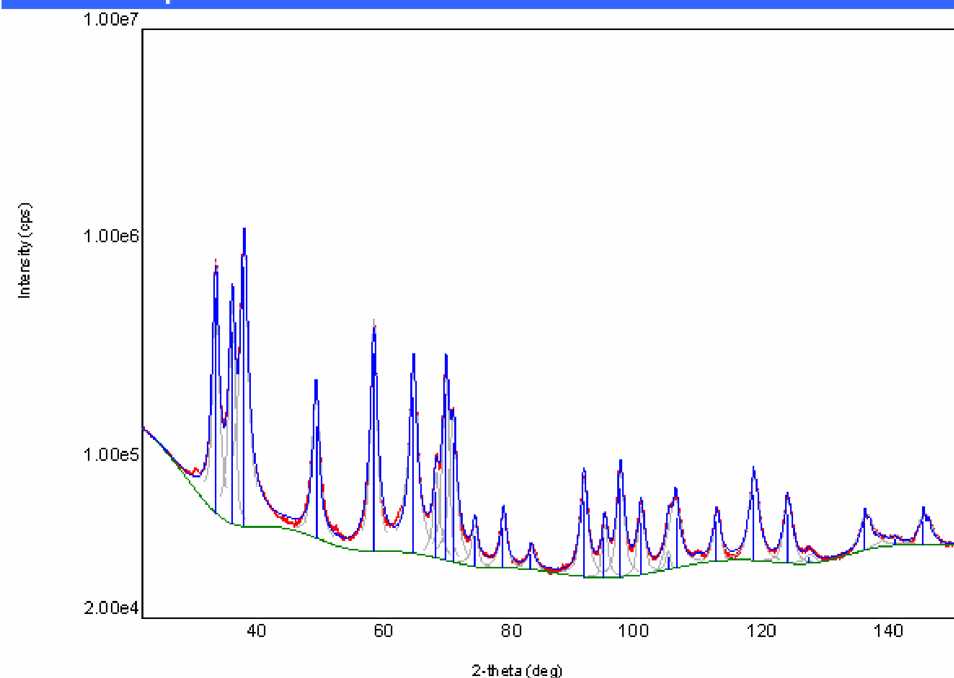


Analysis Results

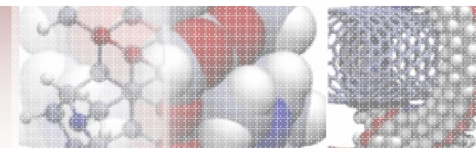
General Information

Analysis date	2/11/2011 8:23:55 PM		
Sample name	NRCWE 031, 203	Measurement date	
File name	NRCWE_031.asc	Operator	
Comment			

Measurement profile

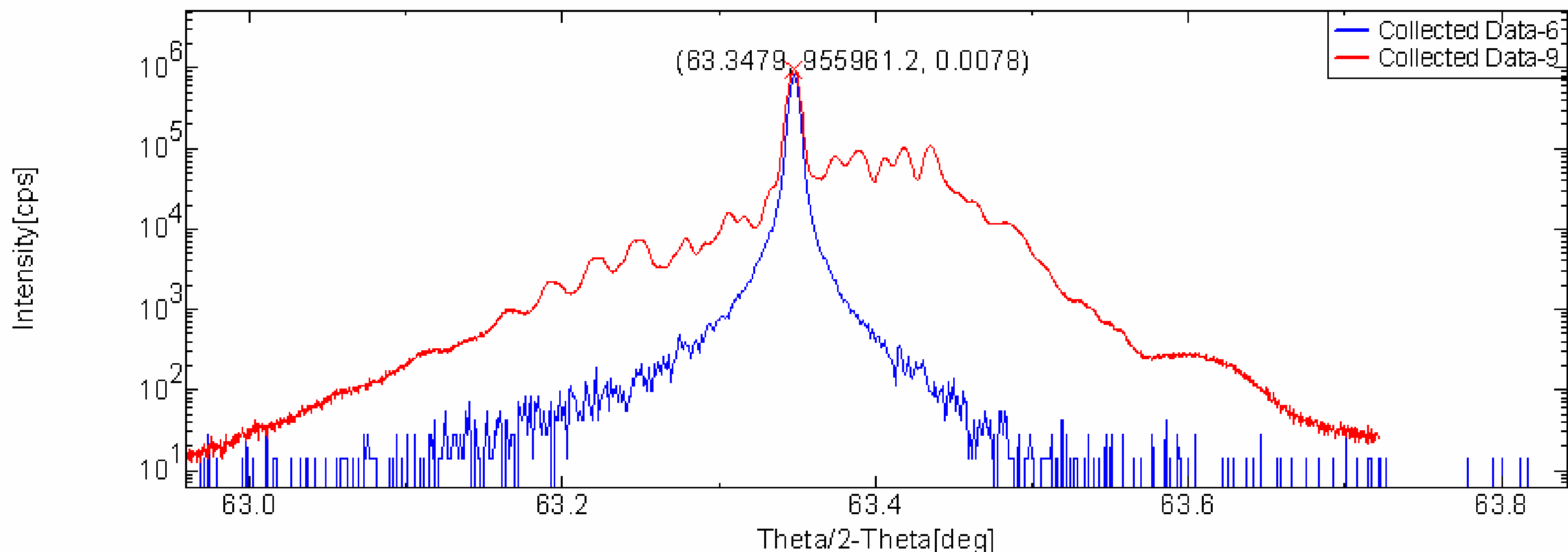


19. HBT InP/InGaAS, Comparatie rezolutie monocromatoare



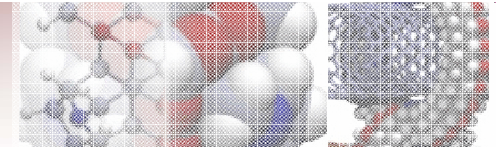
InP_npn_6l_b.ras / Collected Data-9

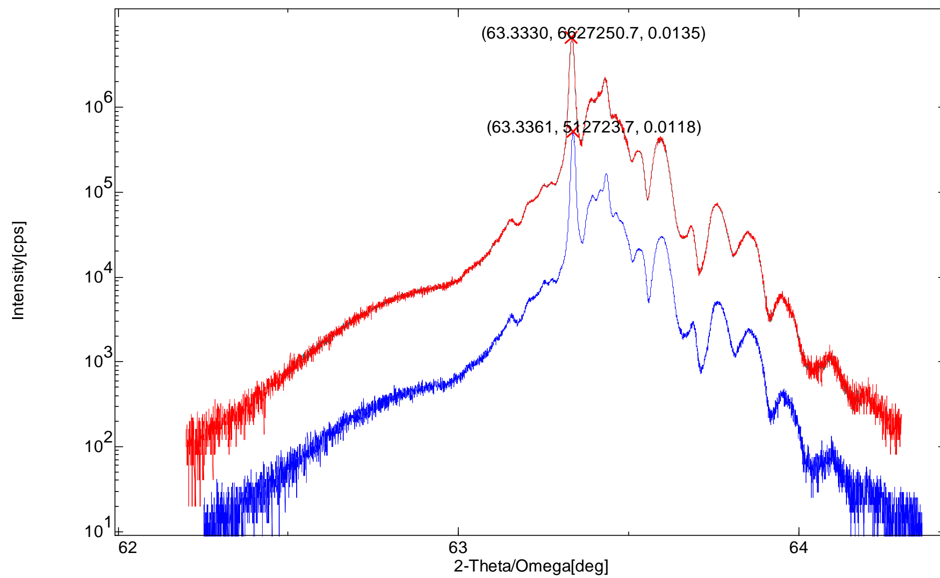
Sample Name	: None	Scan Mode	: CONTINUOUS	CBO selection slit	: PB
Comment	: None	Scan Speed	: 0.0100 deg/min	Incident optical device	: Ge(220)x4
		Scan Step	: 0.0004 deg	Incident parallel slit	: No_unit
Date	: 02/05/10 20:54:57	Scan Axis	: Theta/2-Theta	Incident slit	: 1.000mm
Operator	: Admin	Scan Range	: 62.9500 - 63.7400 deg	Length limiting slit	: 10.0mm
X-Ray	: 45 kV , 200 mA	2-Theta	: 62.9498 deg	Receiving slit # 1	: 1.000mm
Wavelength	: CuKa1 / 1.540593 A	Omega	: 31.4749 deg	Filter	: None
Goniometer	: SmartLab(In-plane)	Chi	: 0.000 deg	Receiving optical device	: Ge(220)x2
Base Att. Config.	: Std. chi cradle	Phi	: 0.000 deg	Receiving parallel slit	: Soller_slit_5.0deg
Attachment	: RxRy	2-ThetaChi	: 0.0000 deg	Receiving slit # 2	: 1.000mm
Detector	: SC-70			Attenuator	: Open
Memo	: None			Diffracted beam mono.	: None
Optics Attribute	: Ultra high res. parallel beam Ge(220)x4/RS			Monochromator slit	: None



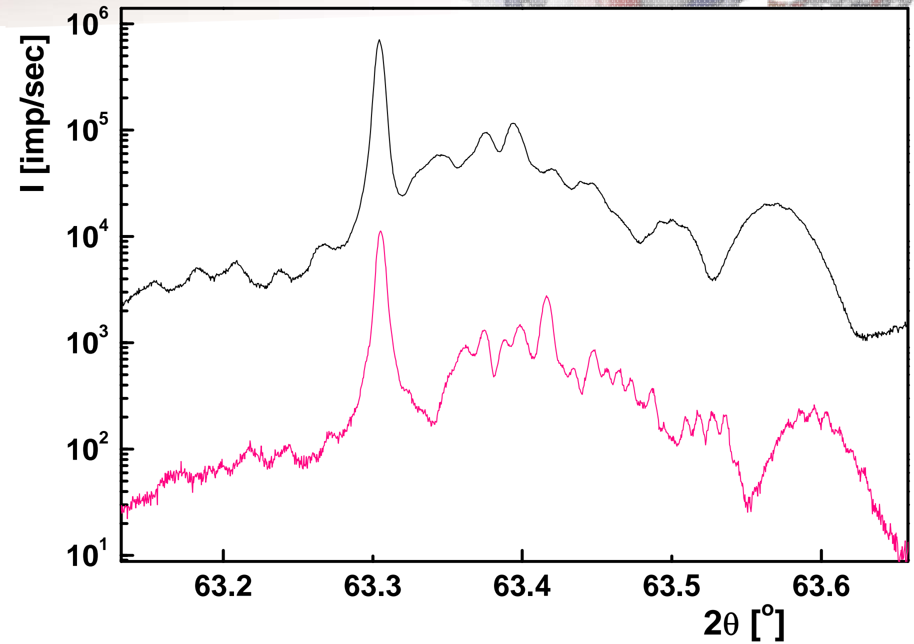
SmartLab Guidance(TM) Admin(System Manager)

May-17-2011 17:57:58 Page-1

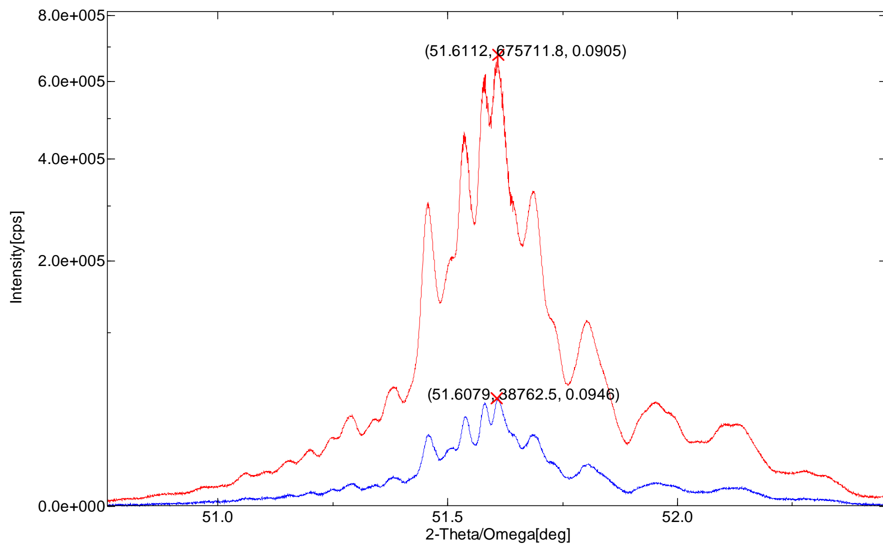




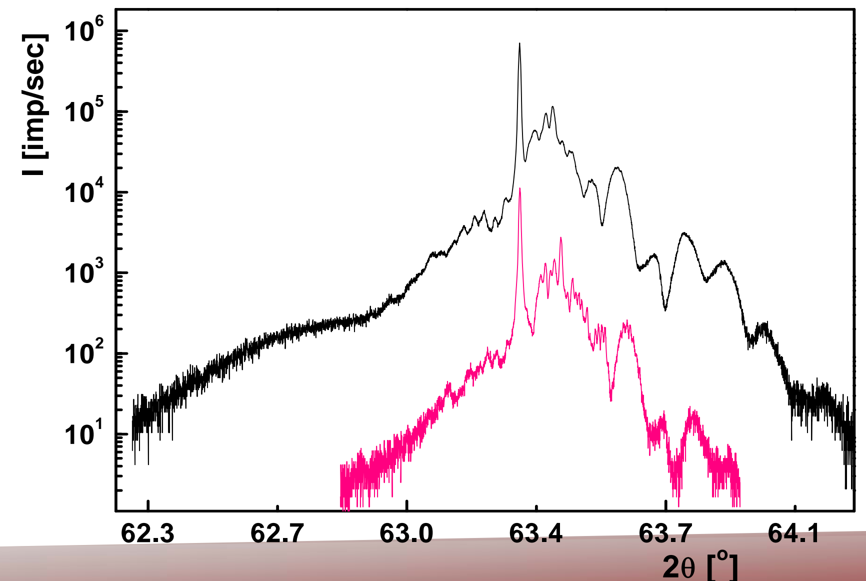
(63.3330, 6627250.7, 0.0135)
(63.3361, 512723.7, 0.0118)
Intensity[cps]
10^1
10^2
10^3
10^4
10^5
10^6
62
63
64
2-Theta/Omega[deg]



I [imp/sec]
10^1
10^2
10^3
10^4
10^5
10^6
63.2
63.3
63.4
63.5
63.6
2θ [°]

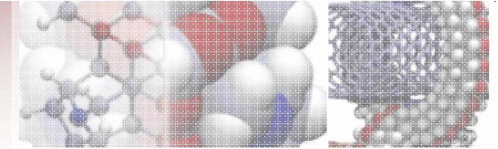


(51.6112, 675711.8, 0.0905)
(51.6079, 88762.5, 0.0946)
Intensity[cps]
0.0e+000
2.0e+005
4.0e+005
6.0e+005
8.0e+005
51.0
51.5
52.0
2-Theta/Omega[deg]



I [imp/sec]
10^1
10^2
10^3
10^4
10^5
10^6
62.3
62.7
63.0
63.4
63.7
64.1
2θ [°]

Concluzii

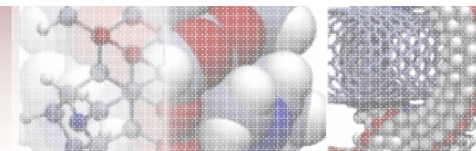


1. Metodele metrologice care folosesc difractia radiatiilor X

- sunt aplicabile unui spectru larg de materiale, procese si tehnologii,
- au un grad inalt de precizie si reproductibilitate
- se preteaza integrarii in linia de productie (fab-line, de ex. In industria semiconductorilor, farmaceutica, metalurgica,etc),
- necesita alegerea judicioasa a metodei de masura, a conditiilor experimentale si a metodelor (software) de prelucrare ulterioara si extragerea parametrilor fizici de interes.

2. Metoda metrologica de determinare a grosimii filmelor subtiri prin reflexia radiatiilor X - XRRare avantajul ca:

- Permite analiza filmelor subtiri cu grosimi de la 1nm (in unele cazuri de 0.1 nm) la cateva mii de nm
- Permite analiza rugozitatii si largimii interfetei (atribuita rugozitatii topografice si interdifuziei)
- Permite determinarea directa a densitatii filmului atunci cand compozitia e cunoscuta
- Permite controlul nedistructiv
- Este aplicabila unui domeniu larg de materiale, de la semiconductori, materiale magnetice, polimeri, indiferent de forma de cristalizare/starea de agregare.



Bibliografie

1. **X-ray Metrology In Semiconductor Manufacturing,** D. Keith Bowen; Brian K. Tanner**,** Publisher: CRC Press, ISBN: 0849339286 (0-8493-3928-6), ISBN 13: 9780849339288 (978-0-8493-3928-8)

2. "1100nm InGaAs/(Al)GaAs quantum dot lasers for high-power applications ",
E-M Pavelescu, C Gilfert, P Weinmann, **M Danila, A Dinescu**, M Jacob, M Kamp and J-P Reithmaier, **J. Phys. D: Appl. Phys. 44 (2011) 145104 (4pp),** doi:10.1088/0022-3727/44/14/145104, **EU project** WWW.BRIGHTER:EU, **financial support offered by the EU project MIMOMEMS (Ref. Nr. 202897)**

3. "Biodegradation of Poly(vinyl alcohol) and Bacterial Cellulose Composites by Aspergillus niger", Anicuta Stoica-Guzun, Luiza Jecu , Amalia Gheorghe, Iuliana Raut ,Marta Stroescu, Marius Ghiurea, **Mihai Danila**, Iuliana Jipa, Victor Fruth, **J Polym Environ**, , **DOI 10.1007/s10924-010-0257-1, Online ISSN pg 1566-2543, 2010**, **Study supported by the project PNCDI II 32-115,. with financial support from the European Social Fund, POSDRU/89/1.5/S/54785 project:"Postdoctoral Program for Advanced Research in the field of nanomaterials"**