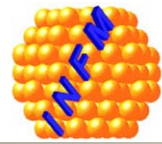


SOI prin smart-cut. Caracterizarea TEM-HRTEM a defectelor structurale induse in Si prin hidrogenare in plasma.

Dr. Corneliu GHICA, Dr. Leona NISTOR

Proiect IDEI, Contract Nr. 233/2007

1. C. Ghica, L. C. Nistor, H. Bender, O. Richard, G. Van Tendeloo, A. Ulyashin
Philosophical Magazine **86**, 5137-5151 (2006).
2. C. Ghica, L. C. Nistor, H. Bender, O. Richard, G. Van Tendeloo, A. Ulyashin
Journal of Physics D: Applied Physics **40**, 395-400 (2007).
3. C. Ghica, L. C. Nistor, M. Stefan, D. Ghica, B. Mironov, S. Vizireanu, A. Moldovan, M. Dinescu
Applied Physics A **98**, 777-785 (2010)

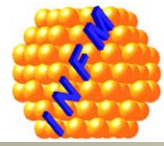


Axioma 1

Caracterizarea TEM/HRTEM este o conditie necesara in domeniul dimensiunilor nanometrice.

Axioma 2

Un microscop electronic TEM/HRTEM \neq rigla scumpa (1-2 M€).

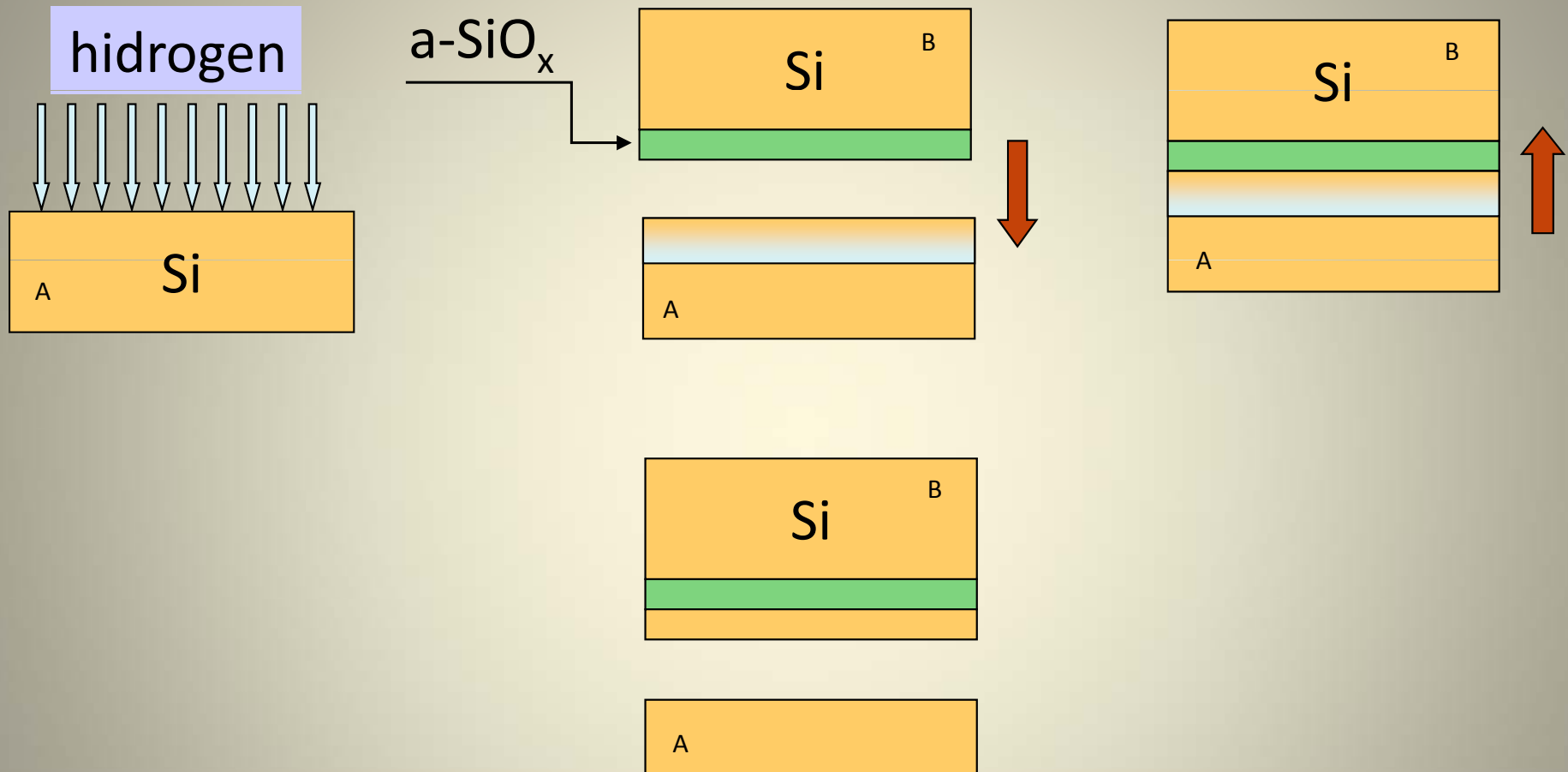
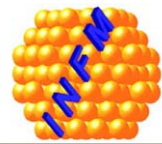


Intrebare:

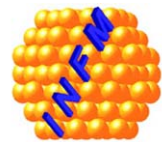
Se poate depune un strat monocristalin peste un substrat amorf?

Raspuns:

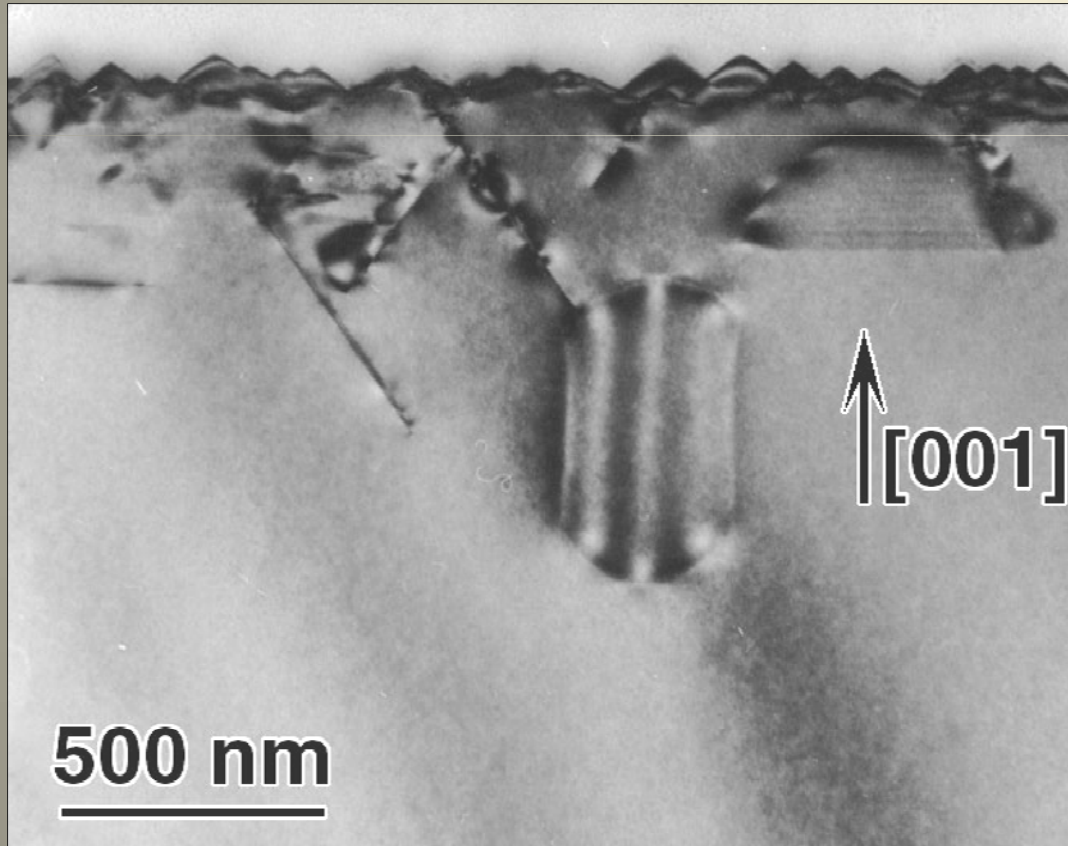
Da, prin tehnica smart-cut.



Prezentare schematica a procesului “smart-cut”.



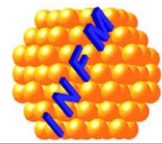
Tratamentul Si in plasma RF de hidrogen



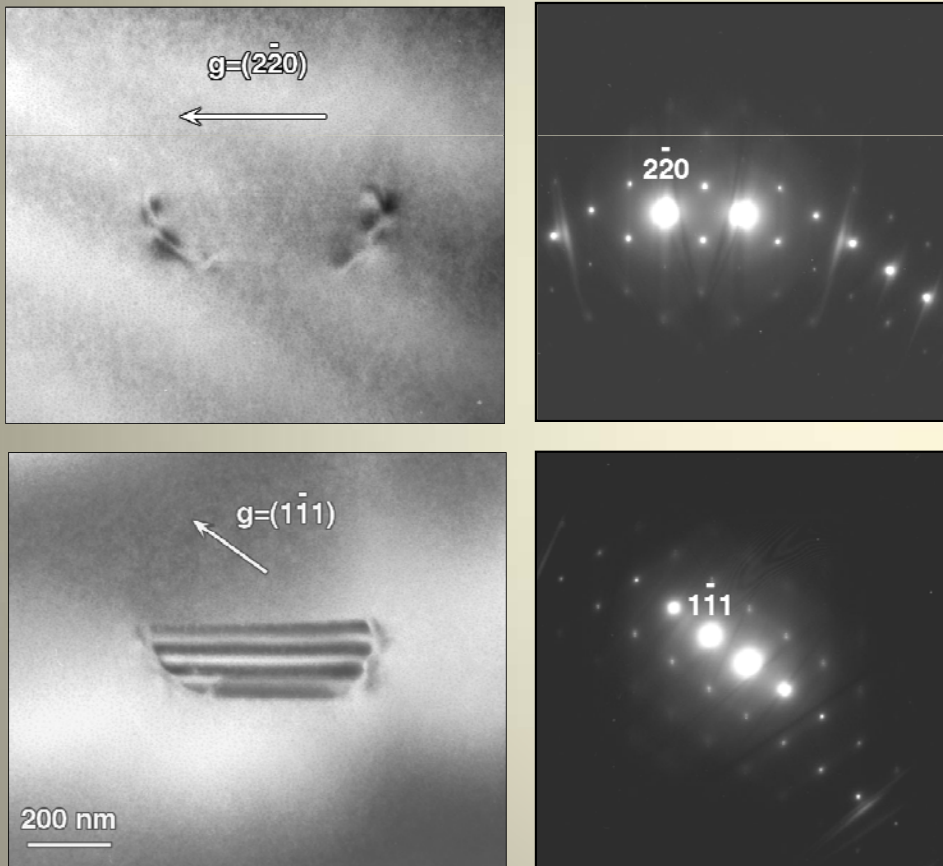
Imagine XTEM* a unei probe de Si hidrogenate in plasma RF:

- Rugozitatea suprafetei
- Formarea de defecte sub suprafata (adancime > 1 μm !).

* INCDFM este, in momentul de fata, **singura locatie din Romania** unde se prepara in mod curent probe XTEM, datorita echipamentelor si in special a know-how-ului existent.



I. Defecte planare {111} in Si hydrogenat – studiu CTEM

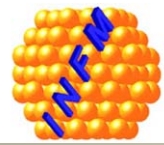


Analiza contrastului Bragg:

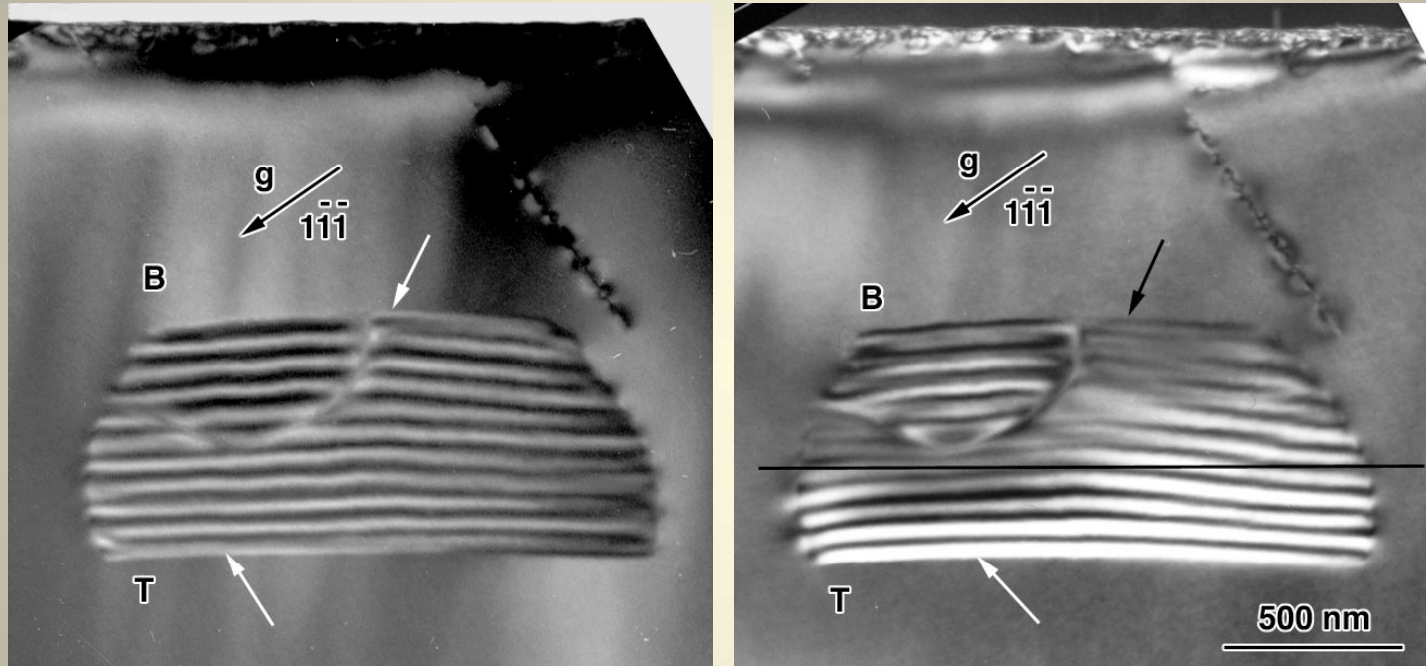
- Criteriul invizibilitatii

$\Rightarrow \mathbf{R} \perp (2-20)$

$\Rightarrow \mathbf{R} \perp \text{planul de habit } (111)$

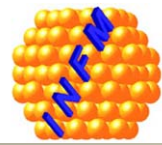


I. Defecte planare {111} in Si hidrogenat – studiu CTEM

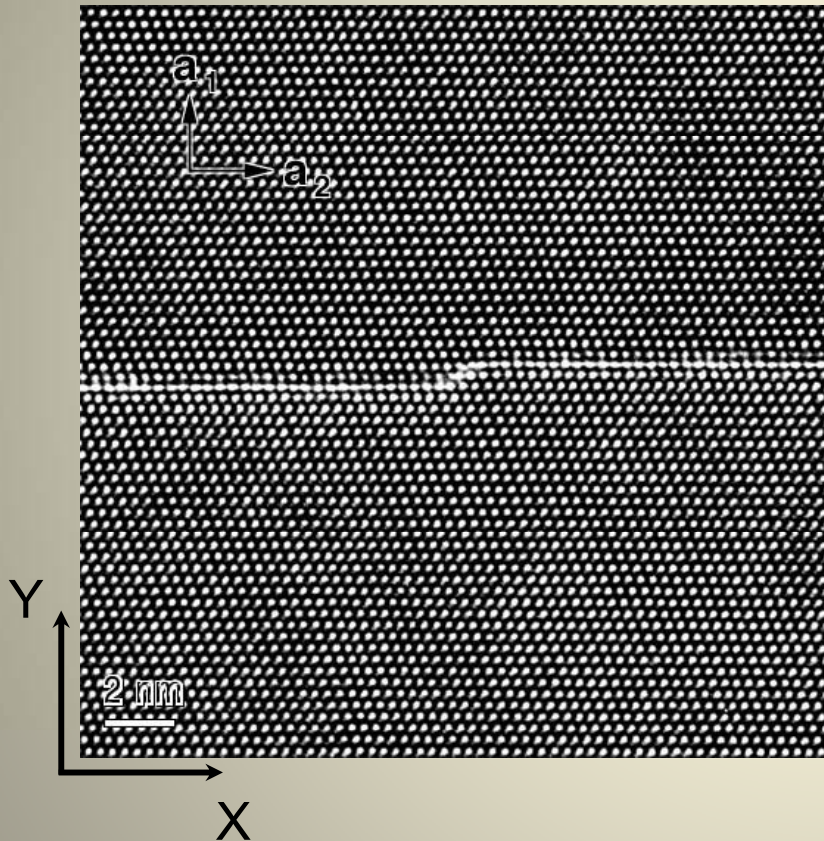


Analiza contrastului Bragg:

- Defect planar de tip {111} cu caracter intrinsec (plan {111} lipsa)
- Plan de habit: (111)
- Defectul migreaza la plane (111) invecinate



I. Defecte planare {111} in Si hidrogenat – studiu QHRTEM

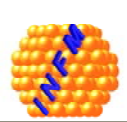


Analiza Fourier a imaginii HRTEM prin metoda fazei geometrice:

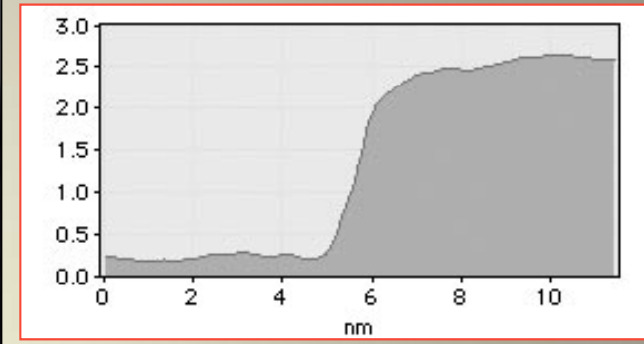
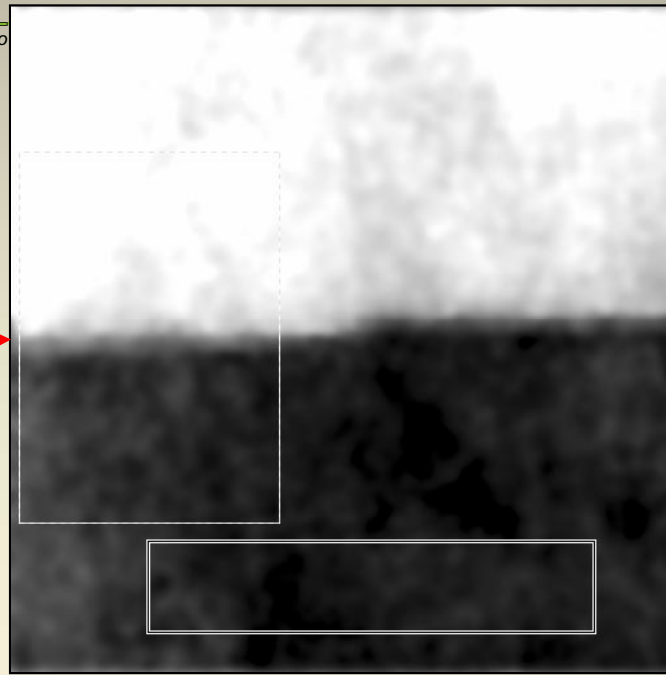
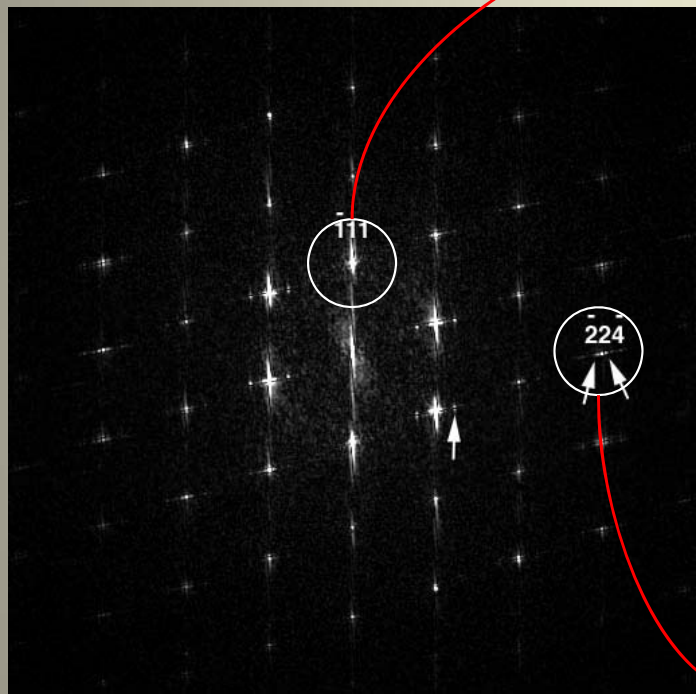
$$I(\mathbf{r}) = \sum_{\mathbf{g}} I_{\mathbf{g}}(\mathbf{r}) \exp(2\pi i \mathbf{g} \cdot \mathbf{r})$$

$$I_{\mathbf{g}}(\mathbf{r}) = A_{\mathbf{g}}(\mathbf{r}) \exp(i \phi_{\mathbf{g}}(\mathbf{r}))$$

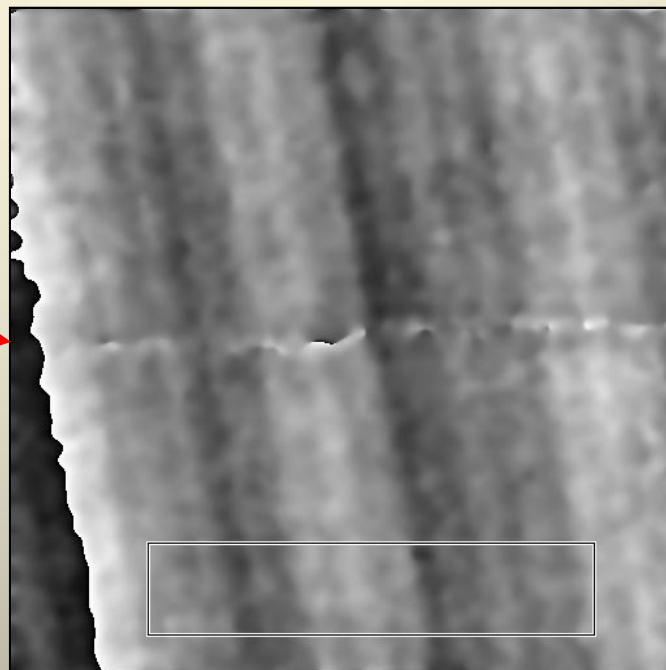
$$\phi_{\mathbf{g}}(\mathbf{r}) = -2\pi \mathbf{g} \cdot \mathbf{u}(\mathbf{r}) \quad \text{or} \quad \phi_{\mathbf{g}}(\mathbf{r}) = 2\pi \Delta \mathbf{g} \cdot \mathbf{r}$$

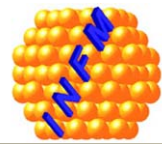


Imagini de faza geometrica obtinute prin FFT⁻¹



$$\Delta\Phi = 0.72\pi \pm 0.044 \text{ rad}$$

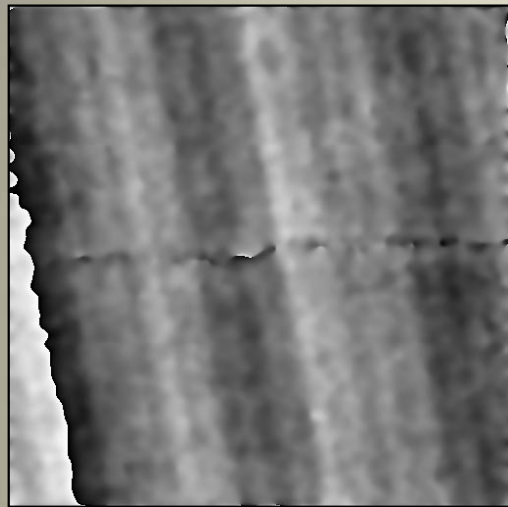




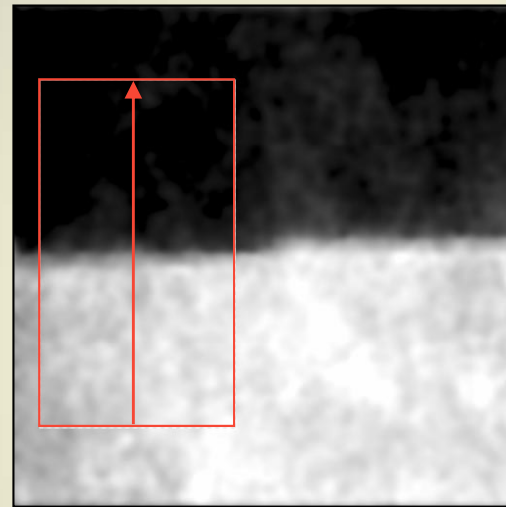
I. Defecte planare {111} in Si hidrogenat – studiu QHRTEM

Calculul campului de deplasari: $\mathbf{u}(\mathbf{r}) = (-1/2\pi) [\phi_{\mathbf{g}_1}(\mathbf{r})\mathbf{a}_1 + \phi_{\mathbf{g}_2}(\mathbf{r})\mathbf{a}_2]$

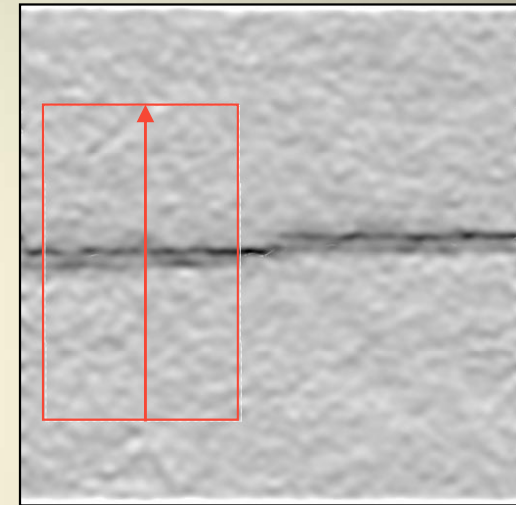
$$\begin{aligned} \mathbf{g}_1 &= [-111]^* & \mathbf{a}_1 &= 1/3[-111] \\ \mathbf{g}_2 &= [-22-4]^* & \mathbf{a}_2 &= 1/12[-11-2] \end{aligned}$$



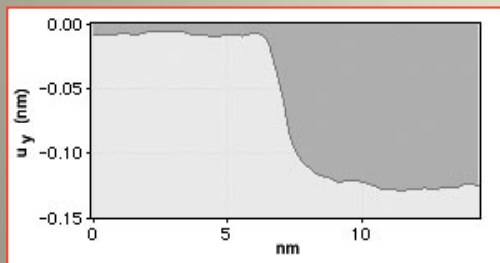
u_x



u_y

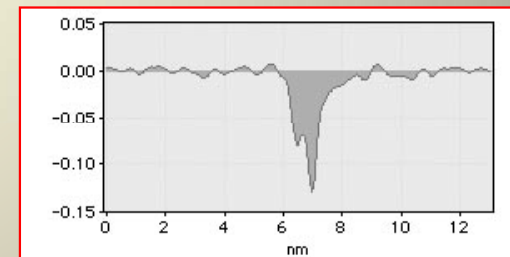


$$\epsilon_{yy} = \partial u_y / \partial y$$

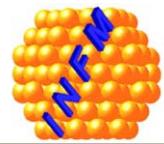


$$u_y = -0.116 \pm 0.002 \text{ nm}$$

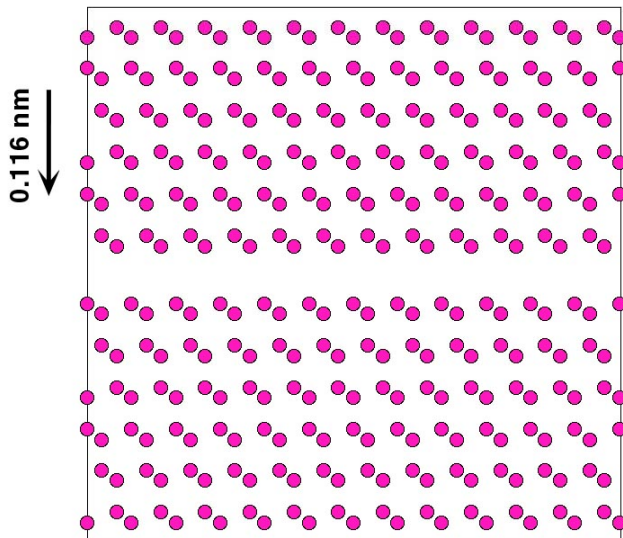
Profilul liniar mediat al u_y



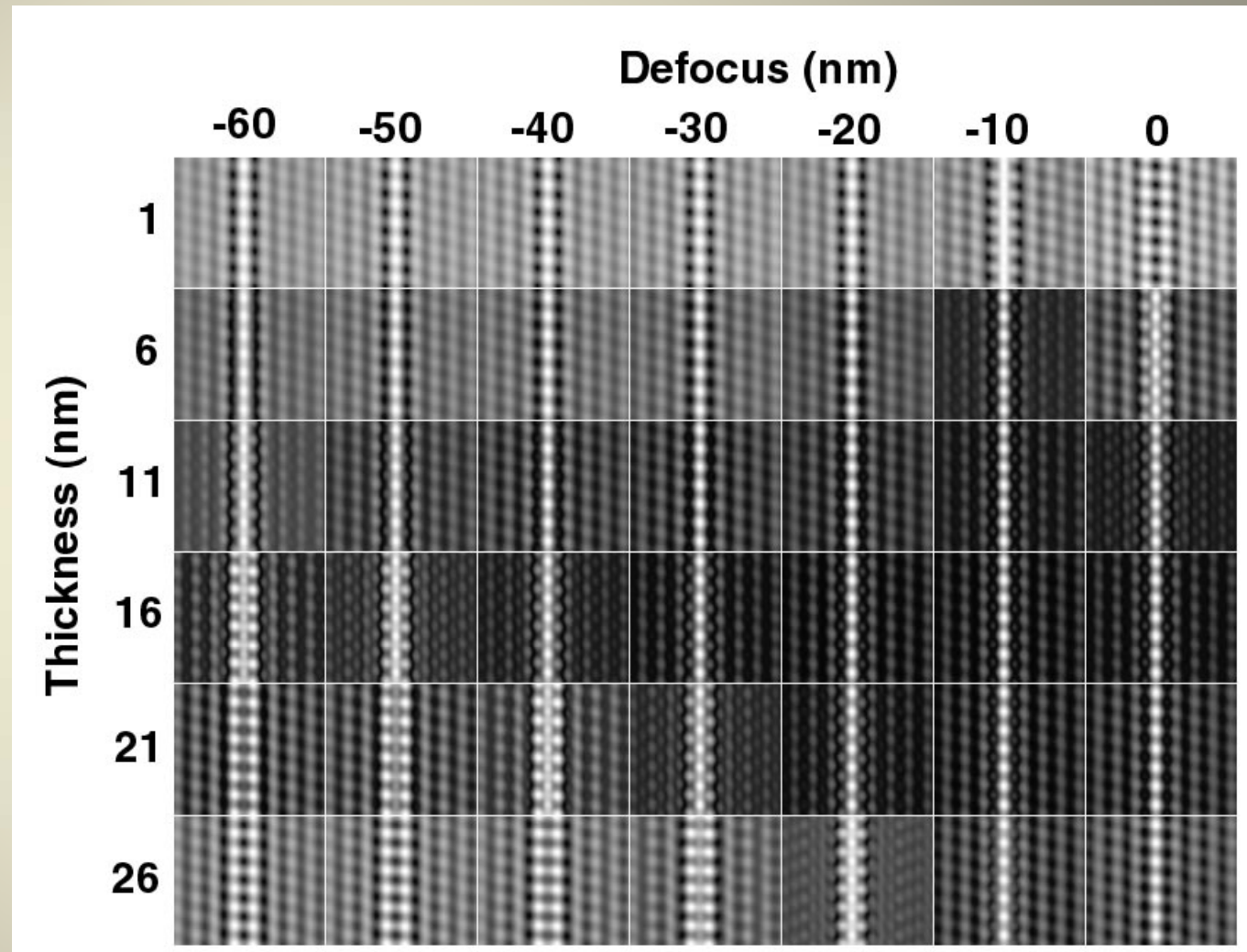
Profilul liniar mediat al ϵ_{yy}



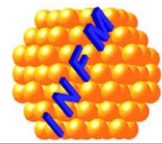
I. Defecte planare {111} in Si hidrogenat – studiu QHRTEM



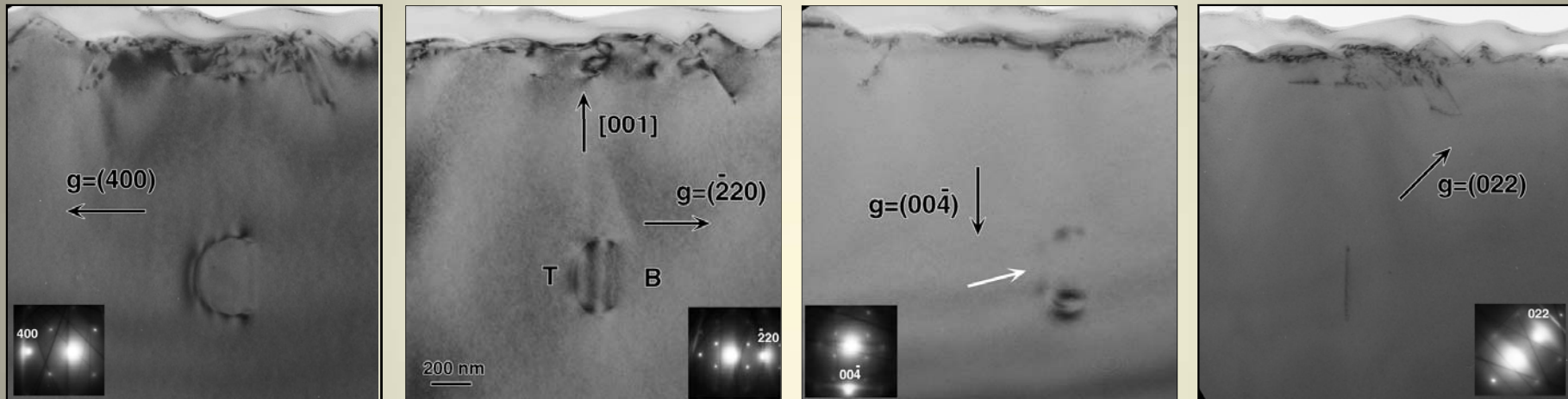
Model structural al defectului {111}.



Matrice de imagini HRTEM simulate ale defectului {111}.

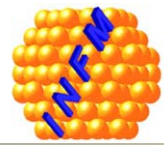


II. Defecte planare {100} in Si hidrogenat – studiu CTEM

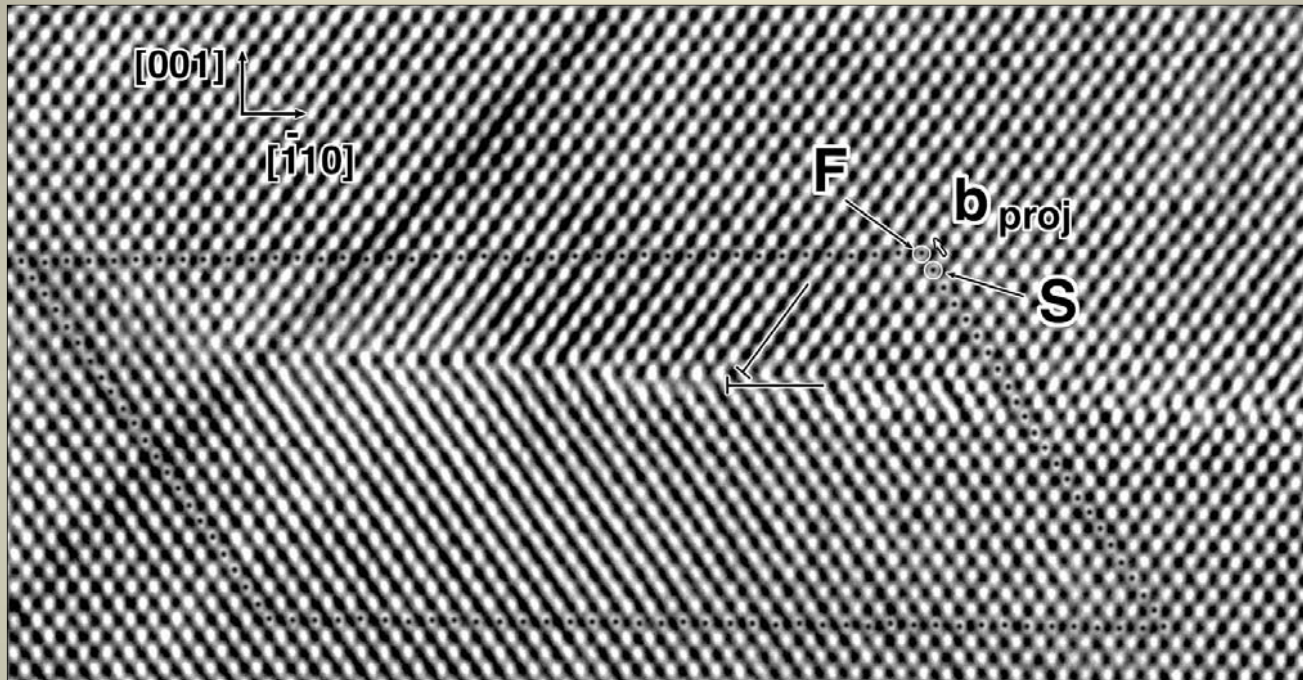


Analiza contrastului Bragg:

- Exista (!) defecte planare de tip {001} in Si hidrogenat in plasma RF
- Plan de habit: (010)
- Defectul planar este limitat de o bucla de dislocatie prismatica, cu vector Burgers $\mathbf{b} \cong 1/2[-1 \ 1 \ 0]$ sau $1/2[1 \ -1 \ 0]$



II. Defecte planare {100} in Si hidrogenat – studiu HRTEM



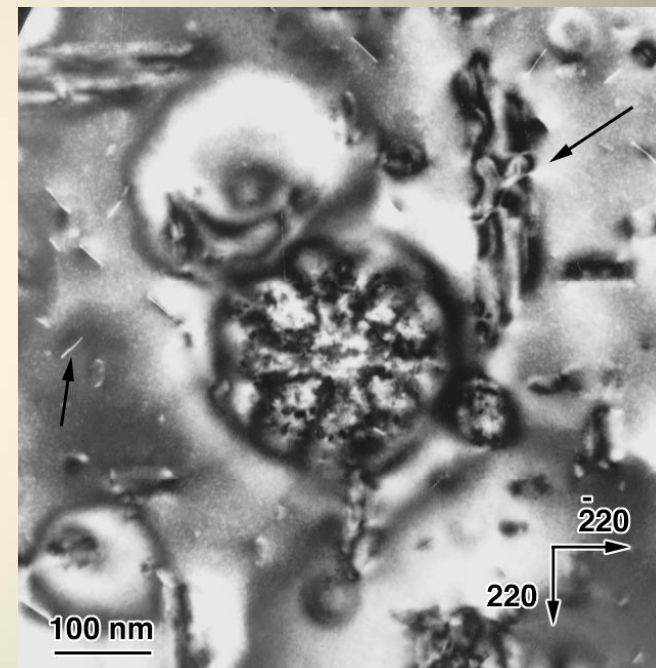
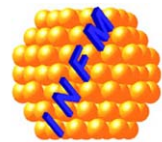
$$\mathbf{B} = [110]$$

Determinarea vectorului Burgers in conventia RHSF

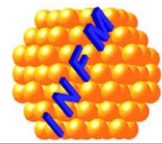
$\Rightarrow \mathbf{b}_{\text{proj}} = a/4 [1-12]$, proiectia vectorului $a/2 [101]$ pe planul (110)

\Rightarrow ca si in cazul unei dislocatii perfecte de 60°

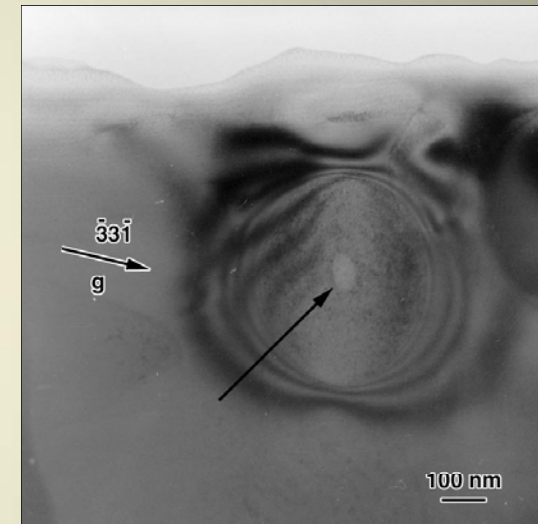
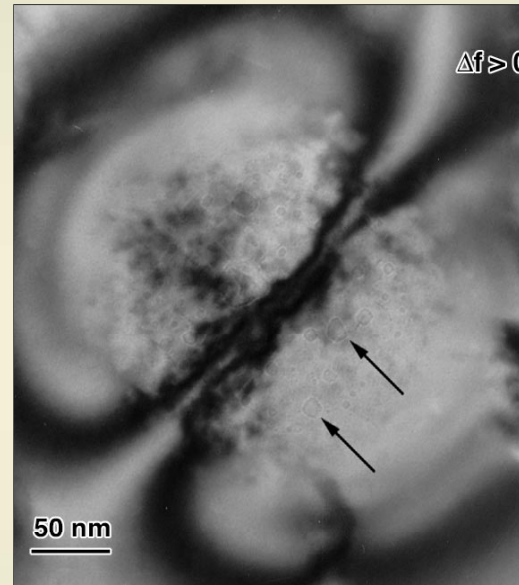
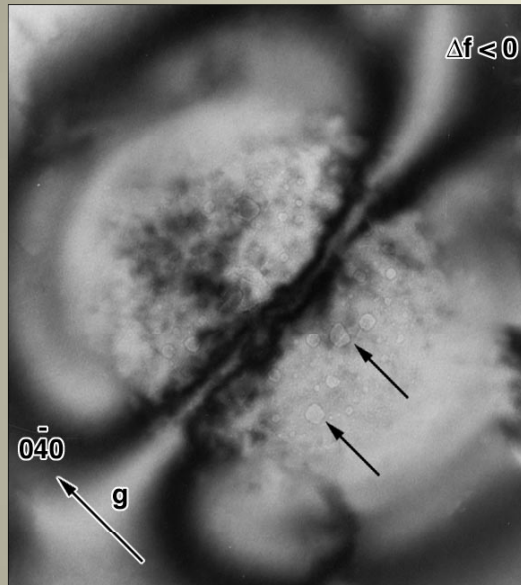
Defect metastabil cu caracter difuz.



Contrast de difracție bizar în probe de Si hidrogenate, $\mathbf{B}=[001]$.

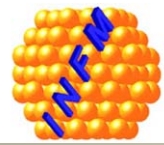


III. Nanocavitati aglomerate sau izolate in Si hydrogenat.

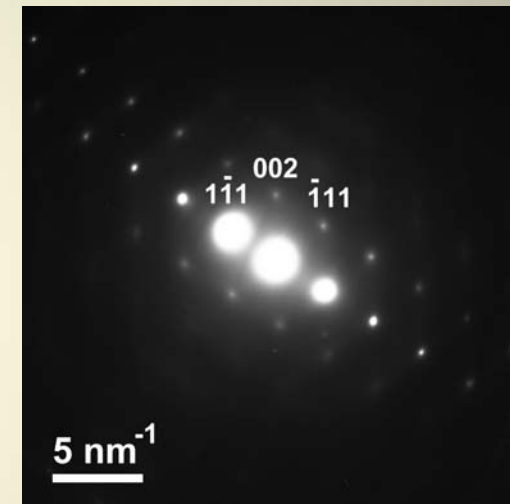
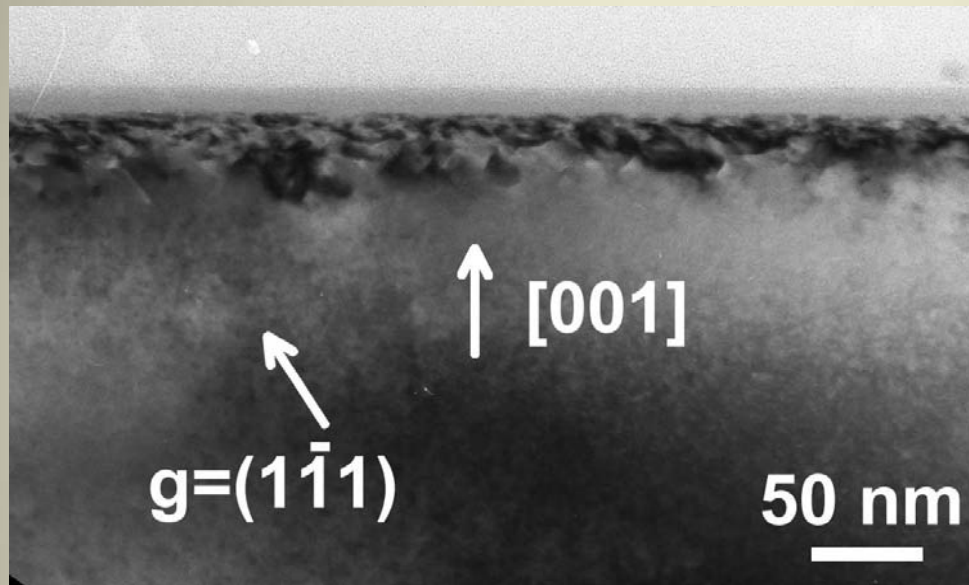


Identificarea nanocavitatilor (5-20 nm) prin variatii de focalizare $\Delta f > 0$ si $\Delta f < 0$.

Nanocavitate si contrastul campului elastic asociat in vedere transversala ($\mathbf{B} \cong [110]$).

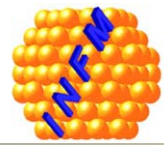


Optimizarea tratamentului in plasma



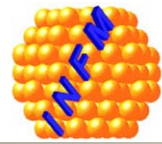
Defecte planare $\{111\}$ si $\{100\}$ in placheta de Si tratata in plasma RF de hidrogen in conditii optimizate.

Grosime strat defectat <50 nm, de la $>1\mu\text{m}$!



Concluzii

1. Tratamentul Si in plasma RF de hidrogen are 2 efecte: corodarea suprafetei si inducerea de defecte structurale specifice sub suprafata.
2. Defectele de tip $\{111\}$ au caracter intrinsec si prezinta particularitati datorate decorarii cu hidrogen.
3. Probele de Si hidrogenate contin defecte planare de tip $\{001\}$ metastabile inexistente in materiale cu structura diamantului.
4. Nanocavitati izolate sau aglomerate.
5. Tratament in plasma optimizat \Rightarrow premise pentru exfolierea prin smart-cut a unor straturi <50 nm.



**INSTITUTUL NATIONAL DE CERCETARE
DEZVOLTARE PENTRU FIZICA MATERIALELOR**

Strada Atomistilor 105 bis, 077125 Magurele-Ilfov, C.P. MG-7

Telefon: +40(0)21 3690185, Fax: +40(0)21 3690177, email: pintilie@infim.ro, <http://www.infim.ro>

Va multumesc pentru atentie!