ESRF	**Experiment title: Strain and morphology of Silicon nanowires superlattices grown in nanoporous alumina template investigated by Grazing Incidence X ray Diffraction and GISAXS**	**Experiment number**: 02 02 806
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Report:

GIXD on high-density silicon nanowire arrays was performed in the light of synchrotron radiation at an energy E=10.8keV (λ=0.1148nm) in order to verify the nanowire crystalline quality and orientation. Figure 1 display SEM images from quasi perfect SiNW array growth confined in (a) and after etching of (b) the nanoporous alumina template, while Figure 2a displays a θ-2θ diffraction pattern acquired near the (−440) reflection of the silicon substrate at q=5.657 nm^{-1}, with q as the scattering vector. Diffraction experiments were carried out using the GIXD geometry to avoid complete overload of the signal by the substrate. Two peaks are clearly visible in Figure 2, revealing the contribution of the substrate at q≈5.657nm−1 and one of the nanowires at a lower q. The presence of a nanowire peak ensures that the observed nanowires are crystalline and oriented in the same crystallographic direction than the substrate. Thus, the diffracting nanowires are in epitaxy with the substrate, and their crystallographic growth direction is [100] instead of the usual [111] direction. The confined growth therefore leads to silicon nanowires oriented in a different crystallographic direction than their preferential one without affecting their crystalline quality. The fit of the GIXD pattern by Pearson VII phenomenological functions shows the presence of multiple satellite peaks on both sides of the nanowires' contribution. The presence of these satellites is due to the constant diameter of the nanowires within the array. The GIXD measurements also highlight the presence of a mechanical strain in the diffracting nanowires revealed by the difference in the scattering vector of the nanowire and substrate peaks. The lattice mismatch parameter expressed as $\Delta a/a=(a_{SiNWs}-a_{Sub})/a_{Sub}$ can indeed be related to the shift of the scattering vector q. Since the nanowires' diffraction peak appears at a lower scattering vector than the substrate one, the silicon lattice parameter is slightly dilated in the nanowires compared to bulk silicon. The calculated strain is $\Delta a/a=1.9\times10^{-3}$ which is one order of magnitude greater than for gold-catalyzed silicon nanowires which grew freely. This increased strain could be explained by the forced growth in the nonpreferential [100] crystallographic direction or by the effects at the interface between the growing nanowires and their Al2O3 growth template, but this still needs further investigation. We have also measure this strain for GeNW (Figure 2b). The second part of the experiment has been devoted to the morpholgy investigation. On the GISAXS images of (1 0 0) and (1 1 0) and their profile according to qy shown in Figure 3, we observe a large number of rods (respectively 5 and 18 rods). Such measurements was then performed for different in-plane angle of rotation μ. (table).

Publication(s):

- L Dupré, T Gorisse, A. Letrouit-Lebranchu T. Bernardin, P. Gentile, H. Renevier, D Buttard, Nanoscale Res. Lett. 8 123 (2013)
- T. Gorisse, PhD thesis Université de Grenoble, 28/03/2014.

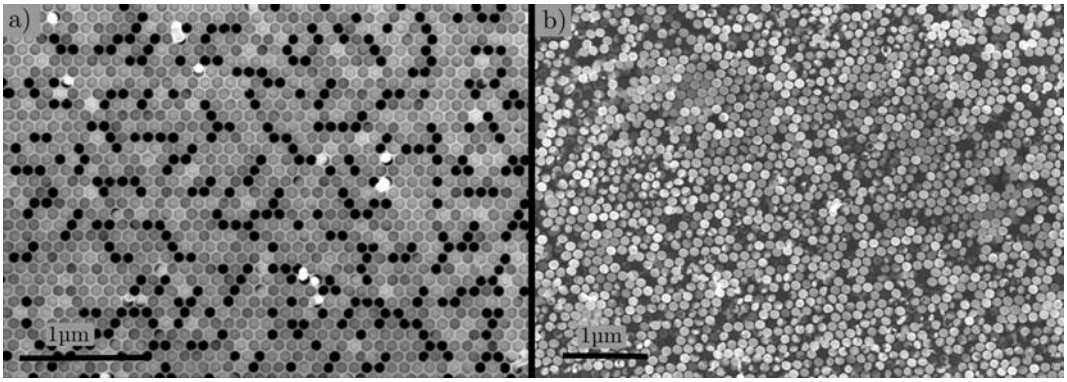

Figure 1. *SEM image in top-view of an array of nanowires, a) with alumina, b) and without.*

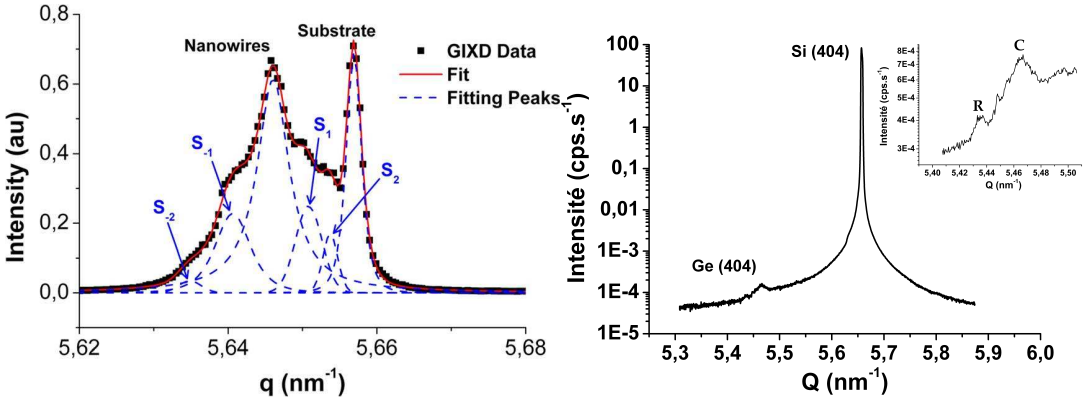

Figure 2 *Grazing incidence X-ray diffraction of (a) a silicon nanowire array grown on a Si (100) substrate near the (−440) reflection of the substrate and (b) germanium nanowire array grown on a silicon substrate. The fit of the diffraction pattern reveals satellites of the nanowires' peak (labeled S−2, S−1, S1, and S2) due to the good diameter homogeneity of the array.*

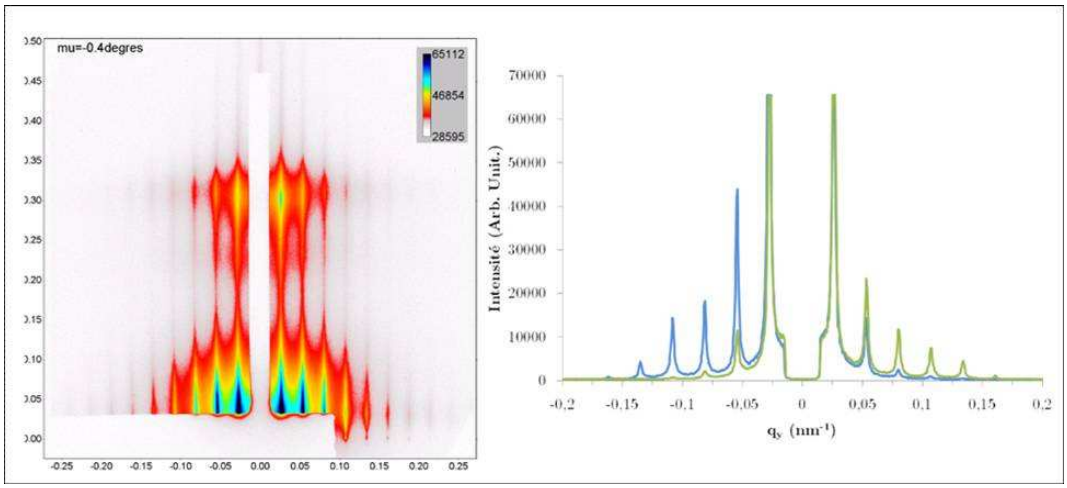

Figure 3 *Scattering image of a silicon nanowire arrays grown in the highly-organized alumina, images corresponding to the plane (1 0 0) and q_y cross section on rods.*

	Theory		Sample	
	Angle	Distance (nm)	Angle (°)	Distance (nm)
(1 0 0)	0	227,8	0	234
			8,2	35,6
(1 5 0)	10	40,9	10	41,6
			12,2	50,5
(1 3 0)	14	63,2	15,6	32,2
(1 2 0)	20	86,1	19,1	85,9
			21,5	26,5
(1 4 0)	23	49,7	24,5	32,7
(1 1 0)	30	131,5	30	128,8

Tableau 19 : Scattering of an arrays of silicon nanowires, Comparison of theoretical and measured angles µ and inter-rod distances (in nm).