STRAIN-INDUCED NANO-PATTERNING OF SILICON (001) SUBSTRATE

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The use of pre-patterned surfaces is a promising way to achieve a well ordered lateral organization of nanostructures. Indeed, parallel self assembling techniques, such as Stranski-Krastanov growth mode, lead to poorly ordered structures, with a quite large size distribution. Serial techniques, like e-beam lithography or atomic manipulation with scanning tunneling microscopes are very slow on large areas. To overcome these difficulties, we study a method to pattern substrates (1), with a controlled periodicity at the nanometer-scale, that can be applied on the full wafer.

Two "twin" surfaces of Si(001), produced by the splitting of a single wafer are bonded together (2). The in-plane rotation angle between the two crystals defines a square network of screw dislocations. The periodicity of the network is related to the rotation angle by Frank's formula. It is therefore possible to tune the periodicity of the dislocation network from few nanometers (<10° of rotation) up to 2.2 µm (~0.01° of rotation). Indeed, we achieve to control the rotation angle with a precision of 0.01°. Moreover, by bonding twin surfaces at low rotation angle, there is almost no flexion disorientation between the two crystals. Consequently, there is no mixed dislocation network (induced by the flexion with wafer bonding), but only some mixed dislocation lines, coming from residual steps at the bonding interface. The density of these dislocation lines is low (as shown by high resolution electron microscopy).

Elasticity calculations show that the dislocations induce a periodic strain field, which propagates through the bonded layer up to the surface of the sample (see Fig. (1a)). To create a patterned surface, we etched our sample (see Fig. (1b)) with a mixture of fluoridric, nitric and acetic acid (so-called Dash-etch). The etch rate of this solution is known to be strain-dependent. Preliminary experiments have been performed on a 0.88° rotation angle sample. STM and AFM measurements have shown that the patterning consists in a square array of silicon nanostructures, regularly spaced, with a height of 5 nm (see Fig. 2). The bonded layer thickness is decreased from its initial value (110 nm), keeping the dislocation network at the interface, as shown by grazing incidence X-ray diffraction.

The observed morphology symmetry will be compared to strain and energy calculations obtained by continuum elasticity theory.

Surface stress and morphology engineering by wafer bonding constitutes a general approach to assembly nano-materials in well-defined functional networks, with the high density required by applications.

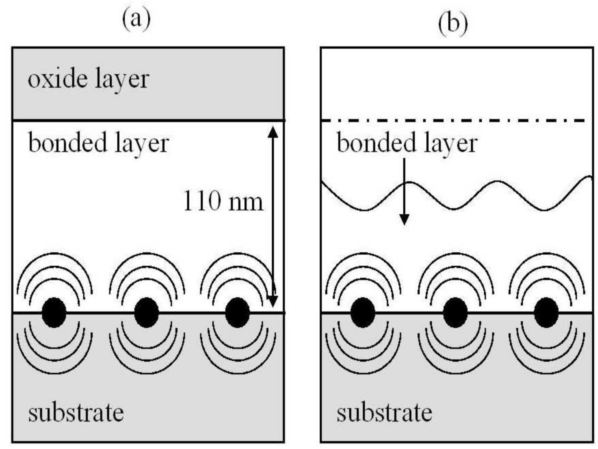

Figure 1: *(a) Sketch of the bonded structure, before the thinning of the bonded layer. (b) Example of patterned substrate, after etching of the bonded layer. The periodicity of the dislocations network is transferred to the resulting surface.*

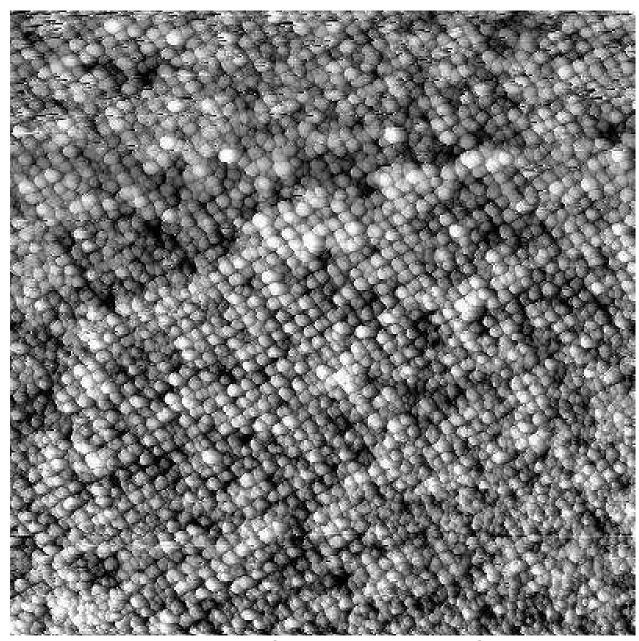

Figure 2: *STM image of the patterned surface. The scale is 800*800 nm. Nanostructures are 5 nm tall. Near the diagonal line, we observe a mixed dislocation line coming from the residual steps of the interface.*

REFERENCES

1. M. Bruel, World Patent 9905711.
   R. Wind, M. Murtagh, Fang Mei, Yu Wang, M. Hines, S. Sass, Appl. Phys. Lett. 78, 2205 (2001).
2. F. Fournel, K. Rousseau, H. Moriceau, J. Eymery, J. L. Rouvière, N. Magnea, and B. Aspar, Appl. Phys. Lett. 80, 793 (2002).