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1 **Kinetics and coupled dynamics of dewetting and chemical reaction**
2 **in Si/SiO₂/Si system**

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Abstract

We report on the observation of a coupling between the dewetting of a Si layer on SiO₂ induced by surface/interface energy minimization and the etching between both materials due to the Si+SiO₂ \rightarrow 2 SiO_g[↑] reaction. In the limit of a thin SiO₂ layer (\leq 10 nm) sandwiched between a Si layer and a Si handle wafer, the front of Si dewetting and the front of SiO₂ etching coexist in a narrow region. The interplay between both phenomena gives rise to specific morphologies. We show that extended Si fingers formed by dewetting are stabilized with respect to Rayleigh Plateau type instability over tenth of microns thanks to a localized etching of the SiO₂ layer. The break up of this structure occurs abruptly by an unzipping process combining dewetting and etching phenomena. We also put in evidence that Si rings are created with a thin SiO₂ layer in the center. These processes are thermally activated with an activation energy of 2.4 ± 0.5 eV and 4.0 ± 0.5 eV respectively for dewetting and the etching reaction. All these results highlight the respective roles of wetting and etching in Si/SiO₂/Si system dynamics and could be a stepping stone for the development of advanced processes based on Silicon-On-Insulator technology.

7 I. INTRODUCTION

8 Wetting of liquids on solids in reactive systems is of great importance with many industrial
9 applications such as soldering or adhesion [1]. The kinetics of reactive wetting is affected
10 by a number of factors like interfacial reactions, diffusion of constituents or dissolution of
11 the substrate [2 and 3]. Under reaction the contact line dynamics can lead to complex
12 behaviours such as oscillatory phenomenon of spreading and contraction [4–7], formation
13 of reaction rings [8] or even droplet motion [9–11]. For example, the reaction-mediated
14 spontaneous drift of millimeter-scale solid-state camphor particles on the surface of water
15 has been known for several centuries [12]. In solid systems only scarce studies have explored
16 the coupling between chemical reactions and wetting dynamics. For instance in metallic
17 systems the alloying driving force can induce the self-propelled motion of solid Sn islands
18 onto a Cu surface [13]. In the context of metal/oxide or semiconductor/oxide systems, solid
19 state wetting properties may also be affected by interfacial redox reactions. For instance in
20 the Si/SiO₂ couple, that plays a key role in the perspective of future devices based on Silicon-
21 On-Insulator (SOI) technology [14–17], wetting and reactivity properties of the interface have
22 been largely studied. Under moderate annealing (~ 1100 - 1300 K) SOI dewetting occurs
23 by edge retraction (see Fig.1 and [18–24]), the expelled silicon accumulates in a receding
24 rim that exhibits a capillary instability giving birth to elongated Si structures (called Si
25 fingers). These fingers are in turn destabilized and periodically form 3D Si islands by
26 a beading mechanism similar to a Rayleigh-Plateau instability. The driving force for this
27 dewetting process arises from the surface/interface free energy gain. In solids mass transport
28 is mediated by surface diffusion [25–27] whereas hydrodynamics dominates in liquid films
29 [28–31]. This makes that the contact line with the substrate is particularly sensitive to the
30 effect of the disjoining pressure in solid thin films whereas surface diffusion is much less
31 affected [32]. Considering high temperature regimes (~ 1300 K) Si and SiO₂ solids are also
32 known to react and form volatile SiO_g[†] molecules. This is perfectly illustrated when a SOI
33 film is completely dewetted at 1000 K, then annealed at 1330 K: the reaction leads jointly
34 to the consumption of the 3D Si islands and to the etching of nanopits in the SiO₂ layer [33
35 and 34].

36 In this article we analyze the combined effects of etching reaction and dewetting on SOI
37 films in the high temperature regime. Their interplay gives complex front dynamics: (i)

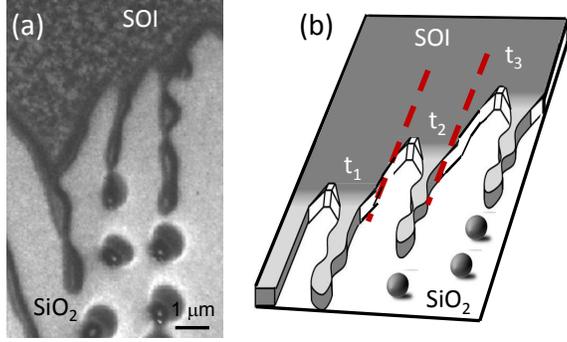


FIG. 1. (a) Low energy electron microscopy image of the dewetting of a SOI film (~ 20 nm thick) at 1160 K. (b) sketch of the dewetting mechanism: a Si finger destabilizes by a lateral undulation (time t_1) that leads to beading and formation of a 3D Si island at its extremity (time $t_2 \sim t_1 + 120$ s). This process repeats periodically (time $t_3 \sim t_1 + 240$ s).

38 formation of extended Si fingers stabilized by lateral etching, (ii) Si fingers break up by an
 39 unzipping mechanism and (iii) formation of Si rings with a thin SiO_2 layer in the center.
 40 The etching and dewetting fronts dynamics are studied experimentally *in situ* and in real
 41 time by low energy electron microscopy (LEEM) and *ex situ* AFM measurements.

42 II. METHODS

43 The SOI wafers are originally fabricated at SOITEC (Bernin, France). They are cleaned
 44 and prepared in Ultra High Vacuum (UHV) conditions as described in Ref. [35]. The studied
 45 thickness is about 30 nm for the Si layer and 8 nm for the buried oxide layer (BOX) of SiO_2 .
 46 Such thin structures are highly sensitive to Si layer dewetting and etching reaction between
 47 Si/ SiO_2 under thermal annealing. In the temperature range $\sim 1300 - 1400$ K, a front of
 48 dewetting of the Si layer forms spontaneously onto a defect at the surface/interface and is
 49 followed by an etching reaction front. Their motion and morphology are recorded *in situ* and
 50 in real time (1 s per image) by low energy electron microscopy (LEEM) in the tilted bright
 51 field mode (electron energy: 4 eV). The characterization of the coupling between the etching
 52 and dewetting fronts dynamics is completed by *ex situ* analysis of the surface morphology
 53 by atomic force microscopy (AFM, PSIA-XE 100).

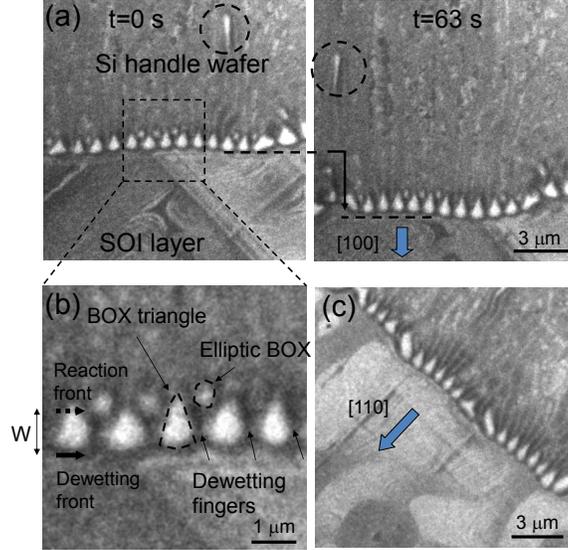


FIG. 2. (a) Sequence of two LEEM images of a thin SOI layer (30 nm) onto a BOX layer (8 nm) at 1370 K. The SOI dewetting front and the etching front Si/SiO₂ advance in the [100] direction (See Supplemental Material S1 at [URL will be inserted by publisher] for the complete movie). The Si handle wafer is on top of the image and the SOI layer is at the bottom. Dotted circles: SiO₂ layers moving opposite to the dewetting/etching front. The linear defects in the SOI layer (bottom right part of the image) occur due to remaining lateral temperature gradients during annealing. They have no influence on the fronts dynamics. (b) Close view of the area of coexistence of the dewetting front (black arrow) and reaction front (dashed arrow): The exposed SiO₂ layer has a bright contrast with a triangular or elliptical shape. Si fingers are formed in between triangular SiO₂ layers. (c) Same as (a) for an advancing front in the $\langle 110 \rangle$ direction.

54 III. RESULTS: INTERPLAY BETWEEN ETCHING REACTION AND DEWET- 55 TING FRONTS

56 A. Kinetics of fronts propagation

57 Figure 2(a) shows two LEEM images of the SOI (30 nm)/BOX (8 nm)/Si handle wafer
58 during solid phase etching and dewetting at 1370 K. The SOI layer exhibits a black/white
59 contrast coming from the $(1 \times 2)/(2 \times 1)$ surface reconstructions. The SOI dewetting front ap-
60 pears as an undulating grey line (fig. 2(b)) that separates the SOI layer and the underneath
61 SiO₂ BOX layer (bright contrast). The fronts recede in a steady state at a constant velocity

62 of $53 \pm 5 \text{ nm.s}^{-1}$. If the front is aligned along the $[100]$ direction very regular structures
 63 ($1.5 \pm 0.1 \mu\text{m}$ period) occur whereas slightly more disordered ones can be observed when the
 64 front recedes in the $[110]$ direction (Fig. 2(c)). A similar observation is obtained for Si(001)
 65 thin layer dewetting onto SiO_2 at lower temperature (1200 K) when etching reaction is neg-
 66 ligible. The $[100]$ front forms regular fingers by front edge instability as described by [36].
 67 In the case of a $[110]$ front, as there are two equivalent directions for the fingering instability
 68 ($[100]$ and $[010]$), the competition between both degrades the long range order [23 and 24].

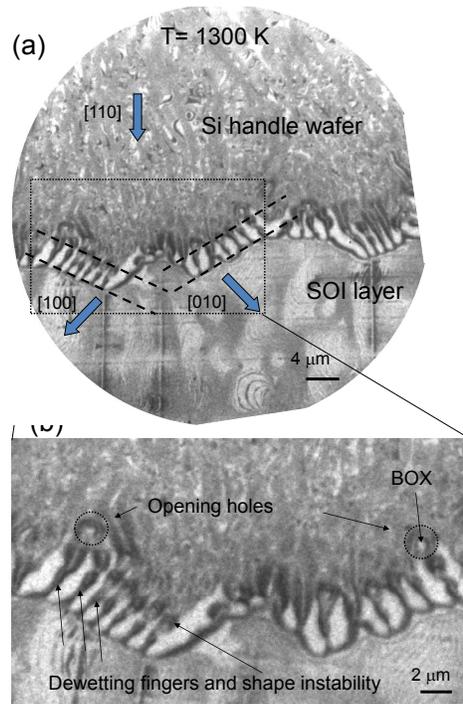


FIG. 3. (a) LEEM image of a SOI layer (30 nm) onto a BOX layer (8 nm) at 1300 K (See Supplemental Material S2 at [URL will be inserted by publisher] for the complete movie). The SOI dewetting front and the etching front Si/SiO₂ (middle) advance in the $[110]$. (b) Close view of the fronts: Si fingers onto SiO₂ layer are visible (black arrows) as well as circular holes in the Si layer (black dotted circles) exposing SiO₂.

69 As the SOI dewetting fronts recede (*via* fingers formation), the underlying SiO₂ BOX
 70 layer is exposed to vacuum (Fig. 2(b)). This free BOX layer shows triangular structures,
 71 the base pointing towards the SOI layer and the tip pointing in the direction of the Si handle
 72 wafer. We can infer that the edges of the triangles correspond to the reaction front between
 73 the remaining BOX layer and the Si handle wafer. As the front recedes in a steady state, the

74 decay of the BOX occurs by a constant etching reaction rate ($\text{Si} + \text{SiO}_2 \longrightarrow 2 \text{SiO}_g^\uparrow$) localized
75 at the Si/SiO₂/vacuum triple-line. To evaluate the activation energies of SOI dewetting
76 E_d and etching reaction E_r we have studied the effect of the sample temperature on both
77 kinetics (Fig. 3(a)-(b)). As the temperature decreases from 1370 K to 1300 K the fronts
78 velocity v_f decreases from $53 \pm 5 \text{ nm.s}^{-1}$ to $18 \pm 3 \text{ nm.s}^{-1}$, the extension of the free BOX
79 layer W increases from $0.9 \pm 0.1 \text{ }\mu\text{m}$ to $2.3 \pm 0.5 \text{ }\mu\text{m}$ and the disappearance time t_d of the free
80 BOX layer increases from $20 \pm 1 \text{ s}$ to $125 \pm 20 \text{ s}$. The SOI front velocity v_f is only driven by
81 SOI dewetting kinetics and can be written as $v_f \sim e^{-\frac{E_d}{kT}}$ assuming it is thermally activated.
82 From the ratio of the velocities v_f at 1370 K and 1300 K, the dewetting activation energy
83 is estimated as $E_d = 2.4 \pm 0.5 \text{ eV}$ that is in perfect adequation with previous SOI dewetting
84 studies [23] that show that Si surface diffusion is the dominant mechanism of mass transport
85 mediating the dewetting process. The etching reaction activation energy E_r is not related
86 to the reaction front velocity. Indeed the reaction occurs at the Si/SiO₂/vacuum triple-
87 line and thus starts when the BOX is exposed to vacuum. Therefore the etching reaction
88 activation energy has to be evaluated from the disappearance time $t_d \sim e^{\frac{E_r}{kT}}$ of the free BOX
89 layer. Measurements of t_d at 1370 K and 1300 K provide an estimate of $E_r = 4.0 \pm 0.5$
90 eV. This is also in adequation with the activation energy reported by [33] from temperature
91 dependent measurements of Si island decay kinetics onto SiO₂. At last we have also measured
92 the width W of the exposed BOX layer with respect temperature. It is related both to
93 dewetting and etching reaction activation energies as $W = v_f \times t_d \sim e^{\frac{E_r - E_d}{kT}}$. We measure
94 that $E_r - E_d = 2.1 \pm 0.6 \text{ eV}$. The large difference between the activation energies of Si
95 dewetting and etching reaction makes that the width W of the free BOX layer decreases
96 strongly with temperature as observed experimentally. At last let us note that despite the
97 difference between both activation energies, the dewetting and etching fronts move at the
98 same velocity (*i.e.* at the Si layer dewetting velocity, see supplementary material S1). This
99 is due to the fact that the etching reaction occurs only when the BOX layer is exposed to
100 vacuum, *i.e.* after the dewetting front passage. Then it takes a time t_d for the BOX layer
101 to be completely etched which can be seen as a delay time for the etching front to progress
102 behind the dewetting front.

103 This evaluation of the activation energies can also be completed with the quantitative
104 analysis of the rate of etching reaction and dewetting front velocity. From the linear decrease
105 of the BOX layer with time (triangular shape) the reaction rate $\nu_{\text{reac}} = \frac{dN}{dt}$ at the Si/SiO₂

106 contact line can be estimated (where N is the number of SiO_2 entities in the oxide layer).
 107 We calculate therefore $\nu_{\text{reac}} \approx 3.2 \times 10^3 \text{ s}^{-1}$ per SiO_2 entity at the contact line at 1370 K
 108 and $\nu_{\text{reac}} \approx 5 \times 10^2 \text{ s}^{-1}$ per SiO_2 entity at 1300 K (oxide layer thickness: 8 nm). This
 109 result compares to previous report [33] on the reaction rate of Si islands onto SiO_2 (3×10^2
 110 s^{-1} per atom) in a slightly lower temperature regime. Concerning the dewetting velocity
 111 of SOI, Cheynis et al. [24] have shown that in the temperature range [1000 K - 1200 K]
 112 $v_f \simeq \frac{5.3 \times 10^{12}}{h^3 kT} e^{-2.0/kT} \text{ nm.s}^{-1}$ where h is the SOI film height expressed in nm and kT is given
 113 in eV. Assuming this expression for a 30 nm thick film at 1370 K and 1300 K we obtain
 114 respectively $v_f=74 \text{ nm.s}^{-1}$ and $v_f=31 \text{ nm.s}^{-1}$ which gives the correct order of magnitude of
 115 the kinetics, the overestimation arising probably from a slightly too low activation energy
 116 in the modeling.

117 Beyond the description of the energetics of SiO_2 etching, figures 2(b) and 3(b) show
 118 also very specific structures that highlight a complex interplay between the dynamics of
 119 dewetting and etching. This interplay occurs because the timescale for the formation of
 120 fingers and 3D islands by dewetting is comparable to the timescale for the consumption of
 121 the BOX layer. We will focus on three main structures: (i) SiO_2 BOX layer of elliptic shape
 122 located in between two free BOX triangles and separated by Si (dotted ellipse in fig. 2(b),
 123 at 1370 K). (ii) Elongated free BOX structures crossing the surface from time to time in the
 124 direction opposite to the dewetting front (dotted circles in fig. 2(a)) with a large velocity
 125 ($> 100 \text{ nm.s}^{-1}$). (iii) SOI islands with a ring shape and exposing a circular BOX layer in
 126 the middle (see fig. 3(b) at 1300 K). To understand all these structures we will describe in
 127 the following part the main stages of their formation and propose different scenarios with
 128 coupled etching and dewetting phenomena.

129 B. Coupled dynamics of dewetting and etching

130 *a. Steady state elliptic shape BOX structure* Figures 2(a)-(b) show LEEM im-
 131 ages of a dewetting/reaction front moving along the [100] direction. The regularly spaced
 132 triangular BOX structures separate Si fingers that are short and perpendicular to the dewet-
 133 ting front. Some Si fingers are prolonged by BOX elliptic structures (dotted ellipse in fig.
 134 2(b)) that are stable during the steady motion of the fronts (See complete movie S1 at [URL
 135 will be inserted by publisher]).

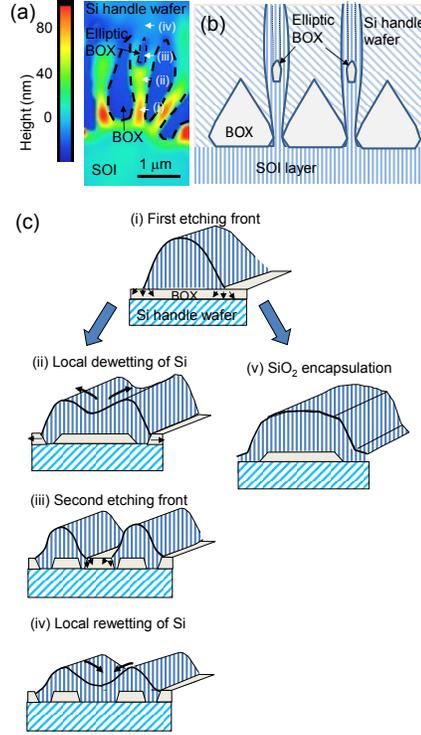


FIG. 4. (a) AFM image of the surface morphology of the front. Si fingers from the SOI layer separated by triangular shape BOX layers are visible. (i) to (iv) address the different steps of Si finger evolution (see scenario in (c)). (b) Scheme of the surface morphology considering elliptic holes (top view). (c) Scenario in four steps of the Si finger evolution: (i) Si finger formed by SOI layer dewetting and simultaneous SiO₂ BOX etching at the contact line. (ii) Complete lateral etching of the SiO₂ layer and contact between the Si finger (from SOI) and the Si handle wafer. Simultaneous lateral progression of the reaction front and Si mass shedding from the center of the finger. (iii) Splitting of the finger into two fingers and occurrence of new etching fronts with the free BOX. (iv) Complete etching of the inner SiO₂ BOX layer and rewetting of the SOI layer onto the Si handle wafer. (i)-(iv) are also sketched on AFM image in (a). (v) Scenario of direct BOX layer encapsulation (without finger splitting).

136 To analyze the morphology of these fronts combining dewetting and etching, figure 4(a)
 137 shows a typical AFM image. We can clearly distinguish the SOI layer (turquoise) and the Si
 138 fingers (yellow and red). The AFM image shows also the SiO₂ BOX layer (blue); it appears
 139 as extremely flat areas located in between Si fingers close to the SOI dewetting front. They
 140 have the same shape as those observed by LEEM (triangular structures in 2(c)). We can

141 also see from AFM that some Si fingers are unstable and split laterally into two branches
 142 exposing a small SiO₂ BOX layer (~500 nm) in between (elliptic shape) as the one measured
 143 by LEEM. From the combination of both methods, a scenario of the process is proposed
 144 (fig. 4(b)-(c)) based on the combined effects of SiO₂ BOX etching and wetting/dewetting of
 145 the SOI layer. The scenario involves four steps labelled (i) to (iv) that can be observed also
 146 by AFM (fig. 4(a)) as time lag is related to the spatial position with respect to the front.
 147 (i) First, a Si finger is formed by SOI dewetting on the SiO₂ BOX layer. This process is well
 148 known and arises from surface/interface energy minimization that kinetically destabilizes
 149 the receding front [37 and 38]. (ii) The Si finger formation results in the occurrence of a
 150 triple line between the freshly exposed SiO₂ BOX layer, the Si finger and vacuum. This
 151 contact line is very active for SiO₂ etching compared to SiO₂ dissolution through the SOI
 152 layer. Indeed, as shown by [39], the limiting mechanism for SiO₂ etching is the diffusion
 153 of dissolved O atoms created at the Si/SiO₂ interface. When O atoms reach the Si surface
 154 they combine to Si atoms and create volatile SiO_g[↑] molecules. The diffusion time is therefore
 155 minimized when O atoms are directly formed at the triple line [33, 34, and 39]. The local
 156 etching thins locally the SiO₂ BOX layer (~8 nm) until the Si fingers meet the Si handle
 157 wafer. (iii) This has two consequences: (1) thermodynamically the Si finger tends to spread
 158 laterally on the Si handle wafer thanks to perfect wetting. (2) Kinetically the newly formed
 159 lateral etching front forces the finger to progress laterally. This enlargement of the fingers is
 160 visible in LEEM (fig. 3(b)) and AFM images (fig. 4(a)). This forced lateral spreading gives
 161 rise to a destabilization of the finger: it splits laterally in two parts with the occurrence of
 162 a newly exposed SiO₂ BOX layer in the middle. (iv) This SiO₂ layer is in turn the place
 163 for preferential etching at the triple line. When this SiO₂ layer in the middle is completely
 164 etched, the two Si fingers meet again and form a flattened structure that encapsulates
 165 the remaining SiO₂ BOX layers that are protected against further fast etching. When the
 166 splitting in two parts of the Si fingers does not occur, no elliptic SiO₂ layer is formed and
 167 another scenario with direct encapsulation of one SiO₂ BOX stripe occurs (see (v) in fig.
 168 4(c)). This last scenario is clearly put in evidence in the unzipping process of Si fingers as
 169 detailed in the following.

170 *b. Unzipping of Si fingers* Figure 5(a) shows a sequence of LEEM images at 1370
 171 K. We can observe a local anomaly at the reaction front edge: the triangular SiO₂ BOX
 172 layer is locally destabilized and this event suddenly generates a free SiO₂ layer that seems to

173 detach and propagate at high velocity ($210\pm 10 \text{ nm}\cdot\text{s}^{-1}$) in the direction opposite to the front.
 174 To understand this process we have performed an *ex situ* analysis of the surface morphology
 175 by AFM. Fig. 5(c) shows an elongated silicon finger away from the front edge ($\sim 10 \mu\text{m}$)
 176 which is hollowed out in the middle. A SiO_2 BOX layer is clearly observed at the bottom of
 177 this hollow as a very flat area surrounded by a Si rim and delimited by lateral trenches in
 178 the oxide layer (see height profile on fig. 5(c)). These very characteristic features of the SiO_2
 179 BOX layer, etched locally by Si, have already been observed in the context of conventional
 180 SOI dewetting [23 and 39] and are found here everywhere at the front edge demonstrating
 181 unambiguously that the SiO_2 BOX can be present far away from the front. The proposed
 182 scenario is the following: The Si fingers formed by SOI dewetting locally etch the BOX
 183 layer on the lateral sides. When a Si finger reaches the Si handle wafer, the SiO_2 BOX
 184 layer may become encapsulated (see scenario (v) in fig. 4(c)) preventing further etching.
 185 This process is highly stabilized when the front recedes in the $\langle 100 \rangle$ direction resulting in
 186 the formation of extremely long SiO_2 BOX stripes ($> 30 \mu\text{m}$) encapsulated into straight Si
 187 fingers. Contrary to conventional dewetting of Si/ SiO_2 , the encapsulation of a SiO_2 layer
 188 inside a Si structure prevents the dewetting of the Si fingers (fig. 5(b)-(1)). However if the
 189 dewetting front is destabilized and a finger detaches from the SOI layer edge (2), then a
 190 new triple line Si/BOX/vacuum appears. Lateral shedding of Si by dewetting is promoted
 191 (3). This process unzips the Si finger from the middle (hollowed Si finger) and creates two
 192 lateral rims of Si (4). Simultaneously the freshly exposed SiO_2 BOX layer is continuously
 193 etched on the lateral sides giving the impression of the propagation of a SiO_2 layer at the
 194 surface (5).

195 *c. Si ring formation* Figures 3(b) and 6(a) address a scenario occurring at slightly
 196 lower temperature (1300 K). At this temperature the width W at the front of the freshly
 197 exposed SiO_2 BOX layer is about $2 \mu\text{m}$ (dashed lines in fig. 3(a)) whereas it is about 0.9
 198 μm at 1370 K. The width change arises because the activation energy for dewetting is lower
 199 ($2.4 \text{ eV}\pm 0.5 \text{ eV}$) than for etching ($4.0\pm 0.5 \text{ eV}$ as described previously). Therefore the Si
 200 fingers formed by dewetting are much longer and have now enough time to destabilize by
 201 a Rayleigh-Plateau type instability. However together with the usual formation of 3D Si
 202 islands, we also observe the formation of Si rings exposing in the middle a remaining SiO_2
 203 BOX layer (see circles in fig. 3(b) and ref. [40]). This is also clearly seen by AFM (fig.
 204 6(a)). Then this BOX layer in the middle of a Si ring is etched progressively and the ring

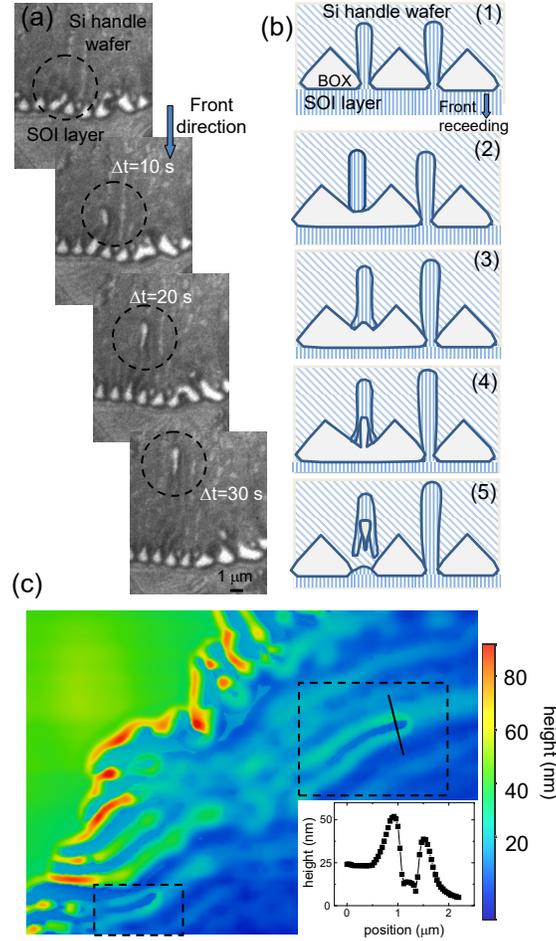


FIG. 5. (a) LEEM image sequence of Si/SiO₂ BOX front at 1370 K. Black dashed circles show the occurrence of a defect at the front that generates the linear propagation of a new front of SiO₂ BOX layer decomposition in the direction opposite to the dewetting front. (b) Scheme of the unzipping scenario of SOI finger with encapsulated SiO₂. The finger is destabilized at the front side. This event allows for the lateral dewetting of Si and splits the finger into two parts. This process progresses all along the finger over tenth of microns (unzipping process). Simultaneous etching of the newly exposed SiO₂ BOX layer. (c) AFM image ($16 \times 10 \text{ } \mu\text{m}^2$) showing the morphology of this unzipping process (black dashed areas). Inset: profile of a silicon finger hollowed out in the middle (black line): Si lateral rim, trenches in the the SiO₂ layer at the contact line with Si and flat area of BOX in the middle.

205 shape smoothens giving a final rough Si surface morphology. We propose a scenario similar
 206 to the one described for Si fingers (fig. 4(c)) but adapted to 3D islands: (i) The 3D Si islands

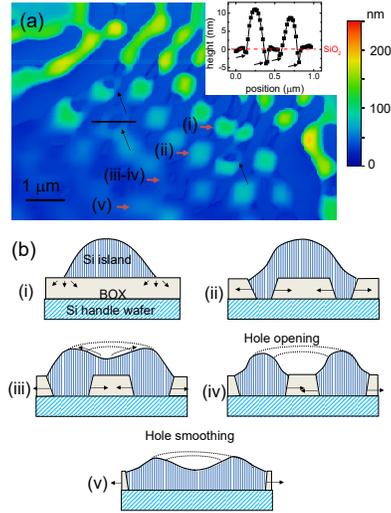


FIG. 6. (a) AFM image of the dewetting/reaction front (1300 K) obtained after quenching to RT. Elongated Si fingers are observed and agglomerate into 3D islands. The islands are unstable against Si rings formation (black arrow). Inset: profile of a circular hole (black line in the image) exposing a remaining SiO₂ BOX layer inside (BOX surface: red dashed line). Black arrows show the trenches in the BOX layer formed by local etching at the Si/SiO₂ contact lines. (b) Scenario of ring formation: (i) Si islands formed by dewetting and Si fingers. (ii) Local breaking through the SiO₂ layer and contact with the Si handle wafer. (iii) Radial progression of the reaction front and Si mass shedding from the center of the island. (iv) Opening of a hole into the center exposing the remaining SiO₂ BOX layer. (v) Etching of the SiO₂ BOX layer and spreading/smoothing of the Si layer.

207 formed by SOI finger dewetting instability [23 and 37] expose the BOX layer to vacuum. The
 208 circular contact line between the Si islands and the BOX layer is the place for preferential
 209 etching of the BOX layer. (ii) When the BOX layer is locally completely etched, the SOI
 210 layer and Si handle wafer are in contact and then the etching front progresses radially as for
 211 Si fingers. (iii) This process favors a mass transfer of Si from the center to the edge. (iv)
 212 This Si shedding destabilizes the compact island shape into a ring and a circular BOX layer

213 appears in the center as it was protected by the 3D island. This observation is similar to the
214 one obtained in the context of liquid Si droplets onto SiO₂ (quartz) forming spontaneously a
215 liquid Si torus [41]. (v) Then the inner SiO₂ layer progressively disappears by lateral etching
216 and when it is completely etched the Si morphology smoothens.

217 IV. CONCLUSION

218 We have shown by *in situ* LEEM and *ex situ* AFM that the Si/SiO₂ interface in ul-
219 tra thin SOI system can lead to different structures/morphologies depending on annealing
220 conditions. The competition between (de)wetting and Si+SiO₂ → 2 SiO_g reaction kinetics
221 makes possible to achieve steady state regimes where the dewetting front and the etching
222 front coexist in a narrow space region. These regimes may create peculiar structures such
223 as 1D thin SiO₂ BOX stripes encapsulated into crystalline Si fingers or Si rings with a SiO₂
224 BOX layer in the center. The formation of these structures follow different scenarios where
225 the localization of the etching at the contact line between Si and SiO₂ and mass transfers
226 induced by Si/SiO₂ wetting properties play key roles. Small modifications at the front edge
227 may also lead to instabilities such as the fast unzipping of Si fingers with encapsulated SiO₂
228 BOX stripes. This analysis of the front dynamics is completed with a quantitative study of
229 the energetics of the process. We show that dewetting and etching reaction are thermally
230 activated with an activation energy respectively of 2.4±0.5 eV and 4.0 ±0.5 eV. To conclude,
231 these results propose a general picture of the dynamics of Si/SiO₂/Si interfaces at high tem-
232 perature in the limit of a thin SiO₂ layer (≤ 8 nm). We believe these results may initiate
233 new approaches to fabricate specific structures based on SOI technology [42 and 43] and to
234 prevent SOI dewetting processes by encapsulation approaches.

235 V. SUPPLEMENTARY MATERIALS

236 See supplementary materials for the complete movies of the dewetting and reacting pro-
237 cesses.

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