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Growth of Low Dimensional Cobalt Silicides structures on Si(001) surface

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1 Introduction

The formation of cobalt silicide islands and nanowires on Si(001) is unexpected since $CoSi_2$ and Si are cubic. At present the underlying causes for the elongation of the nanowires are not fully understood. With reactive deposition epitaxy (RDE) growth and in-situ STM study, we investigated the growth dynamics of these islands and nanowires at (i) different coverage from 0.1ML to 0.5ML Co, and (ii) different growth temperatures between 500 and 800°C.

2 Experimental

The experiments were carried out in a multi-chamber ultra-high vacuum (UHV) system. Each singular Si(001) sample was chemically etched and H-terminated. The sample was cleaned via thermal flashing up to 1130°C. The sample was then deposited with 0.1ML cobalt at a desired temperature. At each deposition stage, the sample's surface morphology was characterized using STM. The experiment was then repeated with other samples at different growth temperatures.

3 Results

Figure 1 shows the typical morphology of the Si(001) surface after deposition. Two distinct silicide islands (i.e. flat (type A) and hut-like/ridge (B)) elongated along the <110> azimuths can be observed.

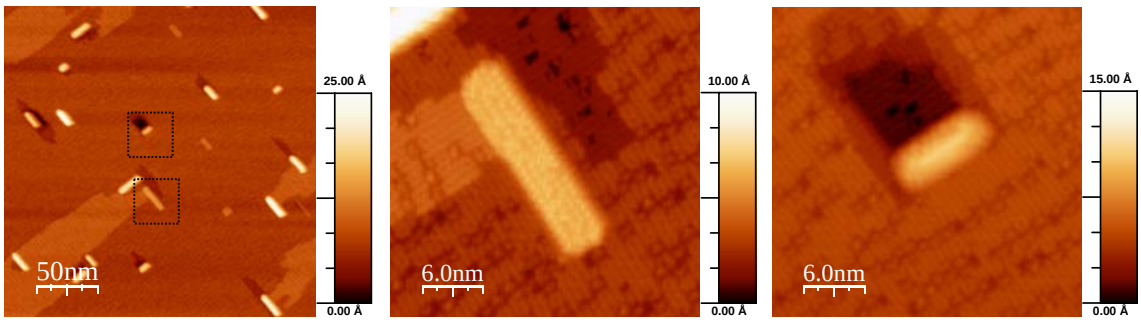

Figure 1 High resolution STM surface morphologies of Si(001) surfaces with (a) flat islands (type A), and (b) ridge/hut-like (type B).

The behaviour of these two types of island as a function of Co coverage and deposition temperature is captured by measuring its length, height, width and aspect ratio. Figure 2 shows a typical result obtained at 560°C and 710°C for low and high temperature growth regime respectively.

4 Discussions

At low growth temperature of 560°C, type A islands forms short nanowires as Co coverage increases. The (length/width) aspect ratio increases with coverage and has a value of ~5:1 after depositing 0.5ML of Co. Comparing to growth at a higher temperature of 710°C, the overall island dimension increases but the aspect ratio is reduced. The flat islands are thus less anisotropic in shape and hence less wire-like at high temperatures. In contrast, type B islands at low growth temperatures of 560°C forms short ridge/hut-like islands with aspect ratio of 2:1. The aspect ratio of these islands increases tremendously and at a growth temperature of 710°C, it has a value of ~ 20:1. The formation of wire-like features (Type A or B) would imply a preferential

growth direction. At low growth temperature, kinetic limitation could arise from the differences in adatom diffusion barrier along the two orthogonal <110> azimuth because of the inherent present of the (2×1) + (1×2) reconstructed Si-dimer-rows [1].

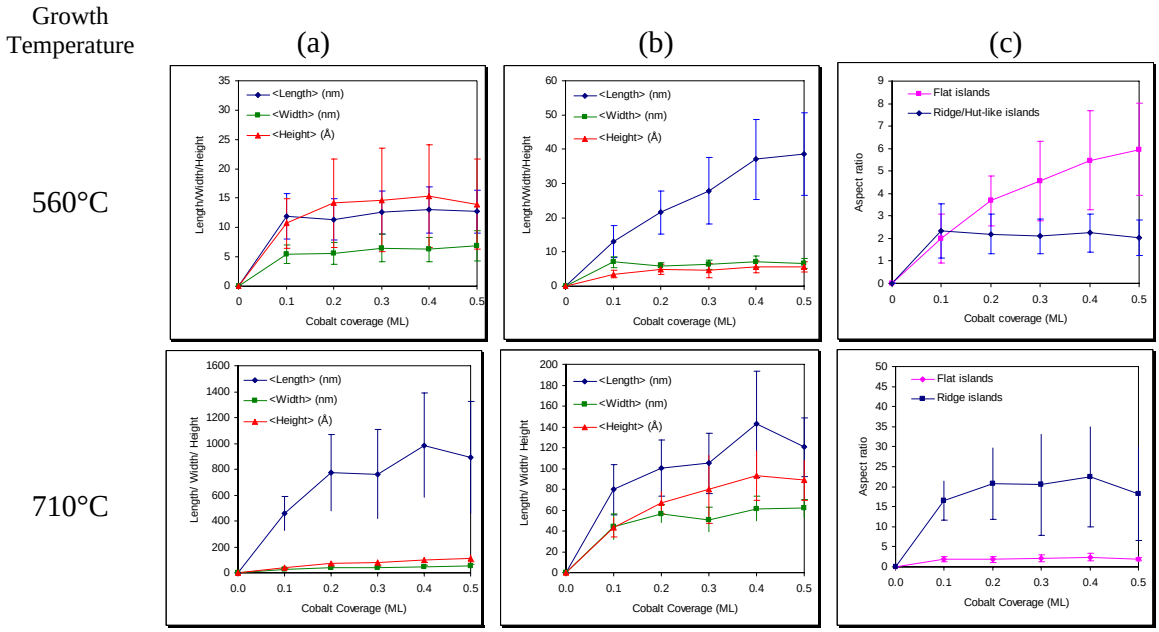

Figure 2 Average lengths, widths and heights of (a) ridge/hut-like islands (type B) and (b) flat nanowires (type A); and (c) aspect ratio (length/width) of these islands/nanowires as a function of cobalt coverage.

Formation of short flat wires and short rectangular ridge-islands are therefore observed. At higher temperature, the difference in barriers along the two orthogonal azimuths is anticipated to become less significant. Islands are anticipated to become more isotropic/less wire-like. However, this does not account for the observation that type B islands which continues to growth even longer at higher temperatures. A possible reason for this to occur is the preferential formation of low energy planes bounding these ridge islands via an endotaxy growth mechanism [2]. This effect may be further compounded by the inherent lattice mismatch between cobalt silicide and silicon [3], leading to the formation of strained silicide islands on Si(001) surface. As wires are preferentially form as a growth mechanism to relief the build up in the strain energy [4,5].

5 Conclusions

Between 0.1 and 0.5ML of cobalt coverage, flat and hut-like nanowires and nano-islands can be formed at temperatures between 500°C to 800°C. Below 650°C, flat nano-islands grew longer forming small nanowires with increasing coverage while hut-like nano-islands remain short. Above 650°C, the flat nano-islands become square-like/rectangular in shape while long hut-like nanowires were formed.

6 References

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