Composition distributions of single GeSi quantum dots and simultaneous conductance studies

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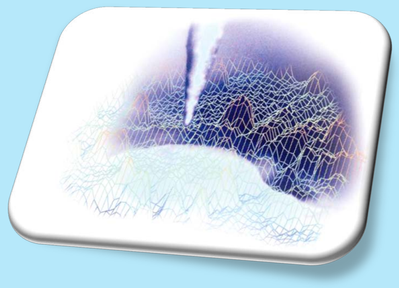
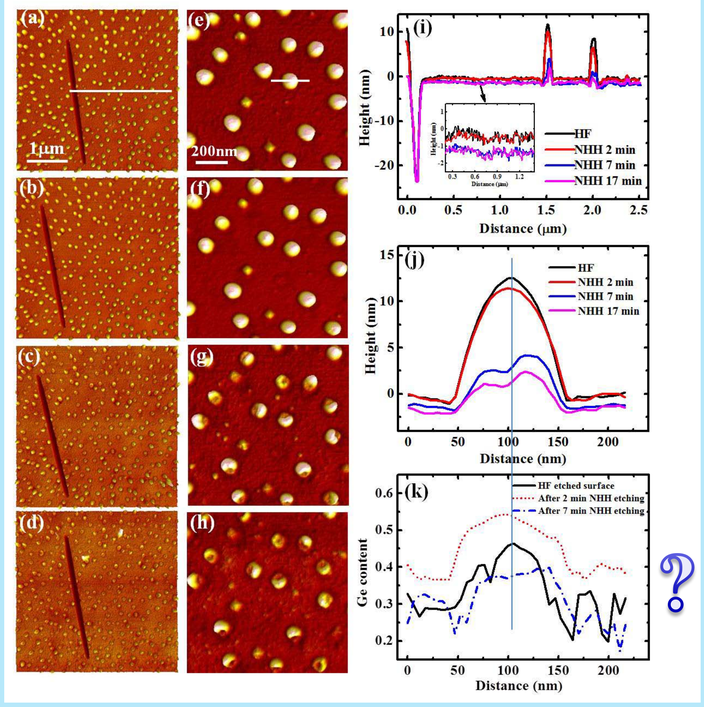


Introduction

A novel method is developed to investigate three dimensional composition and conductance distributions on same single self-assembled GeSi quantum dots (QDs) simultaneously by conductive atomic force microscopy combined with selective chemical etching..

It is surprised to find that the QDs with high Si ratios (grown at 680℃) exhibit poor conductance after NHH etching.

I. In situ selective etching

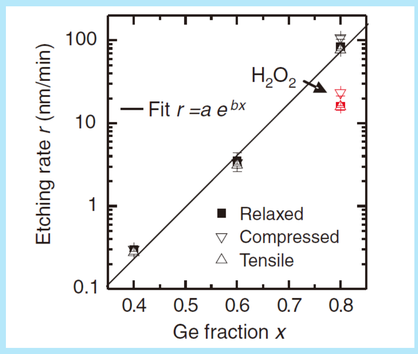


The height drop of wetting layer can't be neglected.

Ge concentrated in the middle ?

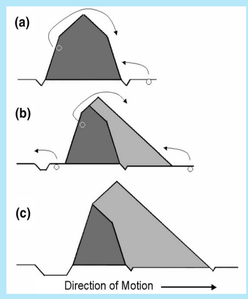
GeSi QDs grown at **680℃**

Topography after (a) (e) HF dip, (b) (f) NHH 2min, (c) (g) NHH 7min, (d) (h) NHH 17min,
(i) Profile of the marked line, which have aligned according to the bottom of the trench,
(j) Height profile of the GeSi QD before and after NHH etching
(k) Ge content calculated (according to etching rate) alone the line



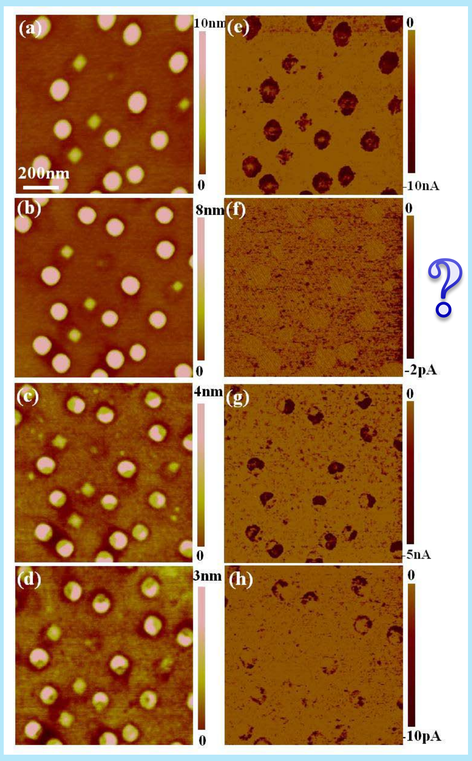
NHH solution etching rate
[1:1 vol. (28% NH_4OH):(31% H_2O_2)]

- etching rate increasing exponentially with the Ge fraction,
- no preferential etching direction,
- a negligible dependence on the strain.



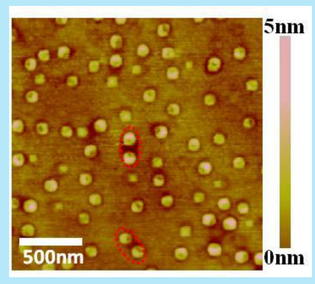
Mechanism of asymmetric Ge distribution

II. CAFM results of GeSi QDs before and after NHH etching



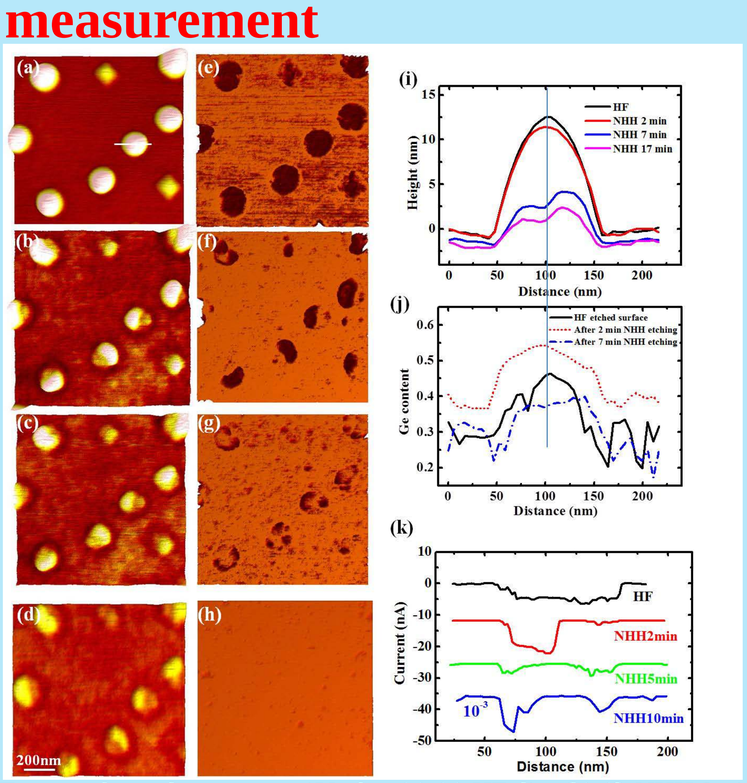
QD's conductance is even poorer than wetting layer.

Why?



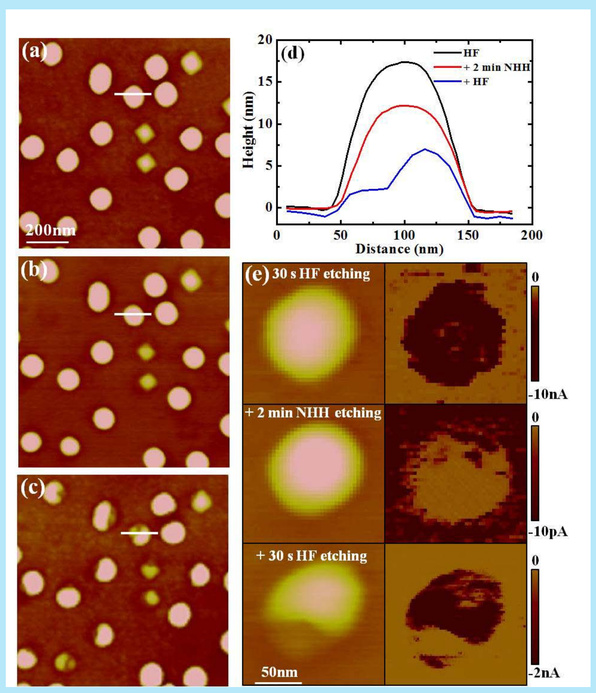
Topography and current at-1V after (a) (e) HF dip, (b) (f) NHH 2min, (c) (g) NHH 7min, (d) (h) NHH 17min.

III. HF dip before CAFM measurement



Topography and current at -1V after (a) (e) HF dip, (b) (f) NHH 2min, (c) (g) NHH 7min, (d) (h) NHH 17min,
(i) Height profile of the GeSi QD before and after NHH etching,
(j) Ge content profile of the GeSi QD before and after NHH etching,
(k) Current profile of the GeSi QD before and after NHH etching.

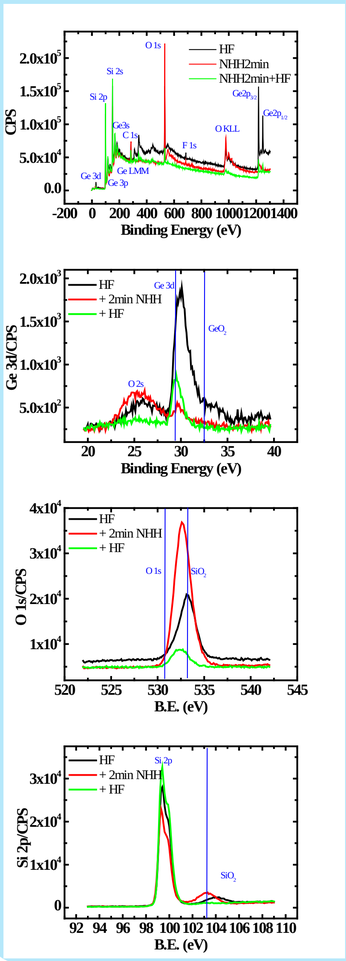
IV. Current distribution of the same GeSi QD after another HF dip



Oxide layer remained after NHH etching on Ge rich side

Topography after (a) HF dip, (b) NHH 2min, (c) another HF dip,
(d) Height profile of the GeSi QD alone the line
(e) The current at -2V after HF dip, NHH2min, another HF dip

V. XPS confirm



Apparently, an oxide layer formed on GeSi QDs.

VI. Conclusion

- **3D composition distributions of single GeSi QDs are achieved by AFM imaging combined with selective chemical etching with a nanoscale trench.**
- **The NHH etching of QDs with high Si ratios has a layer of oxide remained on their Ge-rich surface which cannot be removed by water rinsing.**