Growth of *β-FeSi₂* self-assembled quantum dots

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INTRODUCTION

It was recently observed an accentuated interest in the study of β-$FeSi_2$. This material can be growth on crystalline silicon substrates by several methods and exhibits an indirect band gap that under strain transforms to a direct band gap with energy between 0.87 and 0.89 eV. Such material is stable at room temperature, becoming viable for fabrication of telecommunication devices integrated on a silicon microelectronic platform. In this work we investigate the growth of self-assembled quantum dots of iron silicides on Si (111), as a function of iron coverage and annealing time.

SAMPLES

Two series of iron silicide quantum dots samples were grown by Reactive Deposition Epitaxy. In the first group of samples, the iron coverage was changed between 2 nm and 40 nm. In the second group, the annealing time was varied between 0 hours and 2 hours.

Growth steps

- Substrate cleaning using RCA method and piranha etching.
- Hydrogen pasivation of the surface of the susbtrate.
- Degasing of the susbtrate at 400 ºC 20 min in UHV.
- Heating up of the susbtrated to the growth temperature.
- Deposition of iron.
- Annealing of the susbtrate.

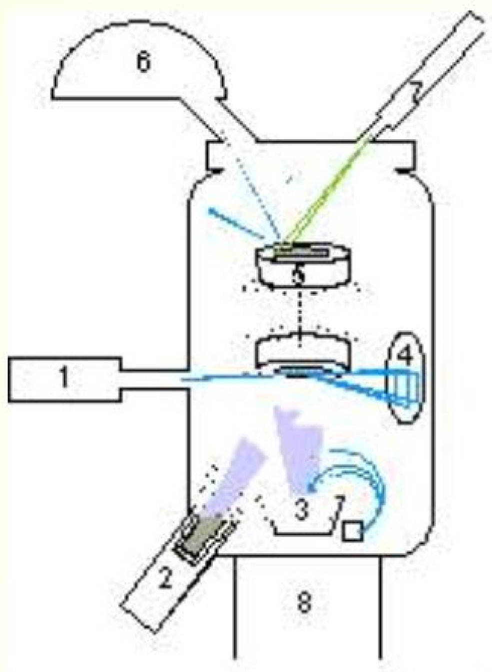

Fig. 1 Growth steps and diagram of the UHV chamber used for growth. 1) RHEED electron gun. 2) thermal evaporation cell. 3) crucible of the e-beam evaporation cell. 4) florescence screen. 5) sample holder in analysis position and growth position. 6) XPS electrons analyzer. 7) x-ray tube. 8) cryogenic pump.

Table I. Series of samples and main growth conditions

Samples	Height (nm)	Growth temperature	Anealling temp. And time
BHM 0503	6	700	700/2h
BHM 0504	6,8	700	700/2h
BHM 0505	4,7	700	700/2h
BHM 0506	3,5	700	700/2h
BHM 0507	2,5	700	700/2h
BHM 0508	2	700	700/2h
BHM 0509	2,6	700	700/2h
BHM 0510	2,4	700	700/2h
BHM 0511	2,8	700	700/2h
BHM 0512	3,2	700	700/2h
BHM 0513	3,2	700	none
BHM 0514	3,2	700	700/30 min
BHM 0515	3,2	700	700/1h
BHM 0516	3,2	700	700/1,5h
BHM 0517	3,2	700	700/2h
BHM 0518	10	700	700/2h
BHM 0519	20	700	700/2h
BHM 0520	30	700	700/2h
BHM 0521	40	700	700/2h

The evolution of the quantum dots growth was investigated by Atomic Force Microscopy and Conversion Electron Mössbauer.

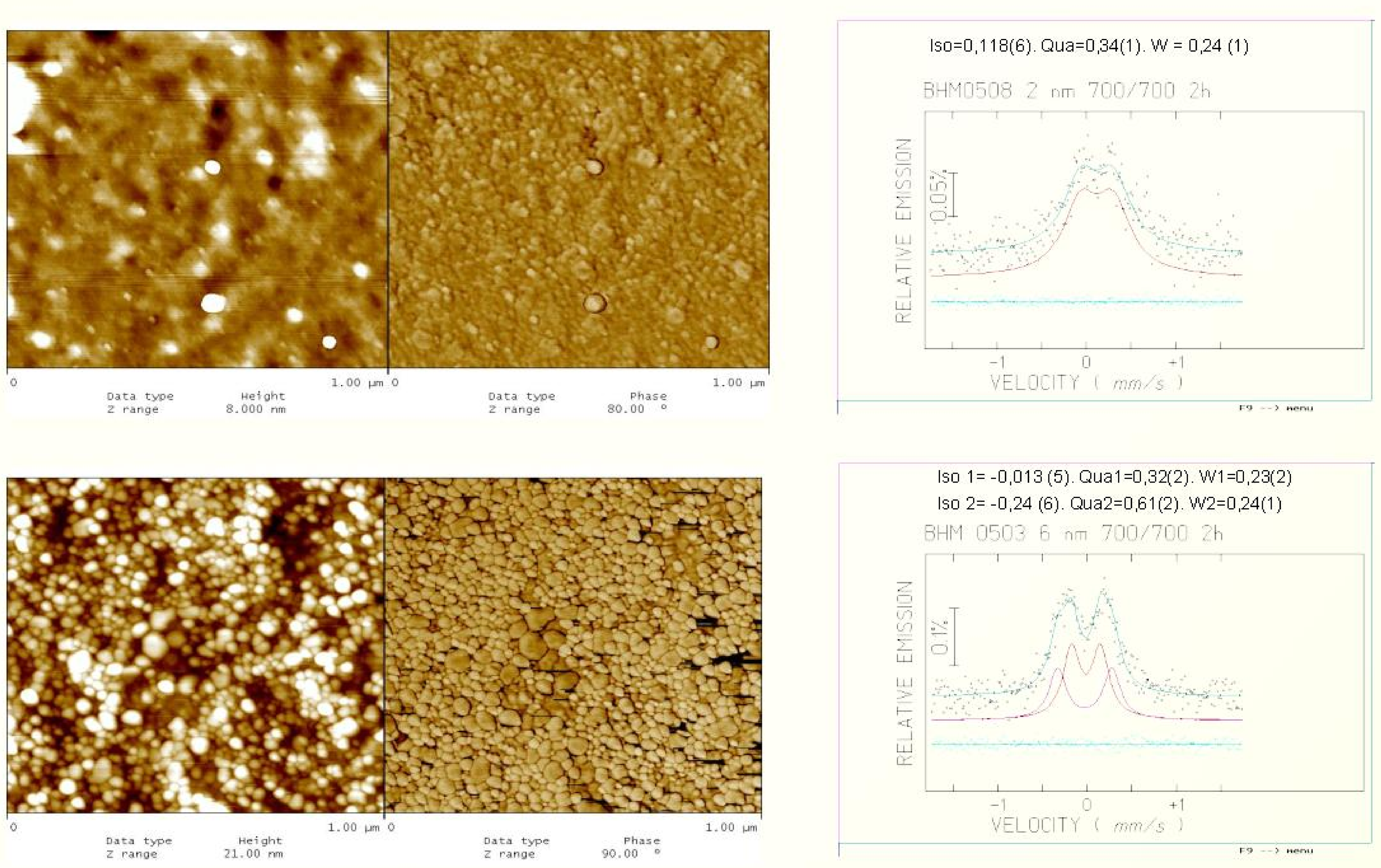

Fig. 2 Topographyc and phase images, and CEMS spectra of the samples BH0508 e BH0503.

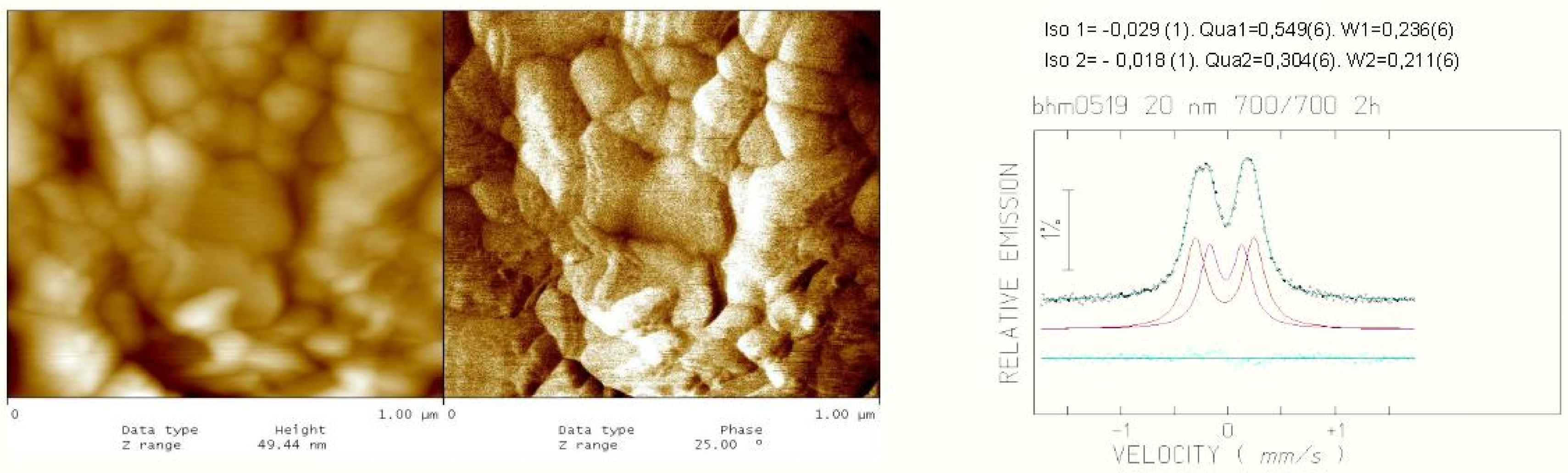

Fig. 3 Topographyc and phase images, and CEMS spectra of the samples BH0519.

The samples were also analyzed by coplanar X-ray diffraction and grazing incidence diffraction.

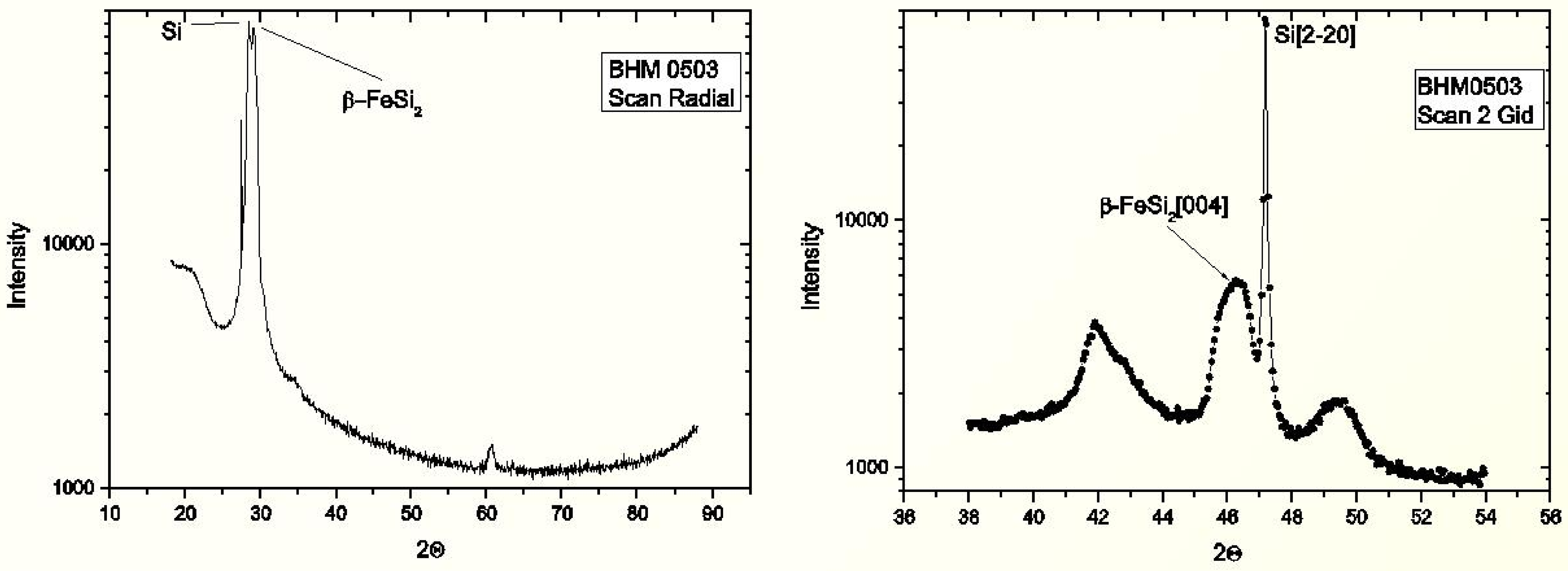

Fig. 4 Coplanar x-ray diffraction and grazing incidence x-ray diffraction of the sample BH0503. Only peaks from the beta phase of iron silicide are visible in the spectra.

Patterns created using nanolitography were also used to selectively growth β-$FeSi_2$ self-assembled quantum dots in hexagonal templates.

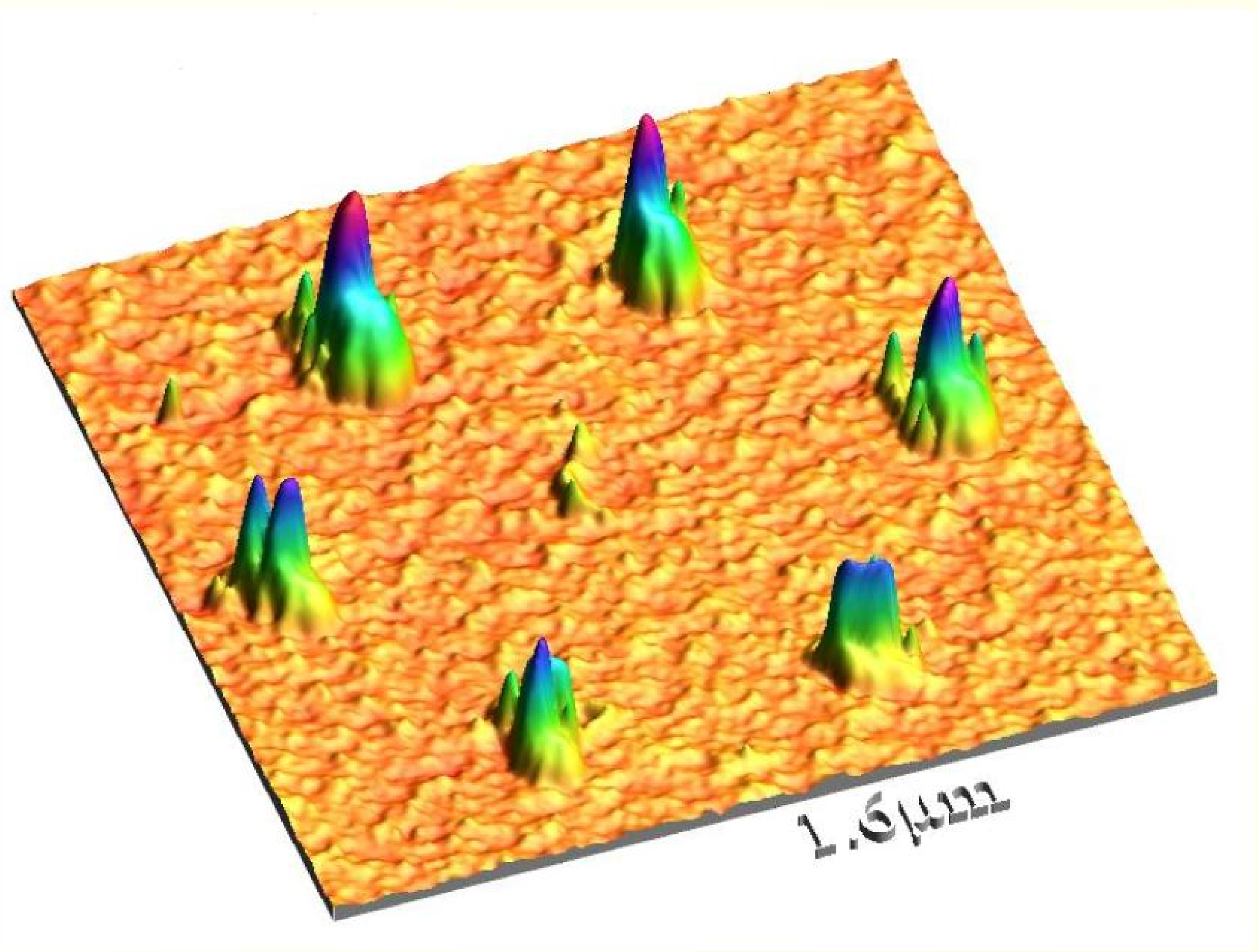

Fig. 5 Hexagonal array of β-$FeSi_2$ self-assembled quantum dots

CONCLUSIONS

Iron silicide self-assemble quantum dots were grown by reactive deposition epitaxy. The morphology and phases of the quantum dots were investigated by atomic force microscopy, conversion electrom mösbauer spectroscopy and x-ray difraction. These studies showed an increase in the density of the quantum dots as a function of the iron coverage and transitions from small lens shape islands to bigger structures with well-develop crystal facets. It was also observed that after the coalescence of the islands the substrate was not fully covered by a thick iron silicide layer, but Si patches were leaved on the samples. Mössbauer experiments shows that only the β-$FeSi_2$ phase was found in samples with large iron coverage, independently of the annealing time. However, for sample with small iron coverage a mixture of β-FeSi2 and a new metastable phase was also found.

SUPPORTS

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico
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FAPEMIG Fundação de Amparo à Pesquisa do Estado de Minas Gerais