SiC epitaxial growth on Si(100) substrates using carbon tetrabromide

G.Attolini[1)], M.Bosi[1)], B.E.Watts[1)], F.Rossi[1)], G.Salviati[1)],
G. Battistig[2)], L. Dobos[2)], B. Pécz[2)]
[1)]IMEM-CNR Institute Parco Area delle Scienze 37 A, 43100 Parma (Italy)
[2)]Research Institute for Technical Physics and Materials Science, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest (Hungary)

Abstract

The most common precursos to grow 3C-SiC layers on Si substrate by VPE (Vapour Phase Epitaxy) using different are silane, chlorosilanes, acetylene, propane, methane, methyltrichlorosilane, but Si has a strong tendency to precipitate and form adducts in the gaseous phase. Halogenous precursors are promising as they may help in overcoming this problem.

CBr_4 is used as a dopant during the MOVPE of III-V compounds and, in some circumstances, is preferred to CCl_4 because of the lower bond strengths of C-Br relative to C-Cl (CBr_4 56.2 kcal/mol, CCl_4 73 kcal/mol).

Bromide synthesis may be an alternative route to deposite SiC on Si substrate.

Here we report on the use of carbon tetrabromide CBr_4 as the carbon source to grow SiC layer after a standard carburisation step.

Experimental

Apparatus
Home made horizontal VPE reactor on non-rotating 2'' n-type Si (001) substrates.

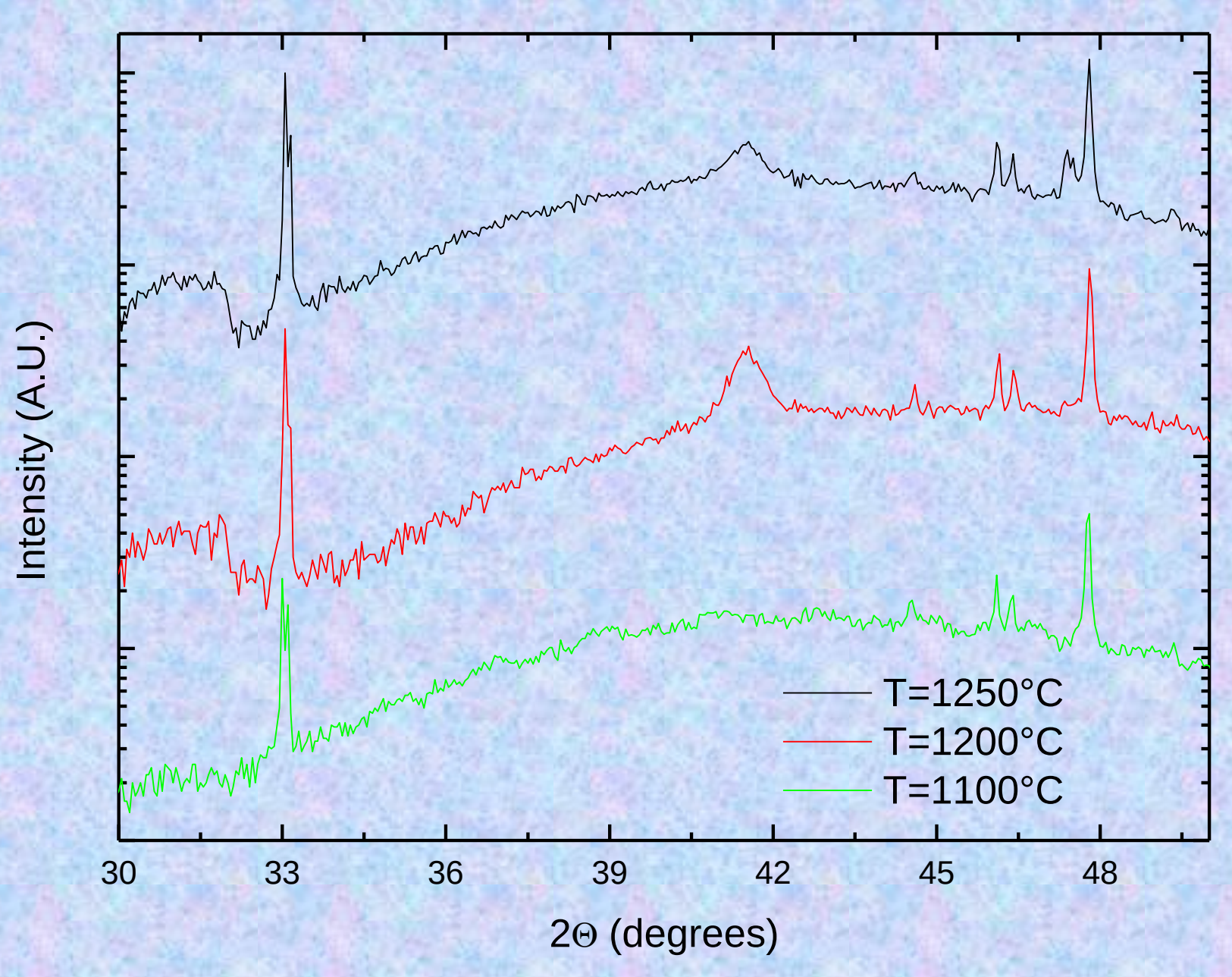
Reagents
Silane and Propane diluted (3%) in H_2
CBr_4 from a standard bubbler line
Carrier gas: Pd purified H_2
(001) and (111) substrates

Growth procedure:
Atmospheric pressure
HF + thermal etching of the silicon substrate (1000°C, 10 min).

Carburization layer deposited with propane: temperature ramp from 400°C to 1100°C, 5 minutes at high temperature.

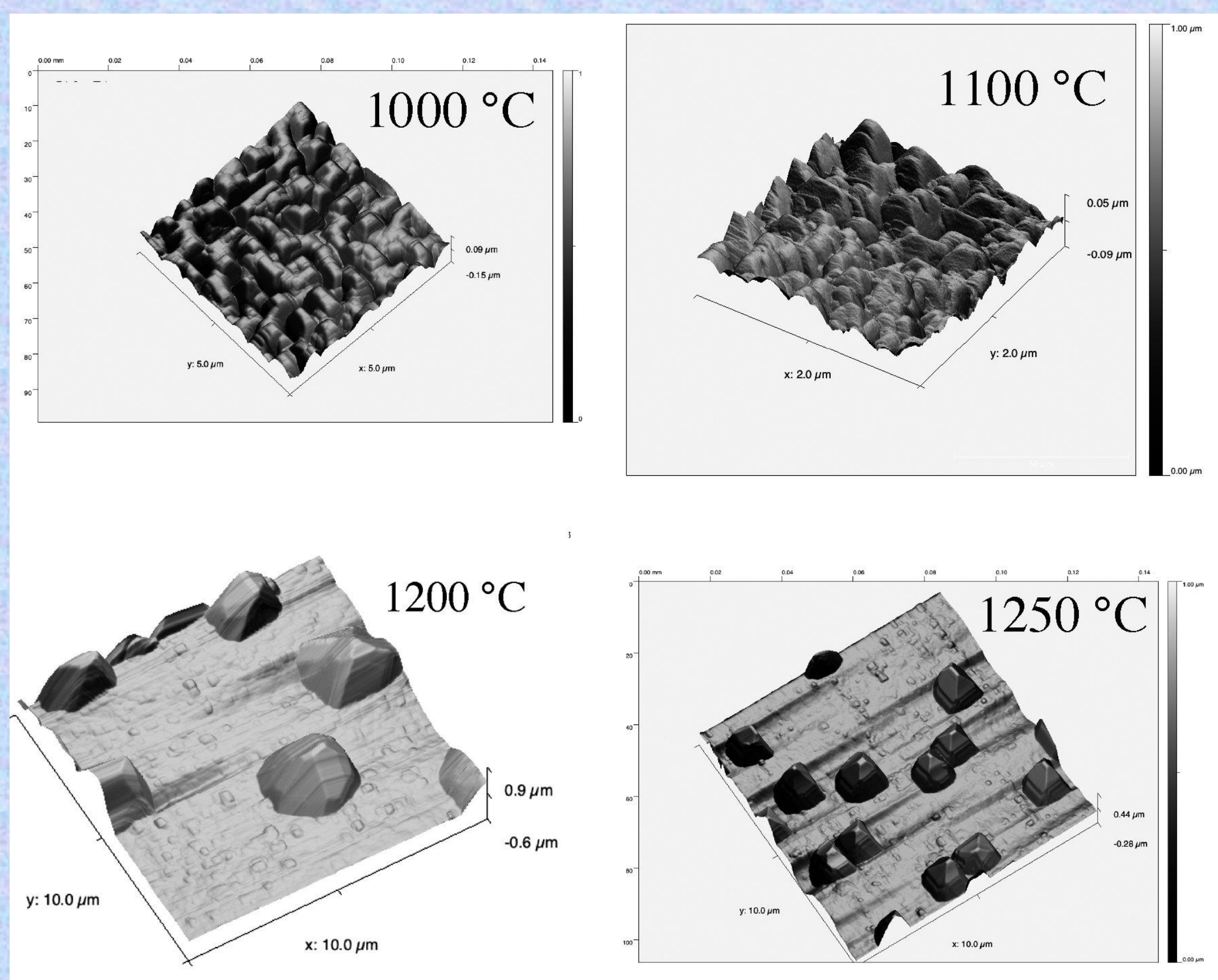
3C-SiC layer deposition at different T using SiH_4 and CBr_4 with a Si:C ratio of about 1.8 for 10 minutes.

Results and discussion



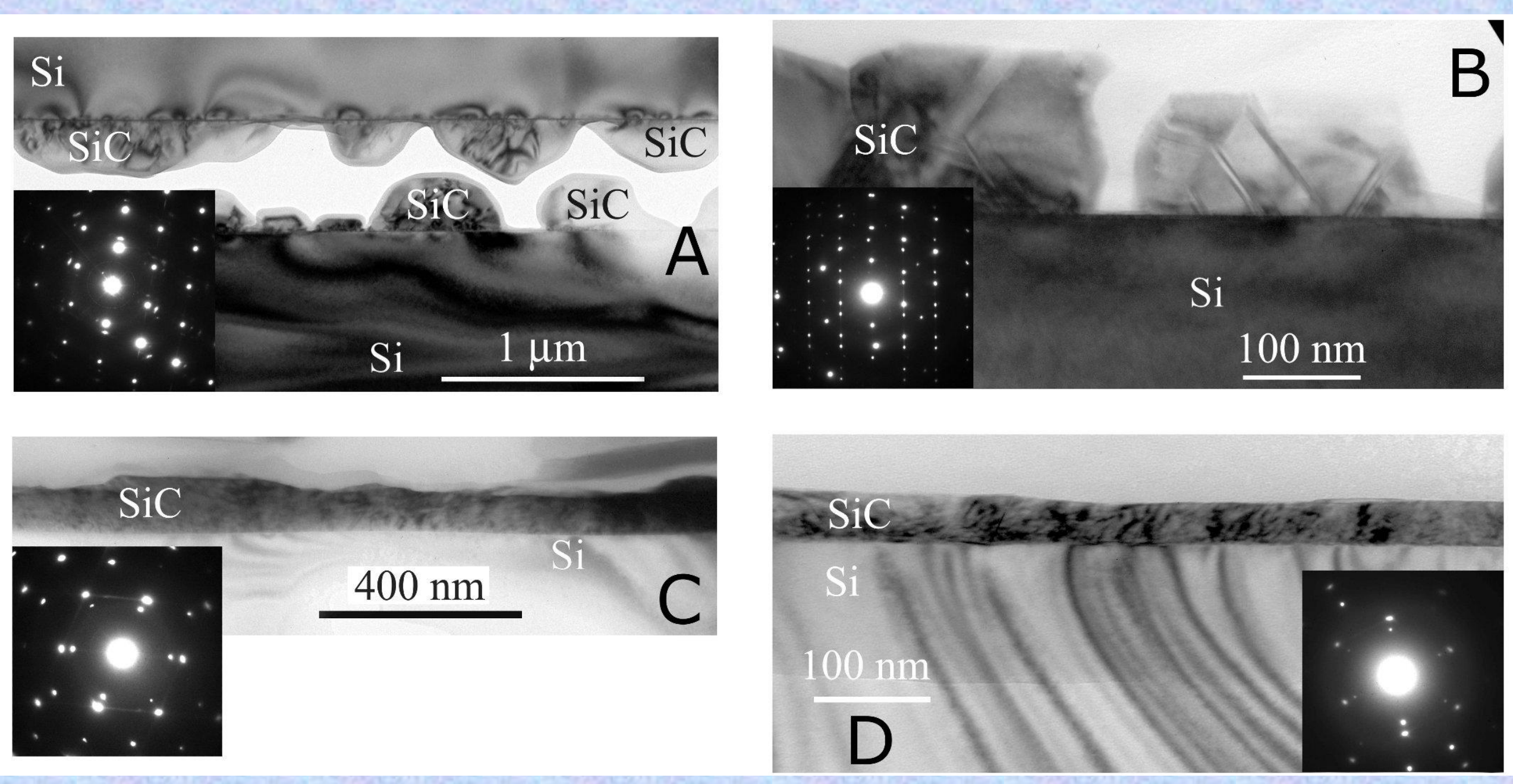
XRD

A single SiC peak is observed at 41.5° of the 200 β-SiC reflection on films grown at 1200 and 1250 °C.



AFM

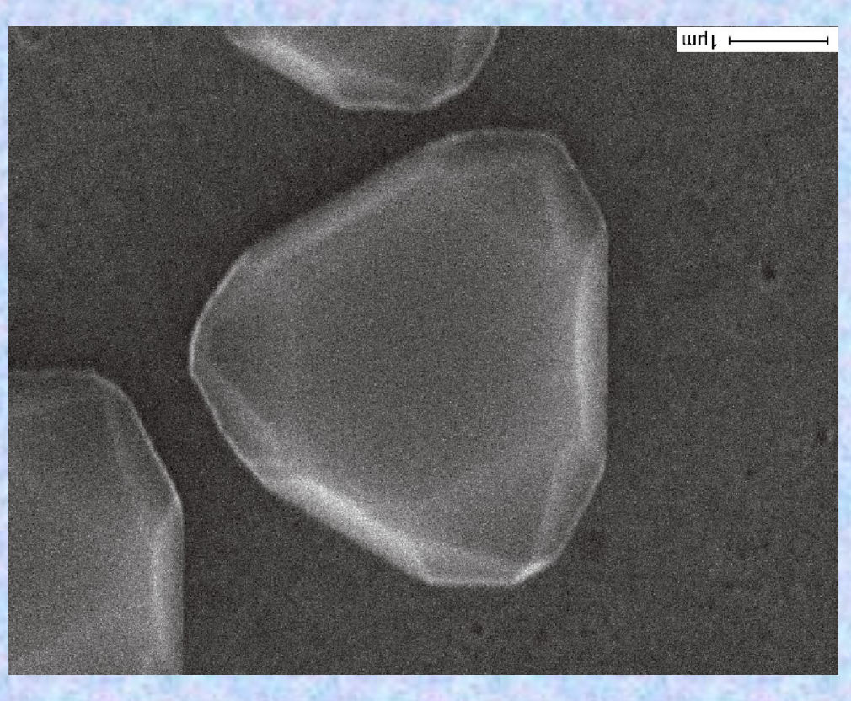
1000 - 1100 °C: the films consist completely of uncoalesced islands
1200 - 1250 °C: 2D film nucleates on the substrate, with hillocks on top.



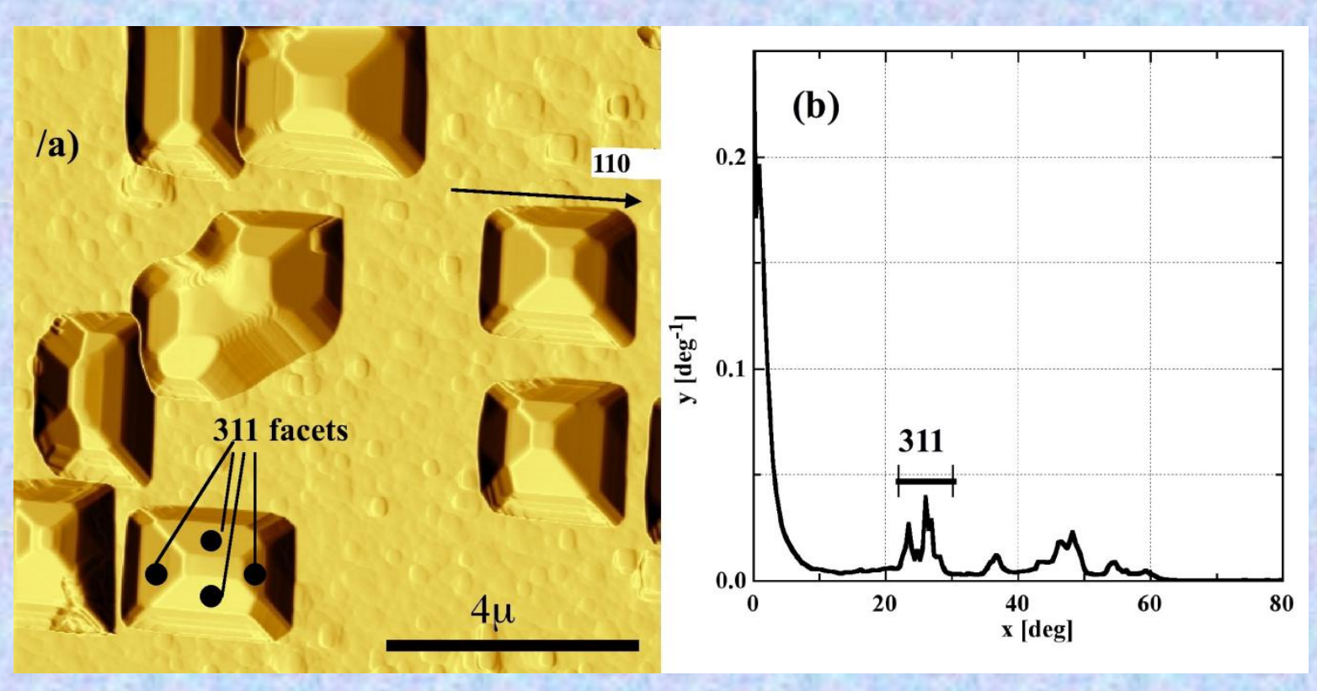
TEM

SiC grows as isolated monocrystalline grains at 1000 and 1150 °C (A,B). After carburisation the observed growth habit is 3D with islands. Few defects are seen on the dark field images, as the stacking faults form where the grains join.
A continuous, epitaxial film at grows 1200 and 1250 °C (C,D).
Furthermore, there are few crystalline defects in the SiC itself, only some stacking faults along the {111} crystalline planes are observed.
No pits or wormholes are observed at the interface with Si.
The insets show SAED analysis

Hillocks analysis

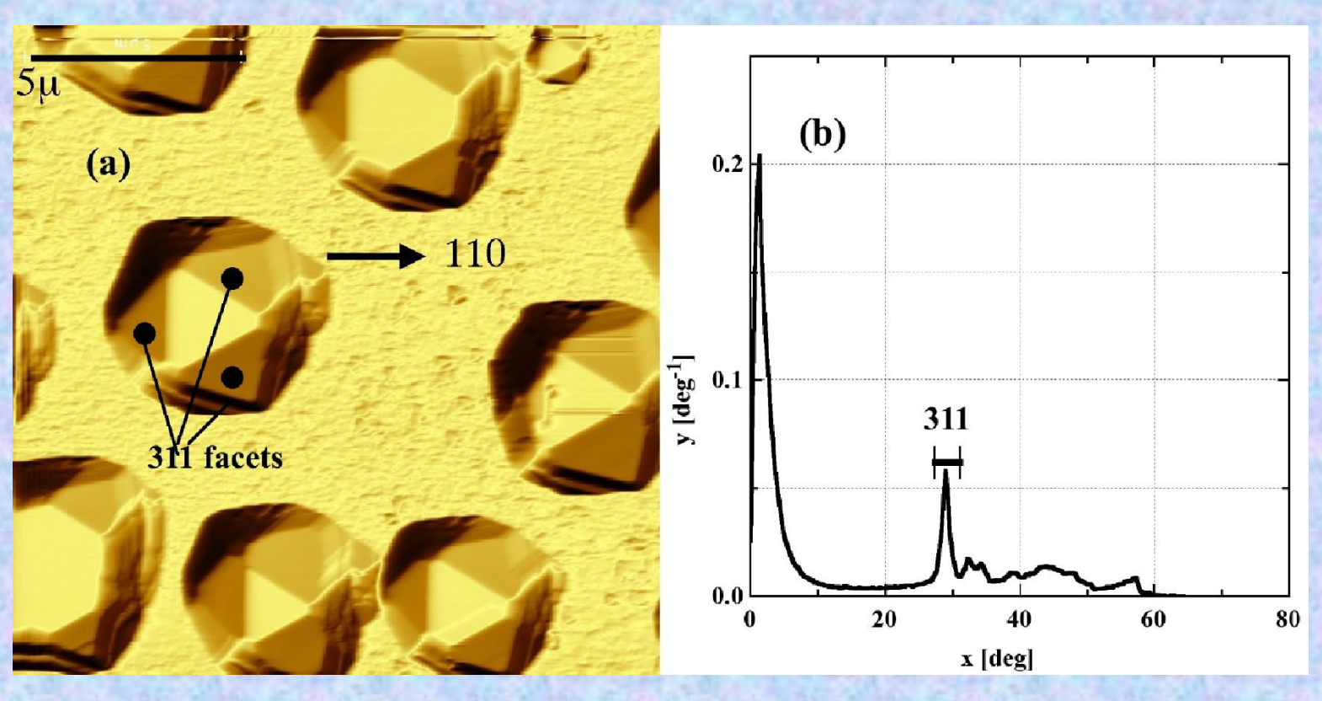


SEM image of a typical hillock



AFM images of hillocks in samples grown at 1200 °C on (001) (left) and (111) (rigth) substrates.

Slope angle plots of the distribution of the facet inclinations obtained by measuring the number of points within a given area having a certain inclination from the surface plane.



An interesting feature of the growth of SiC using CBr_4 is the formation of crystals with well-developed facets. AFM combined with "per-angle" graphs illustrate the distribution of facet inclinations.

The angle of a facet plane is measured from the film surface.

A familiy of facets corresponding to {311} planes is observed on both (001) and (111) substrates. These facets are smooth and well developed.

It seems that under these experimental condition SiC {100} facet is not a stable growth plane.

The polarity of the four {311} facets should alternate around the pyramid axis (Si and C face); two of the facets may be more stable than the others, leading to a greater deviation from the theoretical tilt angle for the other two planes.

This crystal habit is commonly seen in silicon and compound semiconductors.

{311} planes seem to be stable facets for the 3D type growth of compounds having the zinc blende structure, as seen on nanocrystalline GaAs.

Carbon contamination is known to lead to {311} and {111} faceting on the surface of nominally pure silicon etch pits when Si is sublimed from the surface.

Conclusions

- Oriented well crystallised 3C-SiC was grown on Si using CBr_4 with interface free of voids or wormholes.
- Epitaxial SiC grows at temperatures as low as 1000 °C but the growth mode is 3D with islands.
- At T>1200 °C 3D islands appears on a thin 2D layer nucleated on the Si after a standard carbonization step.
- The hillocks were analysed in depth: the growth facets are in prevalence smooth {311} planes for films grown on both (111) and (001) silicon substrates.
- (001) may not be a preferred growth plane.
- The polarity and growth behaviour of the {311} facets are worth to study to understand SiC epitaxy