In situ lift-out FIB for preparation of TEM samples: new applications, future prospects and challenges

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Introduction

• FIB preparation techniques: standard FIB, \textit{ex-situ} lift-out, \textit{in-situ} lift-out

• Why lift-out: no need for mechanical thinning, large tilt range, no pre-FIB wafer cleavage

• Applications

• Practical problems

• Comparison with standard FIB

• Future work
TEM preparation with FIB: Trench milling

Pt deposition 20x2 µm

Milling ~15-20 µm wide, 3-5 µm deep
Remaining ~20-100 nm

gas needle
I₂, XeF₂, ...

tilted view
TEM preparation with FIB: Ex-situ lift-out

Pt deposition 20x2 μm

Milling ~15-20 μm wide
3-5 μm deep
Remaining ~20-100 nm

Deposition on grid

pick-up needle
TEM preparation with FIB: *in-situ* lift-out

pick-up probe on gas needle

**IC**

Pt gas needle

fixing with Pt on Si bar

T. Ohnishi et al, Hitachi
Bert Otterloo – Harry Roberts, Philips Semiconductors
In-situ plucker tool

- optical fiber chuck
- needle gas injector
- fine probe needle
In-situ plucker procedure

- craters and undercut
- cut at the edge

Procedure:
Bert Otterloo – Harry Roberts, Philips Semiconductors
In-situ plucker procedure - 2

- inserting probe needle
- moving stage up

- needle attached
- slice cut free
- stage moved to the grid with Si bar
In-situ plucker procedure - 3

- slice attached to Si bar
- needle cut free
- final thinning to electron transparency
In-situ lift-out specimen
TEM : in-situ plucker specimen
Applications: 10 µm thick poly-SiGe layers

- Samples prepared by either mechanical polishing and ion milling or sawing followed by conventional FIBbing show *delamination* during the sawing.

- Lift-out preparation overcomes the problem.
Applications: strain analysis by CBED

Patterns acquired with A. Armigliato and R. Balboni with a Tecnai TF 30 in STEM-CBED mode at CNR - IMM labs, Bologna, Italy
Applications: strain analysis by CBED (cont’d)

• HOLZ lines splitting near Si/SiO₂ interface: two possible explanations

1. Surface relaxation:
   should be present everywhere on the x-z plane

2. Two or more CoSi₂ grains across the sample:
   each grain would deform the lattice in a different way!

• Previous results on TiSi₂ seem to confirm the latter theory!

Plan view sample of a TiSi₂ stripe
Practical problems

• Thermally insulated samples: overheating, contamination?

• Time consuming: approximately 1.5 times slower than standard FIB (but no sawing needed!)

• Thermal and mechanical properties same as standard FIB? : possible differences in strain results

• Positioning of Si bar: has to be as vertical as possible!
Trench milling vs lift-out

**Conventional**
+ easy handling: **high yield**
+ further milling possible
- limited tilt in TEM

**Lift-out**
+ no pre-thinning:
  - delaminating layers
  - packaged devices
+ no sidewalls:
  - EDS, large tilt possible
+ orthogonal incidence
+ design overlay possible
+ **in-situ**: further thinning possible
- difficult handling: **medium yield**

**Both**
+ site-specific
+ plan-parallel specimens
+ minimal heating
- limited thin area
- Ga ion damage
Ideas for the future

• In-line analysis ?? (from growth chamber to FIB and back!)

• Many lamellas on the same Si bar:

• Lift-out samples prepared from already TEM thin standard FIB samples (involves further thinning!)
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_in-situ_ plucker procedure:
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