

### Objectives

Develop Dark-Field Holography (HoloDark) for Strain Metrology in Devices

- Methodology : 2D → 3D measurements
- Instrumentation : brighter electron sources, in-situ experiments
- Characterisation : model → industrial specimens

➡ *reliable and robust technique for strain measurements*

### Partners



CEMES  
Toulouse

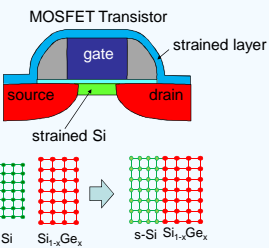


LETI  
Grenoble



STMicro  
Grenoble

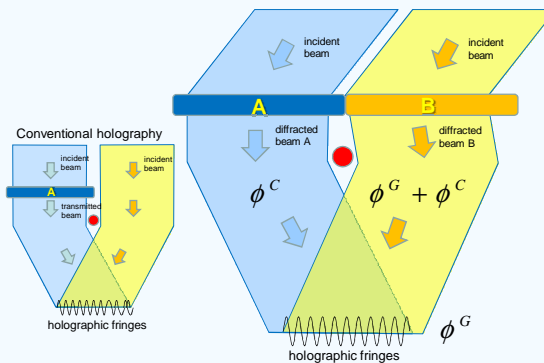
### Strained Silicon



- Strained silicon channel technology is now industrial standard
- Straining silicon increases carrier mobilities (electrons or holes)
- Strain engineering methods include: embedded sources, strained layers

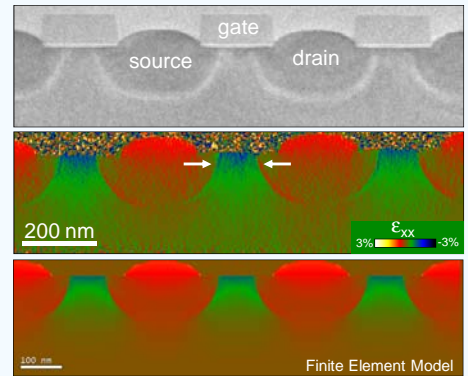
➡ *need for measurement*

### Dark-Field Holography



- New technique interferes diffracted beams from unstrained (A) and strained (B) regions
- Strain determined directly from measured phase
- Advantages: micron fields of view, nanometre spatial resolution and high precision ( $2 \cdot 10^{-4}$ )

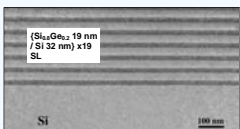
### Strain Mapping



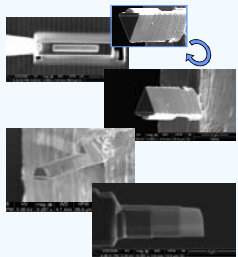
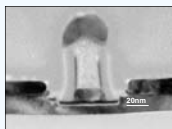
M.J. Hytch, F. Houdellier, F. Hùe, E. Snoeck, *Nature* 453, 1086 (2008)  
 F. Hùe, M.J. Hytch, F. Houdellier, H. Bender, A. Claverie, *APL* 95, 073103 (2009)  
 International Patent Application: PCT/N PCT/FR2008/001302 (CNRS)

### Specimens

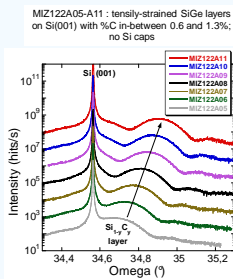
#### Test Specimens



#### State-of-the-Art Devices

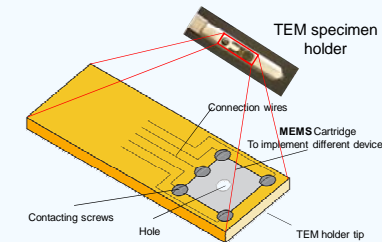


Focussed ion beam (FIB) specimen preparation

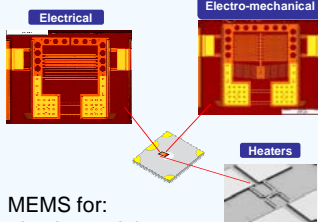


Complementary characterisation

### In-situ Measurements



#### MEMS design



- MEMS for:
- in-situ straining
  - applying voltages
  - dynamic experiments

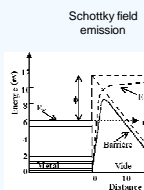
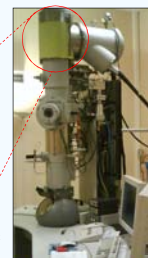
➡ *improved instrumentation*

### Brighter Electron Sources

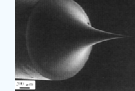
#### Schottky field-emission gun (FEG)



Brightness  $B=5 \cdot 10^9 \text{ A} \cdot \text{Sr}^{-1} \cdot \text{cm}^{-2}$



#### Cold Field Emission Gun



- New cold-FEG for:
- Higher brightness
  - Higher contrast
  - Higher precision

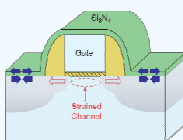


### Tomography

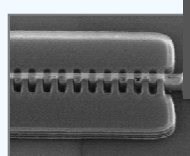
2D → 3D

- Trends in device technology:
- miniaturisation
  - complexity

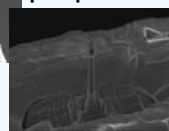
➡ *3D strain distributions*



### 3D devices



### 3D specimen preparation



### Coordination



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