Enabling DRIE processes for high potential MEMS products

Michel PUECH
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Outline

› Introduction
  • who we are ?
  • market and applications

› DRIE for MEMS
  • Bosch Process
  • High etch rate
  • Super High Aspect Ratio
  • Aspect Ratio Dependent Etching

› Conclusion
  • from MEMS to smart Systems integration
Part of a worldwide leader, high technology, Multinational corporation

- World’s leading Communication Group
- >21 B$ (2005 sales)
- >81 000 employees world-wide

Alcatel Lucent

P. Russo
S. Tchuruk

FCG
Fixed Communications Group

MCG
Mobile Communications Group

PCG
Private Communications Group

Enterprise Solutions
Space Solutions
Transport Solutions
Integration & Services

Alcatel Vacuum Technology

196 M€
(2005 sales)

Alcatel Micro Machining System (AMMS)
AMMS Patented Plasma source

- De-coupled plasma process chamber
- Low temperature plasma
- High uniformity on large diameter
- Design for uniform and high gas flow rate
Deep Etching Technique is Key to address the 3rd Dimension

- Inertial Sensors
- Ink Jet Printer Heads
- Silicon microphones
- RF MemS

A common use of ...
Deep Etching
Bosch Process

Thin fluoro-carbon polymer film (passivation)

SF₆ Plasma

C₄F₈ Plasma

SF₆ Plasma

F + ions SiF₄

-SF₆-

-SiF₄-

-SiF₄-
MEMS: Silicon microphones

- Accurate depth control
- Etching of large silicon surfaces
- High uniformity at high etch rate (>8µm/mn)
Technology leadership

- Being first to push Bosch process limits and bring into market cost effective high etch rate capabilities
  
  *(I-Speeder project 2001 - cooperation with Robert Bosch)*

- Introducing MEMS specific handling and clamping solutions

- The only OEM providing both Cryogenic and room temperature etching capabilities
MEMS: Inertial sensors

› Vertical profile control
› High uniformity at high etch rate
› Higher Aspect Ratio
› Etching of large and narrow features with controlled ARDE
Limitations

› Improper removal of bottom polymer layer

With standard “Bosch” process Aspect Ratio limited at 20
Standard ways of improvement

- Decrease process pressure, increase ion energy, ion flux
- Improved Aspect Ratio up to 30 but!
- Decrease of etch rate and/or selectivity
New way of improvement

O₂ Plasma removes polymer 5 time faster than SF₆!!

[Polymer/Si]SF₆ << 1 while [Polymer/Si]O₂ >> 1
New Alcatel process with optimal polymer removal

Aspect Ratio > 60
Super High Aspect Ratio Process

Trench Width: 0.374 µm
Depth: 40.1 µm

Aspect Ratio >100

By courtesy of ESIEE - Paris
ARDE is the physical effect where the etch rate decreases when increasing the aspect ratio.

- Structures with different dimensions have non uniform etch rate.
- Complex devices cannot be made
  - Substrate with etch stop layer ⇒ SOI wafers.
  - High over etch time to complete the etching of the narrow structures.
WHY ARDE?

› Radical’s Depletion
  • Knudsen transport

› Ion Depletion
  • Side wall scattering
  • Electronic deflection
  • Angular distribution
Experimental Setup

- AMS 200 “I-Speeder”
- Alcatel test wafers: trench widths 200/10 µm, 20% Si exposed area
- “Bosch” Process: Time multiplexed etch/passivation
- “ARDE” = (ER max - ER min)/ER max
Ion Flux Effect

ARDE = 45%
max ER = 7.1 μm/min
min ER = 3.9 μm/min

ARDE = 18%
max ER = 4.4 μm/min
min ER = 3.6 μm/min
Passivation Control

ARDE = 12%  
max ER = 3.2 µm/min

ARDE = < 1%  
max ER = 3 µm/min

ARDE = -13%  
max ER = 2.9 µm/min
Conclusion

... from MEMS to Smart System Integration

**Semiconductor**
- Deep Etching
- Lithography
- Bonding, ...

**Manufacturing Tools 3D**
- Deep Etching
- Lithography
- Bonding, ...

**MEMS**

**3D SC**
- 3D Chips
- Wafer Level Packaging

400um

10um

Courtesy of ST Microelectronics

Courtesy of Philips

Courtesy of Toshiba