Endpoint Detection of Low Open Area Contact Nitride Etches by Use of Optical Emission Spectroscopy in an APC Compatible Multi-Sensor Platform

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Content

1. Context
   - ALTIS & HORIBA Jobin Yvon
   - The JY instrument platform
   - Contact Nitride Etch

2. Optical Emission Spectroscopy
   - Data handling
   - Wavelength selection
   - Endpoint detection

3. Results
   - SEM validation
   - Statistics : tool impact, first wafer effect ...
ALTIS Semiconductor
Joint Venture (1991)
50% IBM, 50% Infineon
2000 people
10000 wafers per week
504 M€
CMOS logic, eDRAM & mixed signal

HORIBA Group
3700 people worldwide
750 M$
► Jobin Yvon (joined HORIBA 1997)
550 people worldwide
98 M€
► Thin Film Division (50 people)
Optical metrology (ellipsometry, APC)
MultiCPM Platform

- In-situ multi-sensor and multi-chamber monitoring
  - OES Optical Emission Spectroscopy
  - LEM Camera Interferometry
  - TDM Depth monitoring
- Designed for fab
- Compatible with all etchers and OEMs
  - LAM Alliance
  - AMAT AME 5000 & 5200
  - TEL Unity 2 & M
- Common Windows based software platform
- More than 50 production chambers equipped at ALTIS
Optical Emission Spectroscopy

- **Principle**
  - The relaxation of plasma excited species produces light.
  - Emission wavelengths are characteristic of the species in presence.

- **Instrumentation**
  - Light is guided towards a diffraction grating by a fiber optic
  - Light intensity is measured as a function of wavelength
  - Real time
Application to Plasma Etching

- Plasma / etched layer interaction
  - Plasma emission is modified by the nature of the layer being etched

- Plasma emission change
  - Interface
  - Change in the chemical reaction in the plasma
  - Appearance / disappearance of emission lines

- Interface signature
  - Rupture
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Application to Plasma Etching

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• Interface signature
  – Rupture
The Endpoint Transition

- Transition between 2 levels
- Transition time length is related to the etch rate inhomogeneity
  - Non-uniformity from the center to the border of the wafer (layer thickness ...)
  - Non-uniformity in pattern density
- Only certain wavelengths are concerned
Contact Nitride Etch

Flash Memory

• 0.22 µm technology, open area 2.5 to 5%, non-uniform pattern density
• 5 steps involved: Nitride dep / oxide dep / CMP / (litho mask) / oxide etch / nitride etch
• Nitride etch monitored by OES
The Process Engineer's Work

Step 1: endpoint detection setting
- Collect & understand the data
- Select wavelengths & parameter endpoint detection algorithm
- Perform test on a few lots

Step 2: validation
- Process monitor (still in fixed time)
- Statistics and correlation with electrical tests

Step 3: production and yield improvement
JY solutions

1. Understanding the data
   – Quick navigation
   – Classification

2. Select Wavelength
   – The software selects the best wavelengths from a series of runs

3. Parameter setting
   – Easy and intuitive algorithm parametering

4. Validation
   – Statistics in a database
   – Reprocessing on the saved spectra (change the algorithm parameters)
Classification

• **Principle**
  - Bring together wavelengths that behave in a similar manner and make groups with them

• **Result**
  - The classification offers within a few seconds a summary of the 2048 wavelengths
  - The user can understand quickly what is happening in the process, where it is happening and when
A classification example ...

![Graphs showing wavelength (nm) and time (s) data](image)
Wavelength selection

User inputs
• Time range
• Wavelength range

► The algorithm automatically selects the best wavelengths

► Image
Bottom: selected wavelengths are in red
Top: average kinetics over selected kinetics
Real-time Endpoint Detection

The endpoint detection algorithm in sequence
• The top curve is the average kinetics
• The bottom curve tells if the rupture is well defined
• The left vertical black line on top points to the most highly probable rupture time
• The right vertical black line is the time
Real-time Endpoint Detection

The endpoint is not reached yet, the probability to find an rupture (bottom curve) is still low.
Real-time Endpoint Detection

The endpoint is being reached. The probability start to grow but it is still low: the endpoint can be detected but it is not robust!
Real-time Endpoint Detection

The endpoint is detected. The probability is high and has reached the user defined threshold (value 10). The endpoint detection robustness has increased.
Real-time Endpoint Detection

The endpoint has long been reached. The algorithm still points towards the rupture point at 70 seconds.
SEM Validation & Over-etch

- At rupture time (10s)
  - Dense zone are already open
  - ... but electrical test fails
- At rupture time +15s
  - The land is being etched
  - ... but electrical test still fails
- At rupture time +30s
  - Good!
- At rupture time +40s
  - ... not good again
Statsitics

- **Collected data**
  - Monitoring (endpoint not in production yet)
  - 10000 runs (1 month)
  - SECS II
  - Chamber names for the previous steps

- **Study**
  - Endpoint "normal" variability
  - Tool or chamber impact on endpoint variability
  - Maintenance operation
Endpoint variability

- Average 12 s
- Standard deviation 2.3 s
- 50% between 6.8 and 17.6 s
- Some outliers above 20 s (under investigation)

The endpoint can vary within a range of 10 s. This is to be related to the wafer to wafer nitride layer thickness variability.
First wafer effect 1/3

- **Nitride layer etch**
  - One tool, two chambers (A & B)
  - Average rupture time vs slot number
  - Two populations: odd and even slots
First wafer effect 2/3

- **Nitride layer etch**
  - One tool, two chambers (A & B)
  - Average rupture time vs slot number
  - Two populations: odd and even slots
  - Chamber effect! Odd slot numbers are usually processed by chamber A
  - Problem?
First wafer effect 3/3

- **Nitride layer etch**
  - One tool, two chambers (A & B)
  - Average rupture time vs slot number
  - Two populations: odd and even slots
  - Chamber effect! Odd slot numbers are usually processed by chamber A
  - Problem?
    - temperature and flow correction in the tool cooling system
Tool Matching

- **Previous step:** oxide layer etch
  - 2 tools: T1 and T2
  - Separate study on nitride etcher chamber A and B

- **Results**
  - Significant difference between T1 and T2
  - T1 is more selective than T2: T2 starts to etch the nitride layer so the endpoint comes sooner on T2 than on T1.
Advanced Process Control at ALTIS

- **Process monitoring**
  - Increase process stability

- **Equipment monitoring**
  - Increase equipment uniformity and performance
  - Tool matching

- **Module monitoring**
  - Control the inter-dependent steps of a module

- **HORIBA Jobin Yvon** is a key partner for the OES process control at ALTIS