Integrated CD Metrology for Poly Si Etching

G.P. Kota, V.Venugopal and R.A. Gottscho Lam Research Corporation T.G. Dziura, U.Whitney and A. Levy KLA-Tencor

Plasma Etch Users Group Meeting Jan 17, 2002





Outline

Motivation

A Scatterometer concept

A Results

- comparison to CD-SEM, x-SEM and AFM
- different profiles
- repeatability measurements
- 193nm PR measurements

Summary





What Does CD Mean?

- ▲ For smaller design rules, corner rounding, notching etc can make up a significant fraction of the line shape
 - Examples:



Where do we measure CD?

- Not clear using CDSEM
- Can measure CD at any height using SCD since the entire profile information is available





Demand For Profile Measurement

- ▲ For most processes, dimensional measurements are required at specific locations on the feature
- **Example: STI application**







SCD Measurement Process

240-780nm
Ellipsometer
Amplitude
and phase are
acquired
Best match
determines
target
parameters



Offline: Library generation

<u>Online</u>: Film measurement Profile measurement



Film 2

Film 1



Advantages of SCD

- ▲ Integrated metrology use
- Low cost of ownership
- High throughput
 - 100 wafers per hour with 5 measurement points for each wafer
- ▲ CD as well as profile information
- ▲ Non-destructive technique
 - prevent shrinkage of 193nm PR
- Average profile of the grating area inspected





Disadvantages of SCD

- ▲ Creation of off-line spectral libraries
- ▲ Library needs to be re-created if any of the grating parameters are changed
- ▲ Test structures (grating) required
 - Current minimum grating size ~ 50μ m x 50μ m







Applications of SCD

▲ Integrated CD measurement (iCD) tool can be used in real time for

- Feed forward control
 - » measure pre etch CD/profile and adjust process recipe for desired post etch CD/profile
- Feed back control
 - » measure post etch CD/profile and adjust process recipe for desired CD/profile
- Fault detection
 - » measure post etch CD/profile to detect any process excursions and avoid further mis-processing of wafers





Stacks and Features

Stack: resist / organic ARC / a-Si / gate oxide / Si

- CD: 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 120, 140, 160 nm
- L/S ratio: 1:1, 1:2, 1:3, 1:5









Processes

Process step: pre etch, post-BARC etch, post a-Si etch, post a-Si etch and clean



• **a-Si etch**: "nominal", "tapered", "bowed"







Sampling Plan



▲ 49 sites across the wafer

 Measurements made at different process steps were made on sister wafers







Pre etch Results: XSEM & SCD

Good match to XSEM & spectral data



XSEM – SCD comparison

SCD model match to data





Pre Etch Wafer Maps (160 nm 1:1)







SCD compares well with AFM measurement

Pre etch wafer: PR thickness measurements

Measurement Technique	PR thickness (nm)
SCD	396
x-SEM	390
AFM	396





Post Etch Results: XSEM & SCD

▲ 160 nm 1:5 L:S

▲ Mask erosion, a-Si profile are correctly measured







Post Etch & Clean Results: XSEM & SCD

▲ 160 nm 1:1 L:S, tapered etch



XSEM – SCD comparison

SCD model match to data





Post Clean Wafer Bottom CD and Profile Maps

160 nm 1:1 L:S; tapered etch cross wafer profile uniformity is excellent







Post Clean Wafer Sidewall Angle Map

▲ 160 1:1 tapered etch

k sidewall angle distribution is tight







Post Clean Wafer Results: XSEM & SCD

- ▲ 160 nm 1:1 L:S, bowed etch
- ▲ sidewall profiles are accurately measured









Good Correlation between CD-SEM and SCD

SCD: Static and Dynamic Repeatability <0.02nm







CD-SEM Measurement Issues of 193nm PR

▲ 193nm PR is known to shrink ~ 10nm during CD-SEM measurements (e-beam exposure)

This can be minimized by using SCD

▲ 193nm PR typically has rough sidewalls which lead to ambiguity in CD measurements

- This can be minimized by using a non-localized measurement technique
 - » SCD averages over the beam spot area
 - » CD-SEM is a very localized measurement





Localized CD-SEM measurement can result in unrepeatable CD measurements

CD measurements on the same die



CD measurement = 131.9



CD measurement = 125.5





193nm PR: Static Repeatability on pre etch wafer







Summary

SCD provides accurate CD and profile information

low 3sigma dynamic and static repeatability

- SCD shows good correlation to CDSEM and x-SEM
- **SCD** enables process control
 - integrated on to the etch platform
 - feed forward, feed back and fault detection
- SCD better for measuring 193nm PR than CD-SEM due to PR shrinkage



