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In-Situ UV-Visible Reflectometry for STI, Recess and Gate Etch Endpoint

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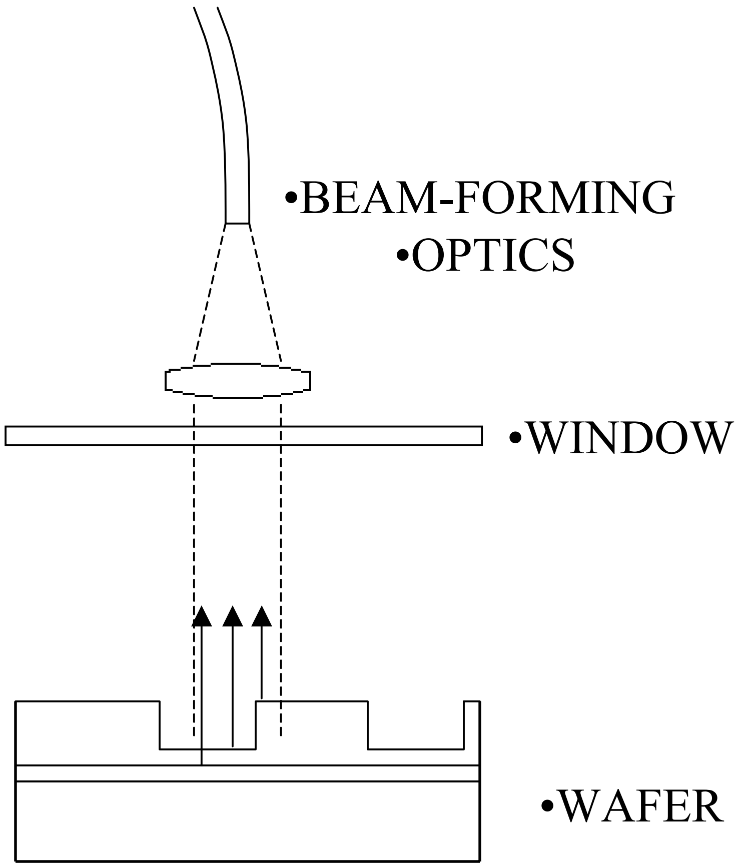
INTRODUCTION

Problem:	Control Etch to a Predetermined Dimension (no Stop Layer)
Examples:	Recess Etch Gate Etch Shallow Trench Isolation
Approach:	UV-Visible (Interferometric) Reflectometry

Interferometric Reflectometry



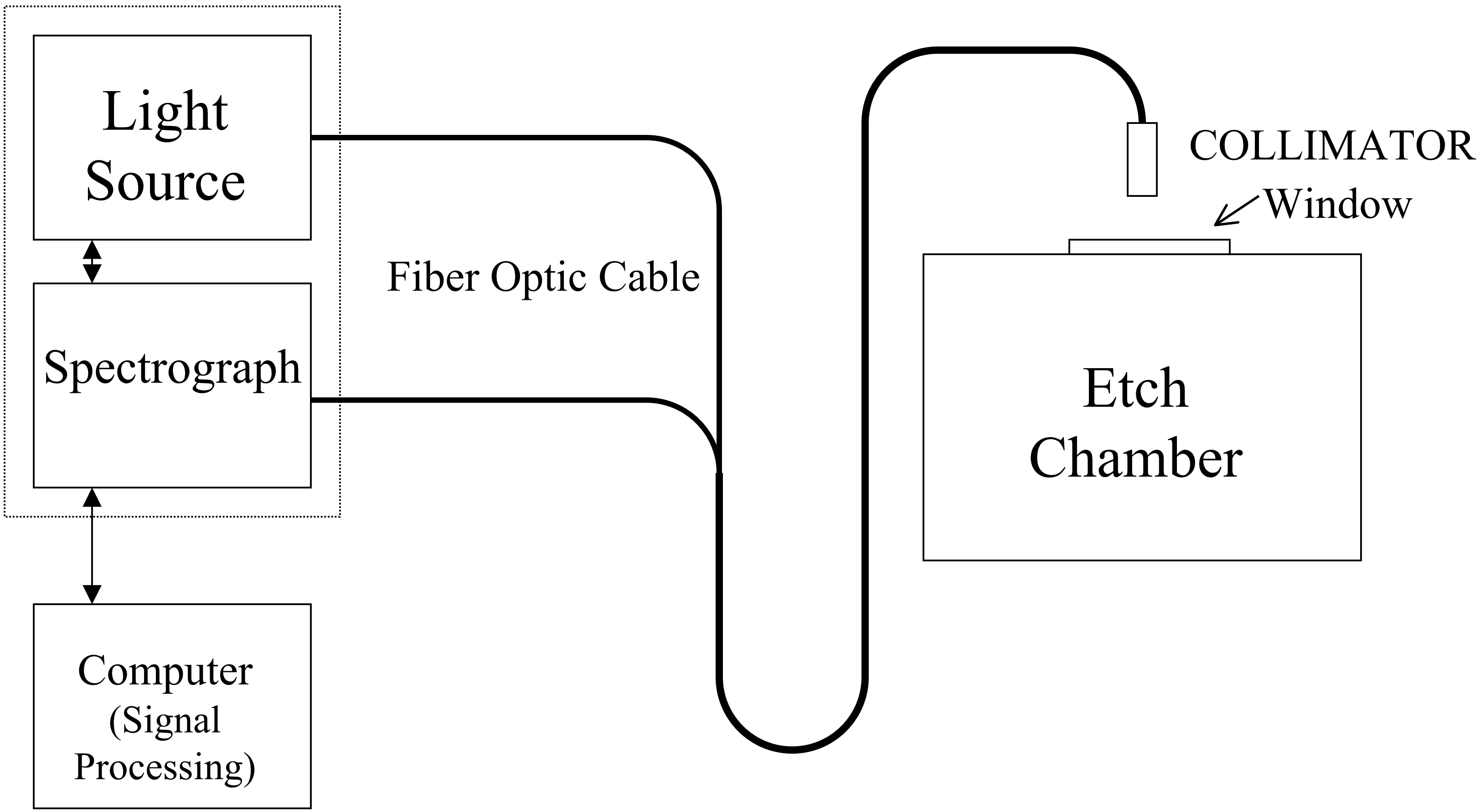
- Light incident on the wafer reflects from surfaces and interfaces
- Multiple reflected beams combine in far field
- Used for in-situ etch monitoring since at least 1975 [1]

[1] K. L. Konnerth, F.H. Dill, IEEE Trans. Electron Dev. ED-22, 452 (1975)

CHALLENGES

- Plasma emission in chamber (may contaminate spectra)
  - Use pulsed source, do background-subtracted measurement
- Small Length Scale (thin layers, narrow trenches)
  - Extend measurement to UV

SYSTEM SCHEMATIC



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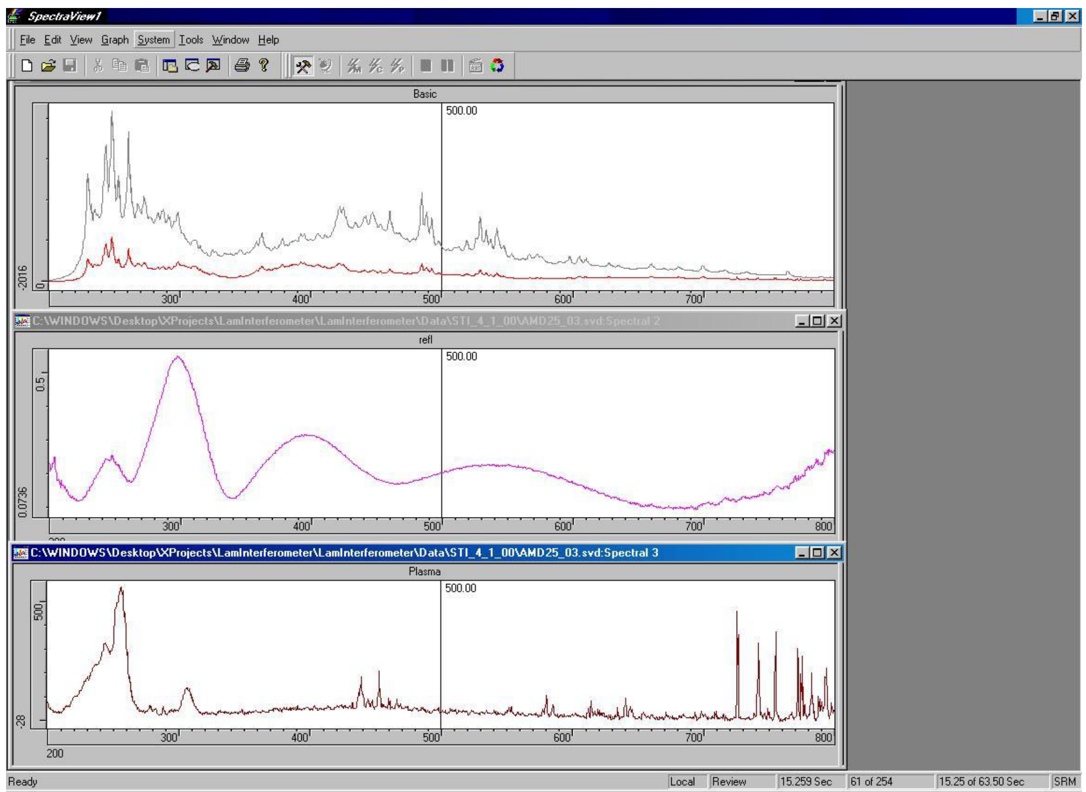
SP2000

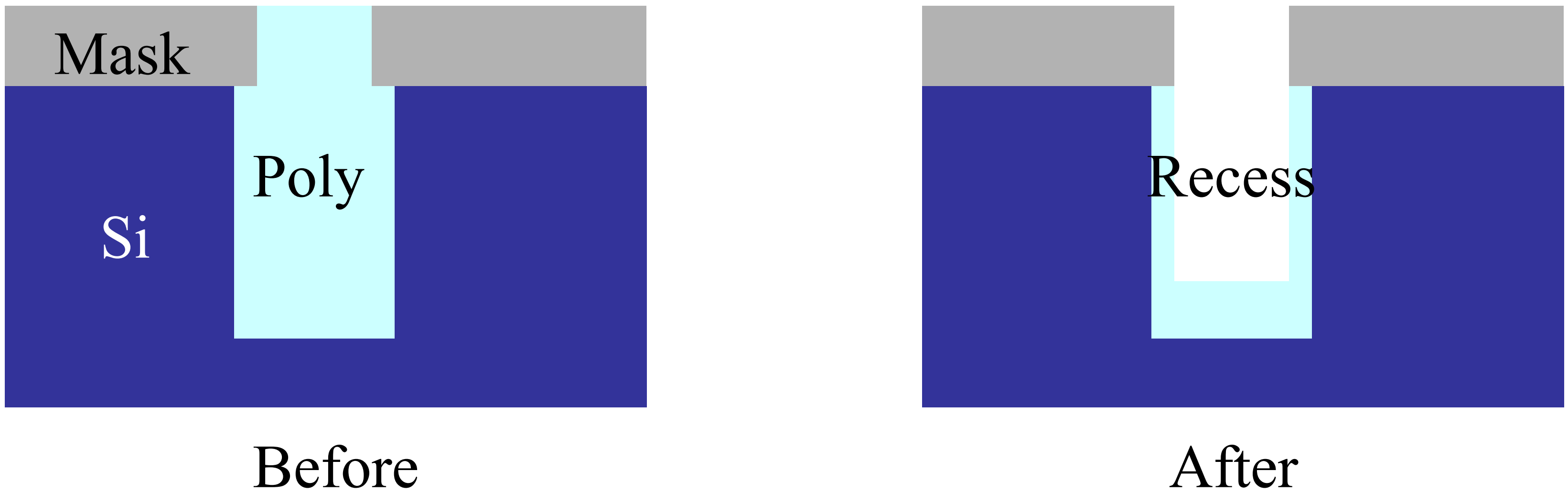
SP2000

Sample screen showing:

- Raw incident lamp light
- Normalized Wafer Reflectivity
- Plasma Spectrum



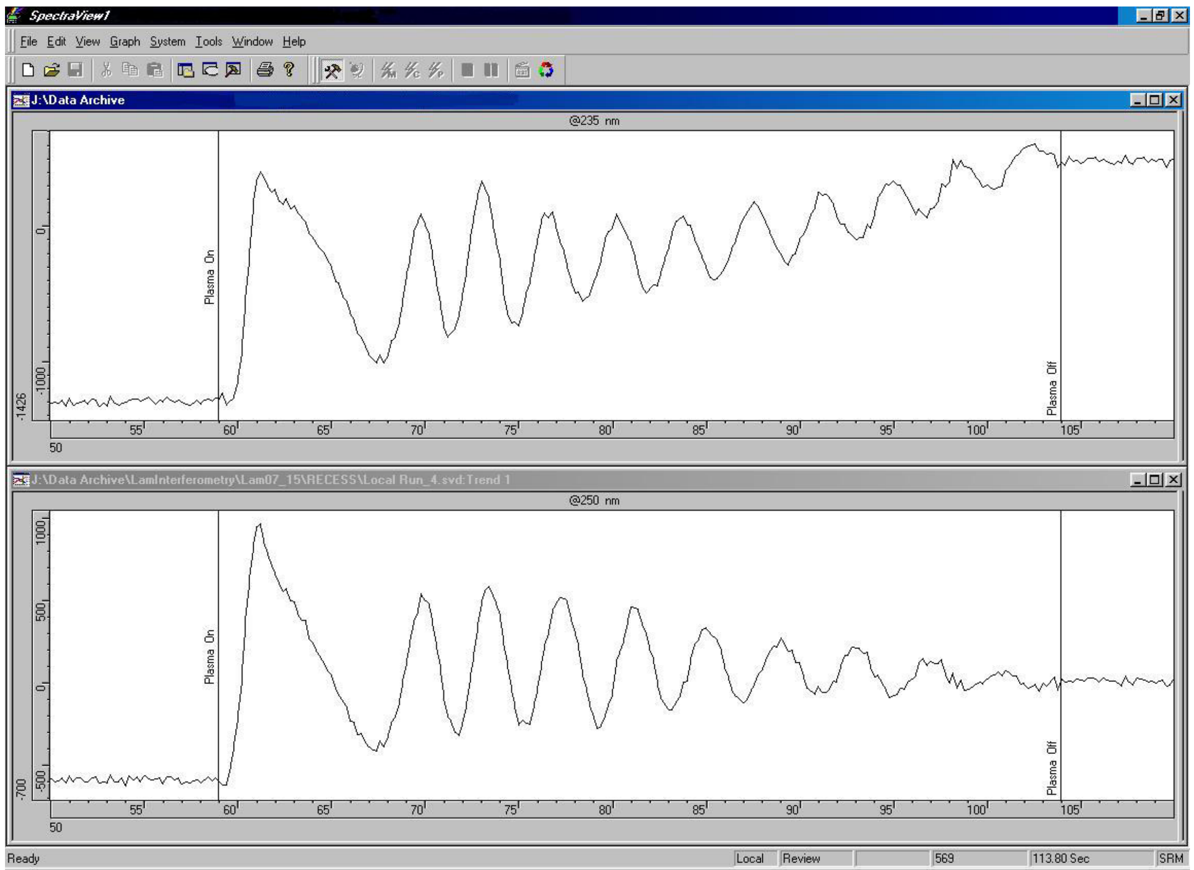
RECESS ETCH



- Recess depth measurement: count interference fringes as Poly etches
    - One cycle means depth increased by $\lambda/2$
- Wavelength chosen affects fringe visibility
- Resulting measurement is from top of mask
    - To know depth into Si, mask thickness measurement needed

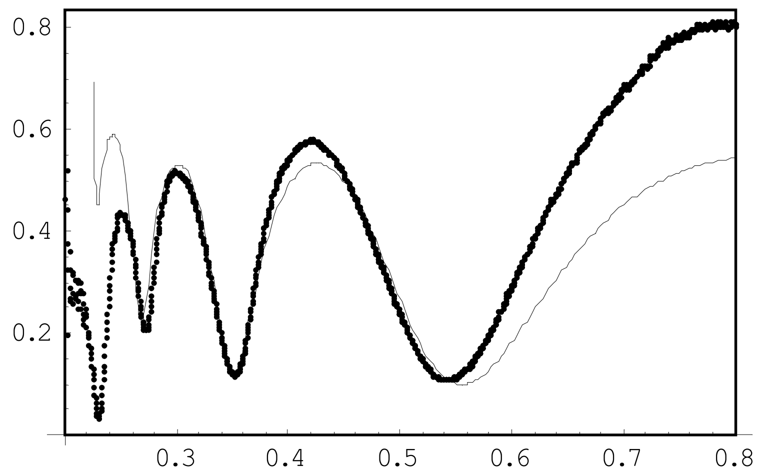
RECESS ETCH

- Interference traces at 235nm and 250nm during recess etch step
- Shorter wavelength significantly improves fringe visibility at end
- Depth, including mask: 1293nm (From SEM: 1336 nm)



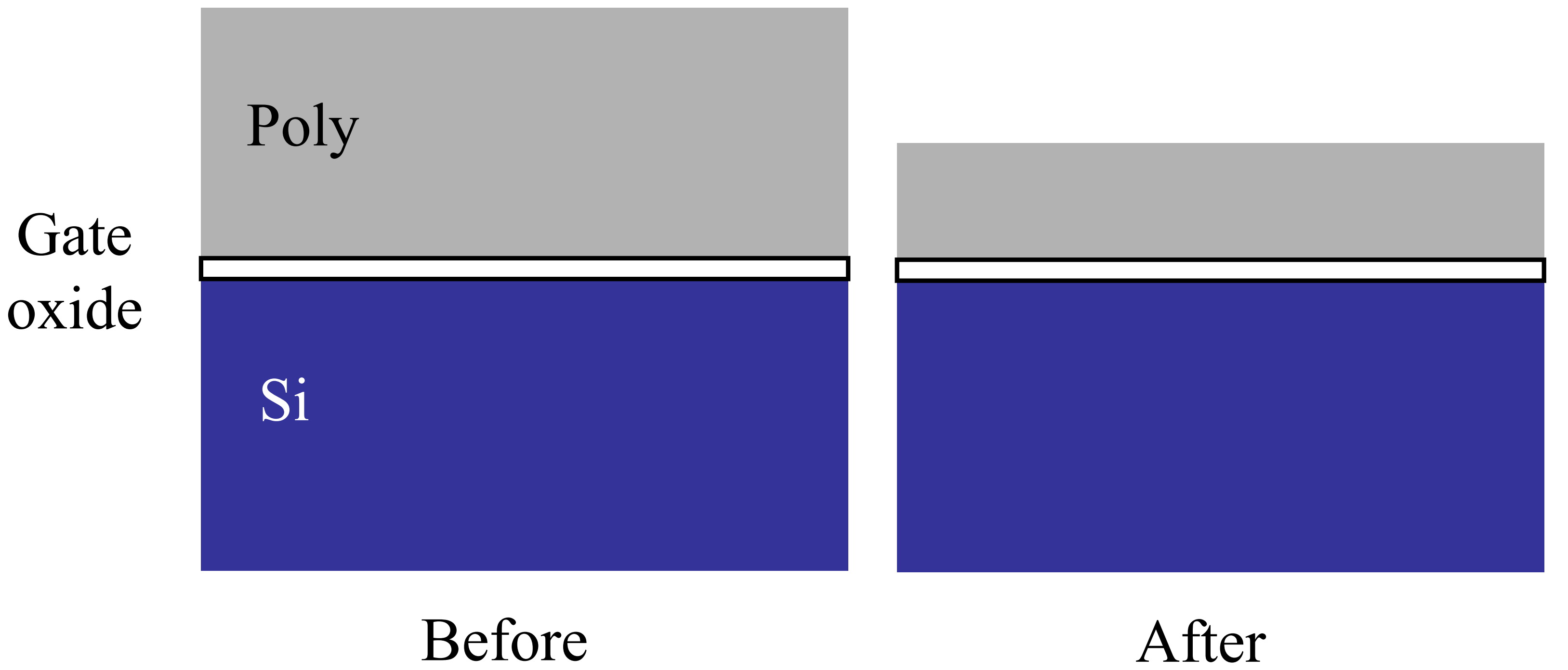
RECESS ETCH

Mask thickness measurement from full spectrum



- Mask thickness measurement from single measurement on patterned wafer
- “Model” is single continguous nitride layer, regress on thickness
- Optical measurement: 2180Å (SEM: 2200 Å)

GATE ETCH



Goal is to control the poly thickness (typically few hundred Å)
Etch rate, initial poly thickness are variable

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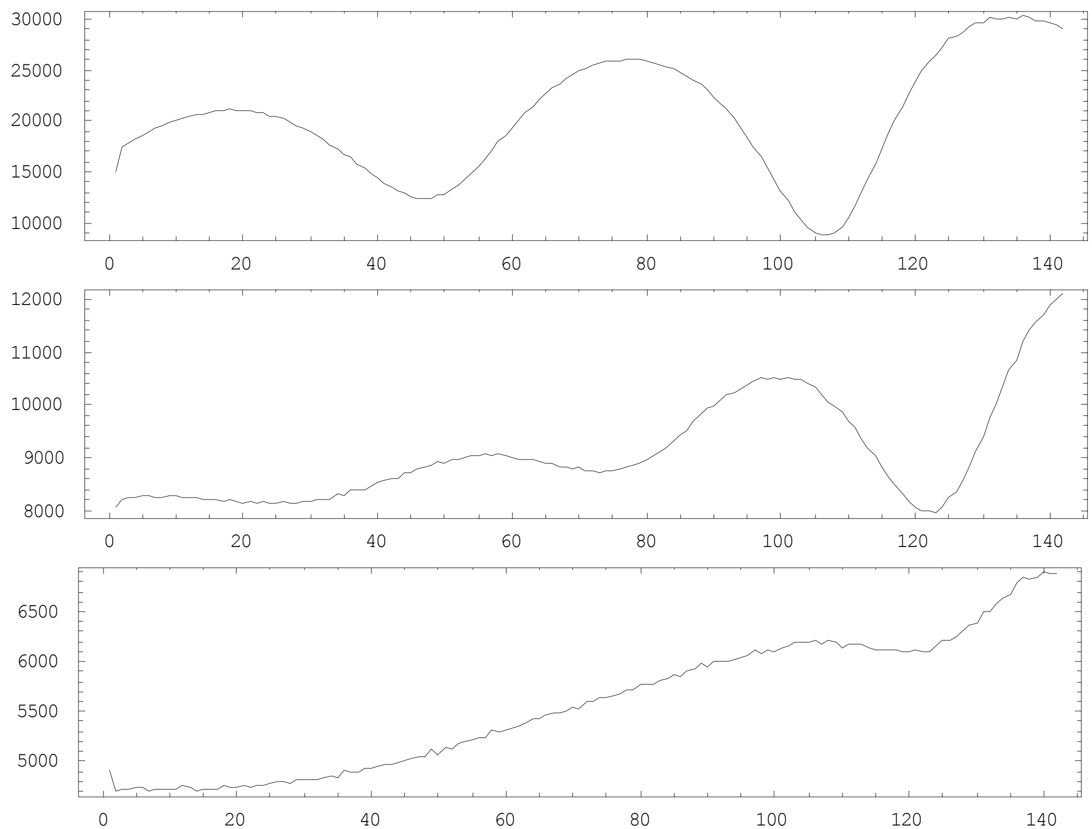
GATE ETCH

At shorter wavelengths, fringes seen only for thin poly layers



450 nm

400 nm

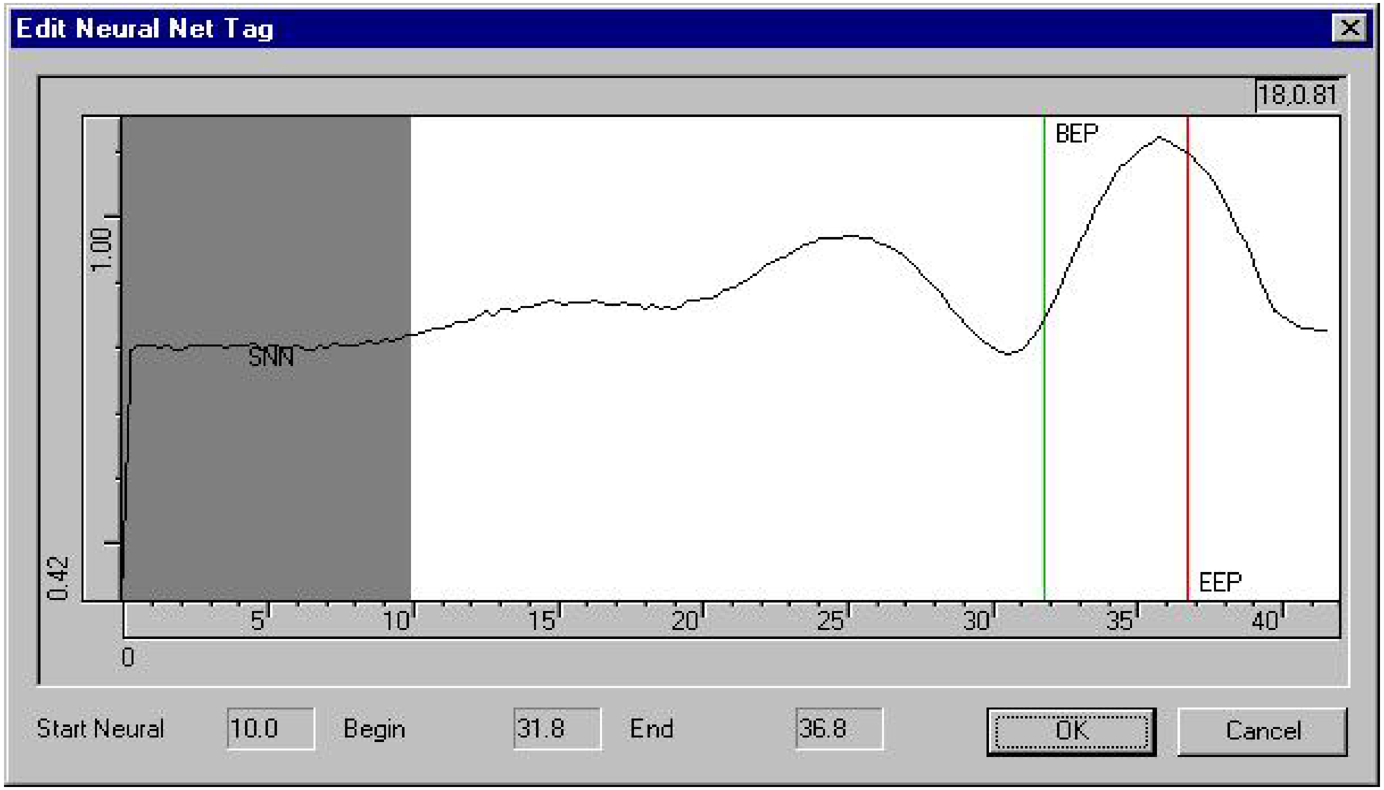
350 nm

TIME →

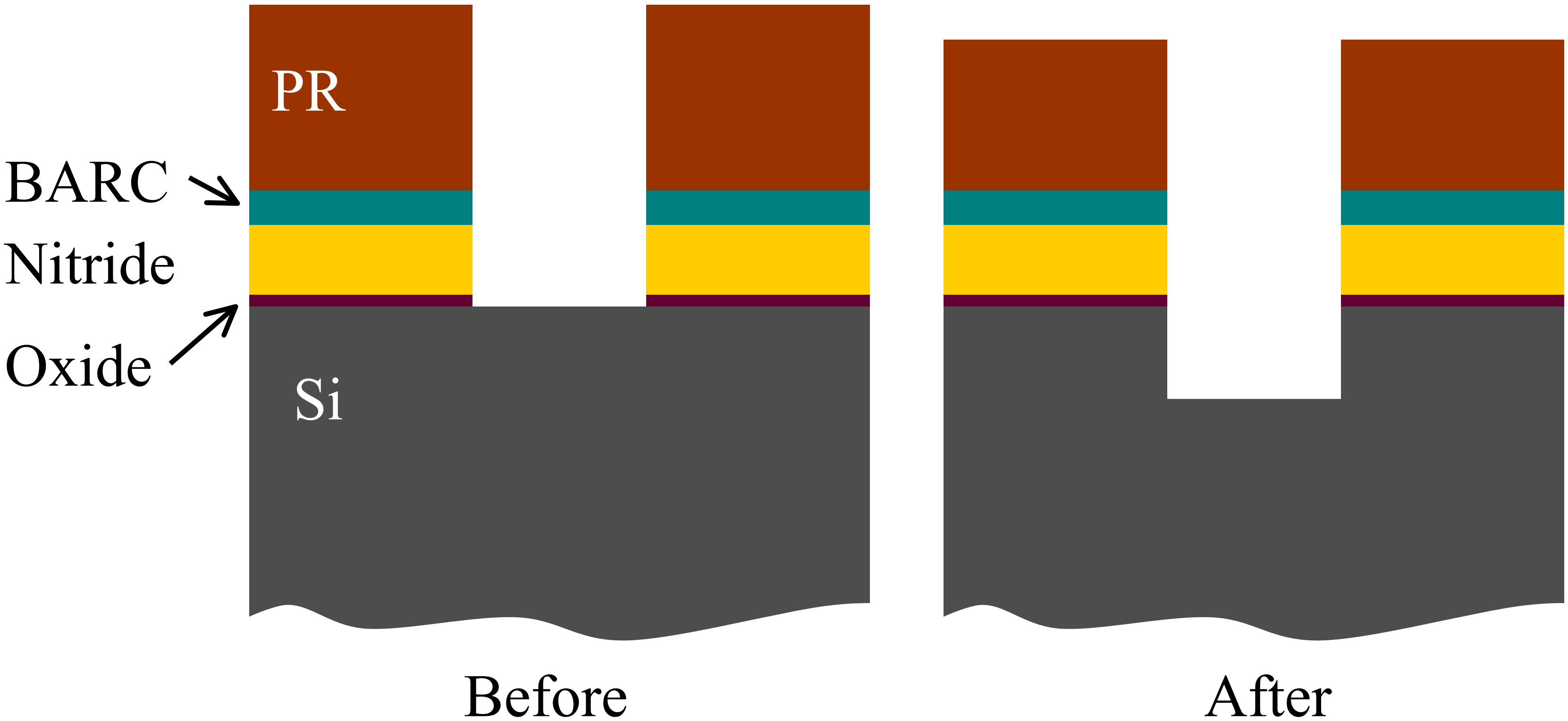
GATE ETCH

Simple, robust endpoint on gate is possible using pattern recognition on trends at one or more wavelengths:

Training the neural net algorithm on a file



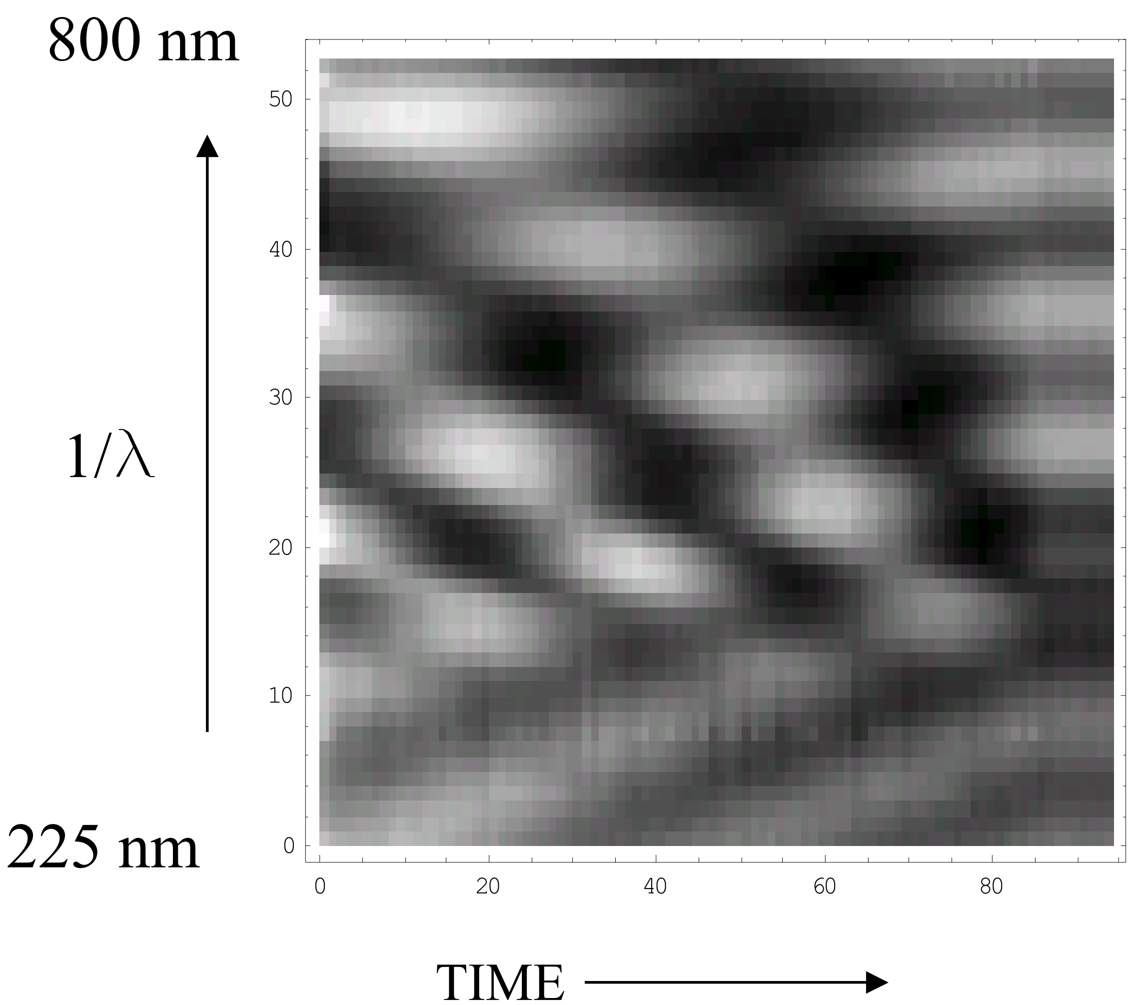
SHALLOW TRENCH ISOLATION



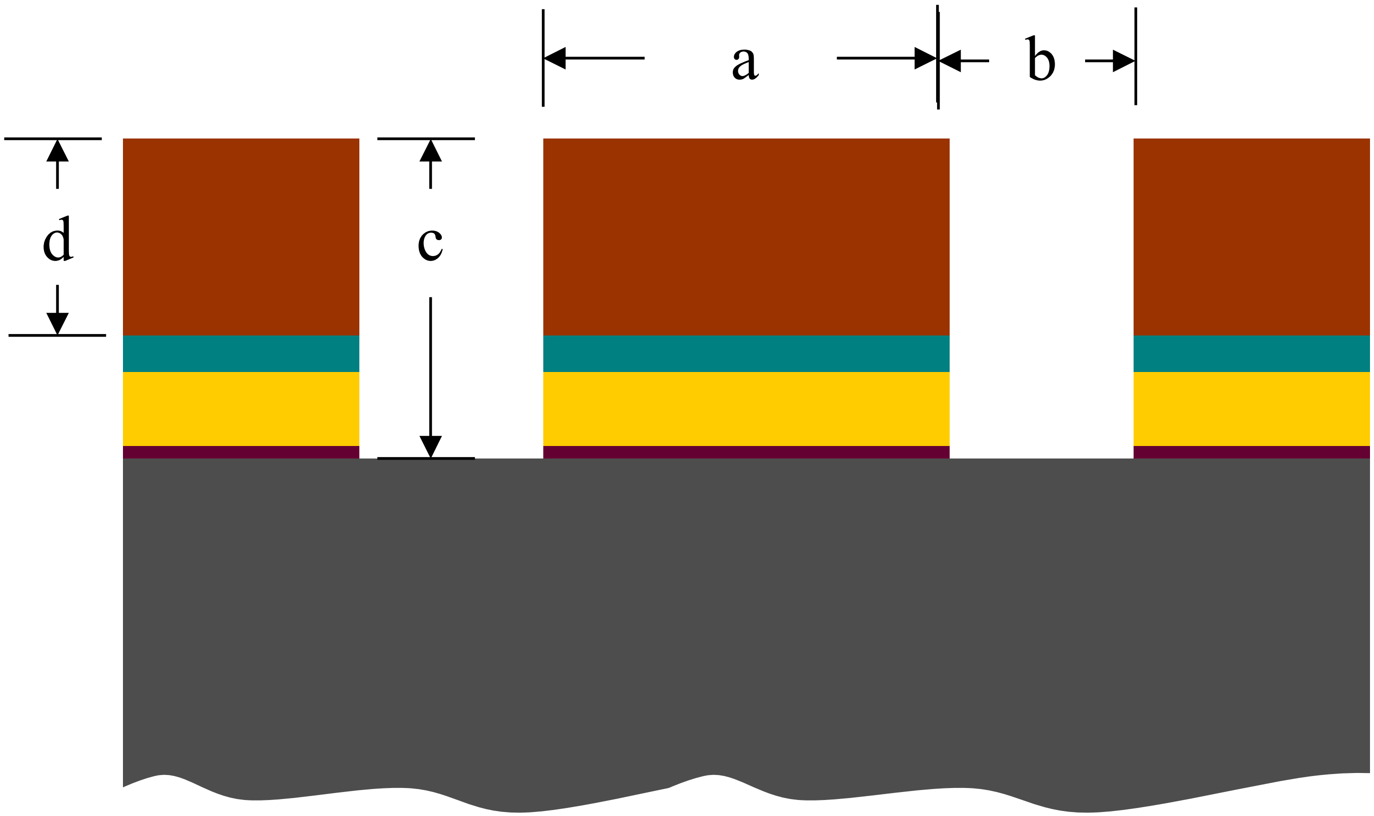
- Goal is to control the depth of the trench in the Si
- Complication - photoresist mask is also etched

SHALLOW TRENCH ISOLATION

2-dimensional plot of wafer reflectance vs time, STI etch

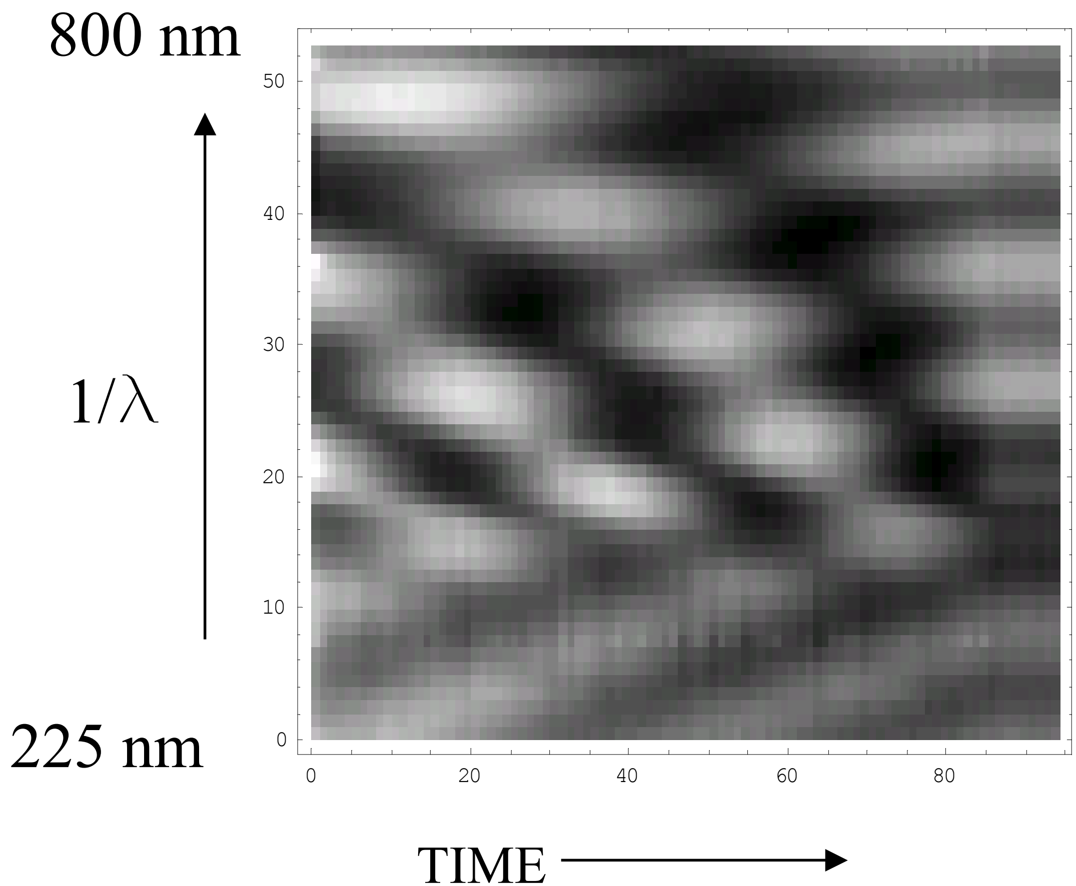


SHALLOW TRENCH ISOLATION



- To measure trench depth, we use a full spectral reflectivity model of the structure.
- c and d are regression variables
- All other layer thicknesses, n's and k's, and average a/b are fixed

SHALLOW TRENCH ISOLATION

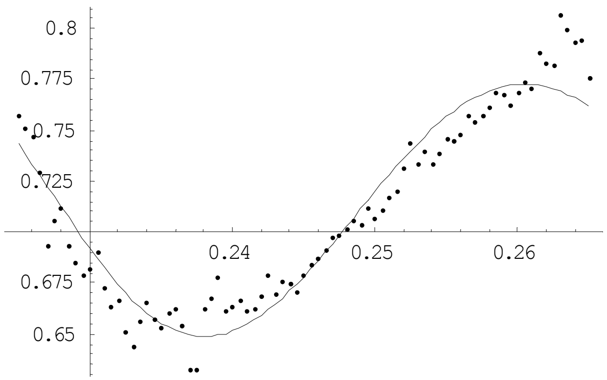


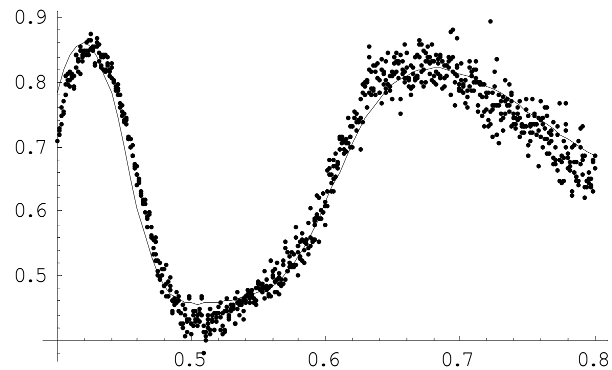
At each time step (1sec):

2nd: 2-parameter fit with c constrained yields d

- *1st*: 1-parameter fit yields c;
- Layers opaque at UV end
- No complex stack reflection

SHALLOW TRENCH ISOLATION





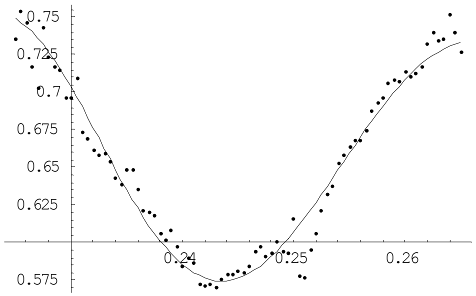
Initial 1parameter fit of c
(λ = 225 – 265 nm)
c = 644 nm

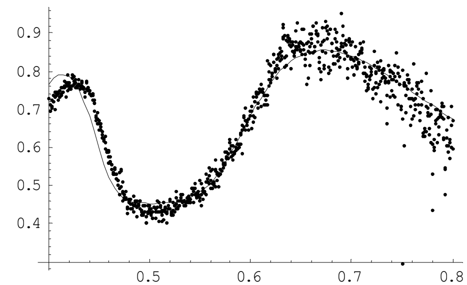
Initial 2 parameter fit of d
(λ = 400 – 800 nm)
d = 377 nm

SHALLOW TRENCH ISOLATION

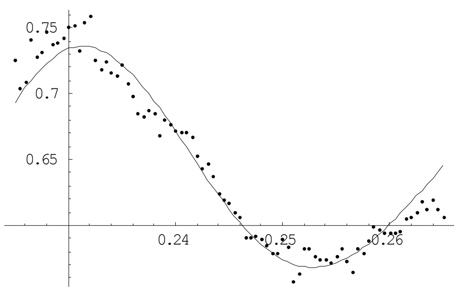
Representative fits during etch

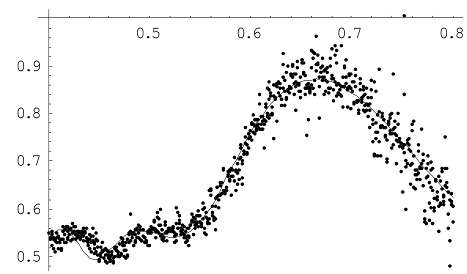
10 sec



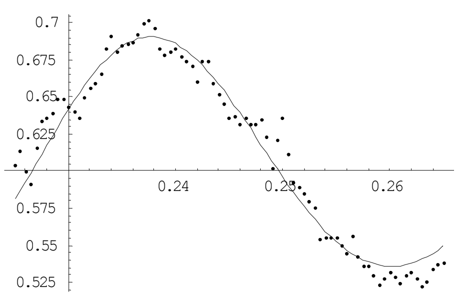


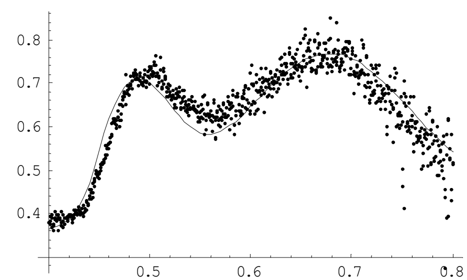
20 sec





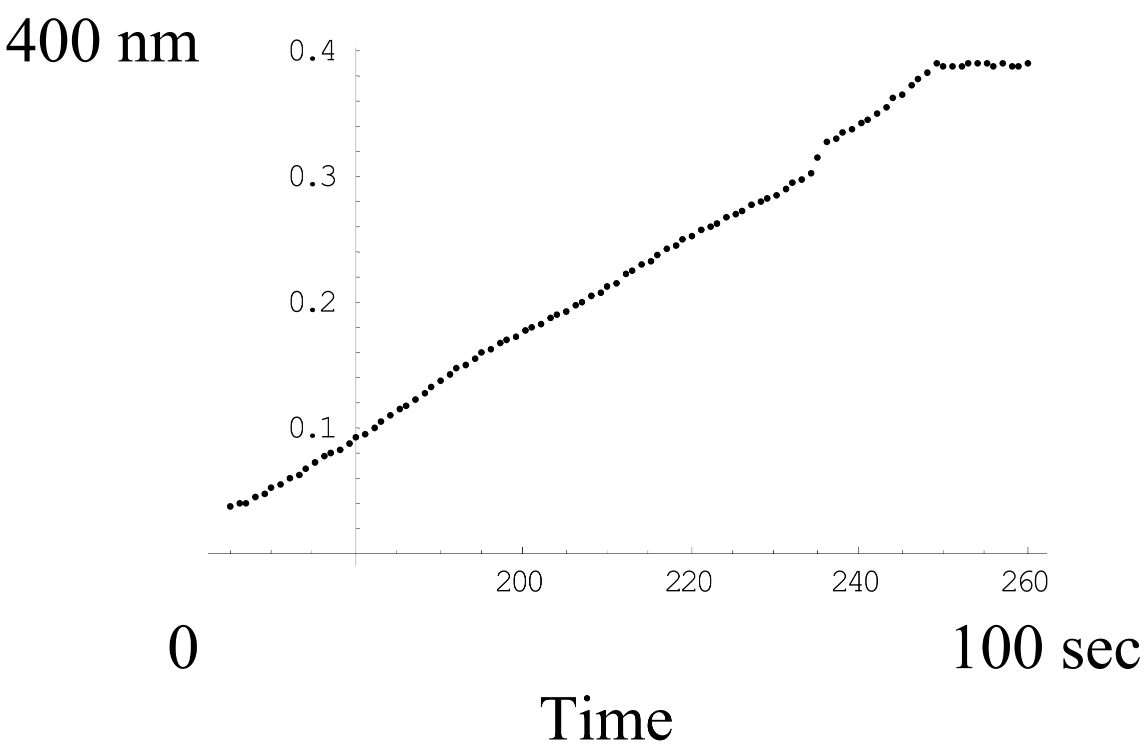
30 sec



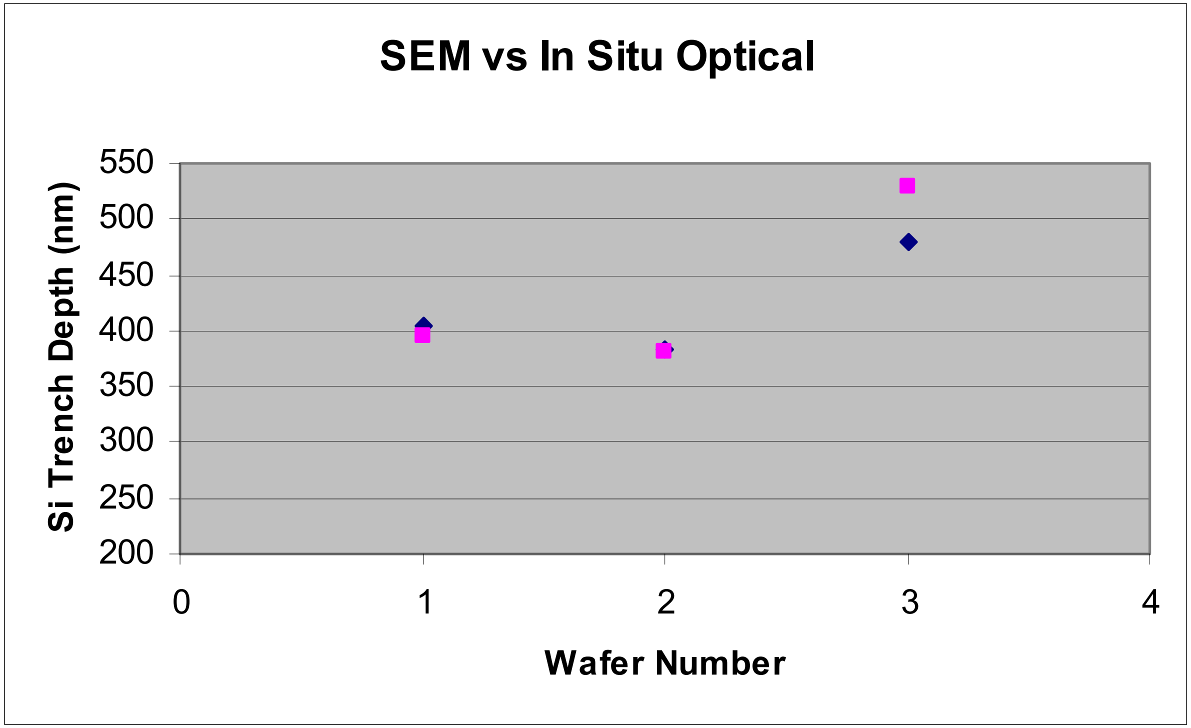


SHALLOW TRENCH ISOLATION

Depth into Si during Etch



SHALLOW TRENCH ISOLATION



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SUMMARY

• UV-Visible Interferometric Reflectometry is a valuable in-situ process control tool for gate, recess and STI applications

• Recess applications can use simple fringe counting for depth monitoring, and simple spectral models to accomodate varying mask thicknesses

• Gate applications can use simple pattern-recognition to control poly thickness

• STI applications with non-selective etch require full spectral model regression, but can be used successfully