MOTIVATIONS AND OBJECTIVES

- **Definition**

  Run-to-run (RtR) control is a generic methodology in control of semiconductor manufacturing processes. It is a model based process control strategy whereby process inputs (recipes) are adjusted on a run-to-run basis in response to measurements (responses) of process state variables.

- **Why Nonlinear**

  In semiconductor manufacturing, if the perturbations are small enough, they can be compensated by the exponential weighted moving average (EWMA) method. But, unfortunately, this is not always the case.

- **Nonlinear Process Examples**
  - Plasma process
  - Photoresist process
  - Chemical-Mechanical Polishing process

- **Objectives**

  Develop set-valued nonlinear RtR controller for semiconductor manufacturing.

METHODOLOGY AND SIGNIFICANCE

- **Methodology**
  - Combines the set-valued method with the ellipsoid algorithm.
  - Provides an approximate minimum bound on the parameter sets.
  - Identifies the process model within the parameter set at the beginning of each run.
  - Adjusts inputs according to the updated model.
- **Significance**
  - Applicable for various types of noises and disturbances, which are present in real industrial processes.
  - Robust to model errors and sensor errors.
  - The ellipsoid algorithm is easily applicable.
  - Efficient use of innovation data.
  - Applicable for both linear and nonlinear semiconductor manufacturing processes.

SIMULATIONS AND PROCESS MODELS

- **Simulations**

  The following real industrial processes were simulated:

  – Light pressure chemical vapor deposition (LPCVD) process under large model error.

  – LPCVD process under drift (Compared with the EWMA controller).

  – LPCVD process under shift (Compared with the EWMA controller).

  – Photoresist process under drift.

  – Photoresist process under shift.

- **Process Models**

  – LPCVD Process

$$R_1 = \exp(c1 + c2 \cdot \ln P + c3 \cdot T^{-1} + c4 \cdot Q^{-1})$$

$$R_2 = R_1 \left[\frac{1 - S \cdot C_{gs} R_1 Q^{-1}}{1 + S \cdot C_{gs} R_1 Q^{-1}} \right]$$

Where R_1 and R_2 are the deposition rates in Angstroms/minute on the first and the last wafer separately.

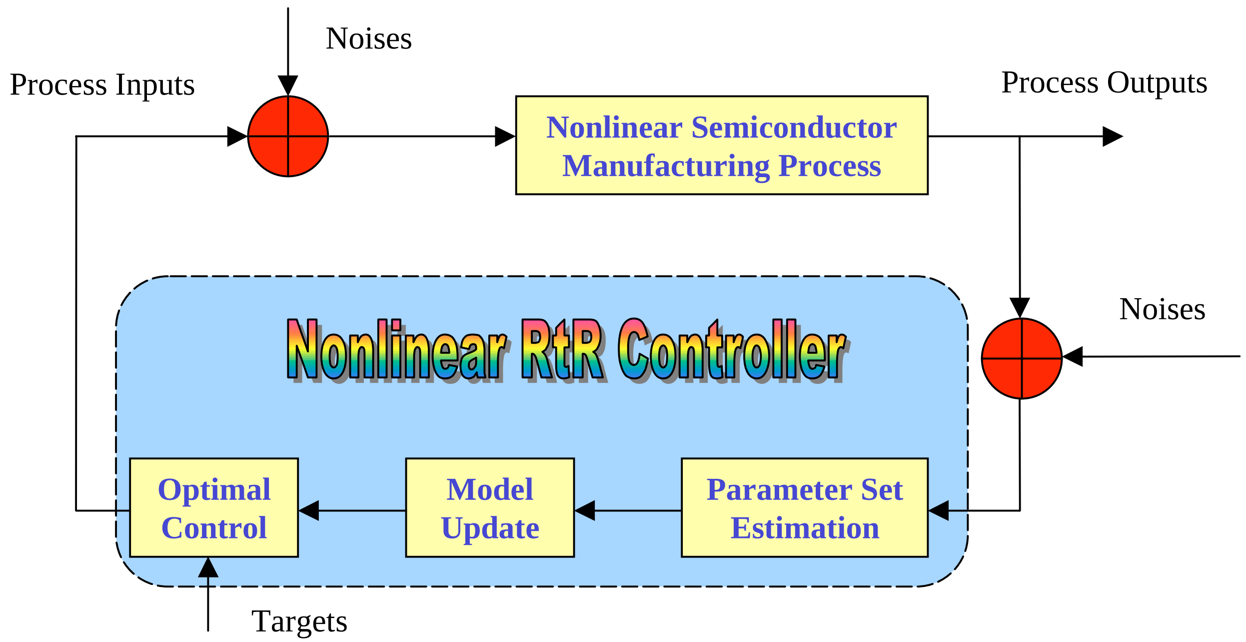
– Photoresist process

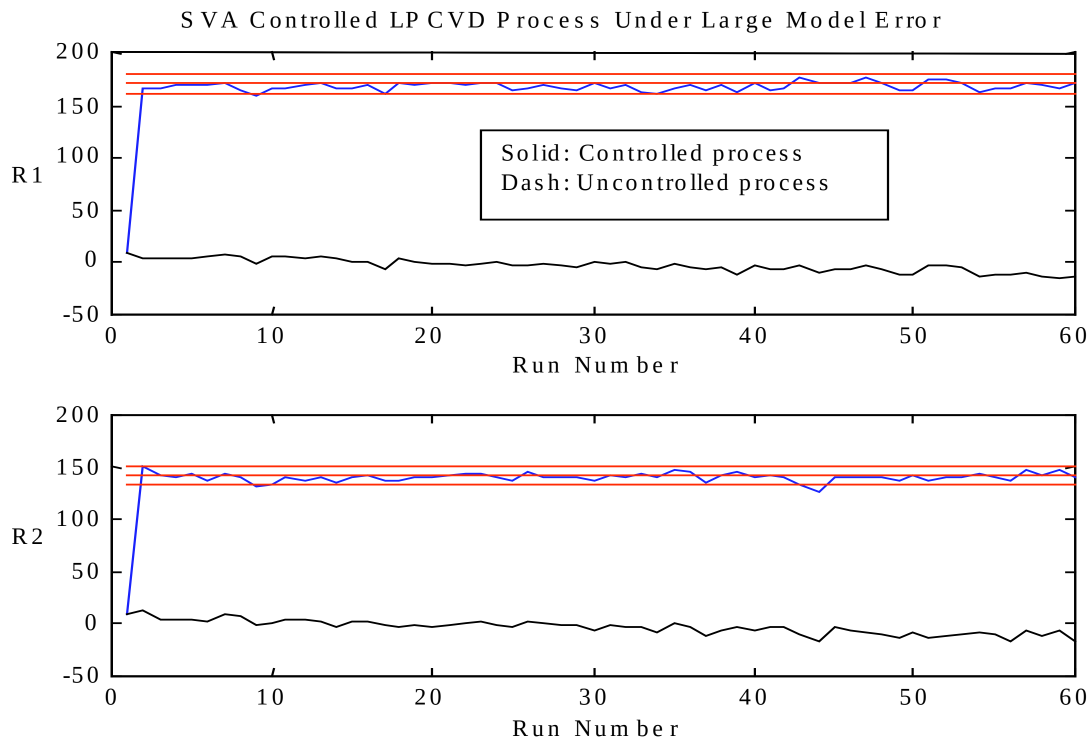
$$T = -13814 + \frac{2.54\times10^{6}}{\sqrt{SPS}} + \frac{1.95\times10^{7}}{BTE\cdot\sqrt{SPS}} - 3.78BTI - 0.28SPT - \frac{6.16\times10^{7}}{SPS}$$

Where T is the resist thickness in Angstroms, SPS the spin speed in RPM, SPT the spin time in seconds, BTI the baking time in seconds, and BTE the baking temperature in degrees Celsius.

RESULTS AND FUTURE WORK

- **Results**
  - Comparable to the EWMA controller under drift in linear case.
  - Better than the EWMA controller under shift or large model errors.
  - Can successfully control second or higher order nonlinear processes which are hard for other nonlinear methods to control.
- **Future Work**
  - Control of the severe nonlinear processes is still an open field.
  - Combine intelligent control with RtR control.


Noises
Process Inputs
Nonlinear Semiconductor Manufacturing Process
Process Outputs
Nonlinear RtR Controller
Noises
Optimal Control
Model Update
Parameter Set Estimation
Targets


SVA Controlled LPCVD Process Under Large Model Error
Solid: Controlled process
Dash: Uncontrolled process
R1
R2
Run Number
Run Number
200
150
100
50
0
-50
0
10
20
30
40
50
60