An XML-Based Approach to Integrating Semiconductor Process Information

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Outline

- **Project motivation**
  - **Need to integrate data archiving and simulation activities in collaborative semiconductor processing research**
- **XML**
  - **Overview**
  - **Use in representing wafer processing data**
- **Applications**
  - **Java**
  - **MATLAB**

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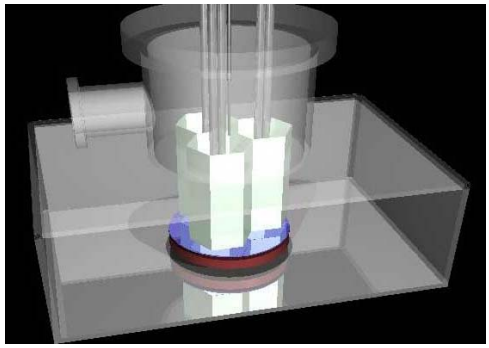
Spatially programmable equipment – A new design paradigm for semiconductor processing equipment

- Joint research with G. W. Rubloff;
- A new concept in semiconductor manufacturing intended to address limited sensing and control capabilities of current chemical vapor deposition processes;
- Main design innovation: segmented showerhead with individual control of gas composition/flow and sampling at each segment.



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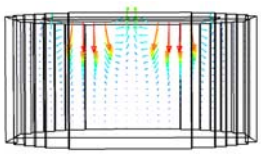
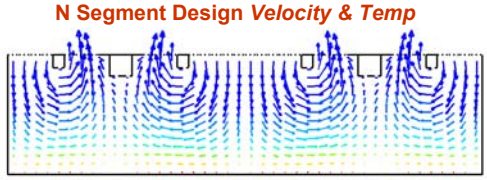
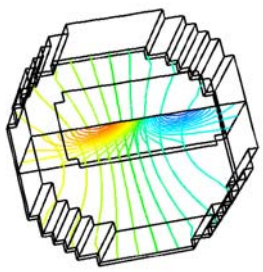
Segmented showerhead design

2 Segment Reactor *Velocity & Conc*



N Segment Design *Velocity & Temp*

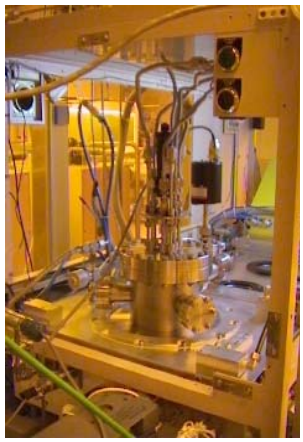


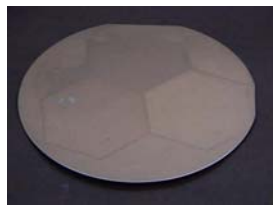


- Periodic gas flow fields minimize inter-segment convective transport;
- Inter-segment region mass transfer is governed by diffusion, making much better control of across-wafer gas composition;
- Residual gas can be sampled from each segment, simplifying spatial composition measurements

Spatially programmable equipment – IT issues

- 3-zone prototype is running;
- First films deposited have demonstrated that spatially patterned wafers can be produced by controlling gas phase composition;
- Large amount of heterogeneous data types, incomplete data sets;
- Significant simulation research is needed to understand prototype and materials produced by prototype.





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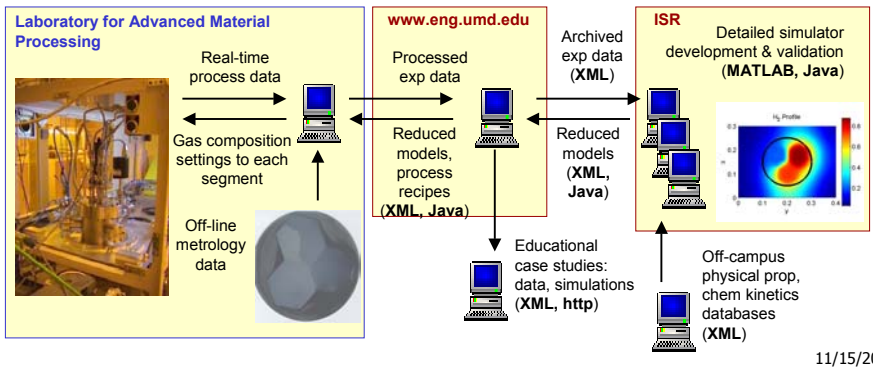
Programmable CVD reactor data archiving/analysis

1. XML for representing experimental data;
2. Java parser methods called from a MATLAB application;
3. Java and MATLAB methods for data analysis.



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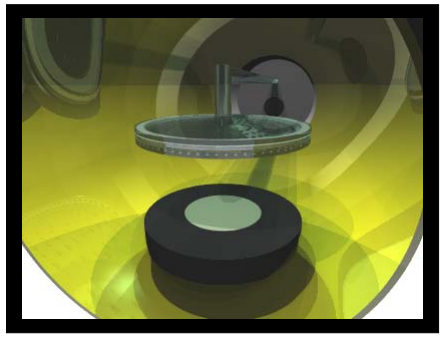
GaN MOCVD reactor design

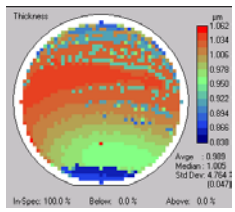
Potential IT Issues

- **Joint collaboration between University of Maryland and Northrop Grumman Electronic Systems research groups at separate research facilities;**
- **CVD reactor design has followed iterative simulator development and experimental evaluation cycles;**
- **Elements UMD/NG simulators can be shared;**
- **Secure transfer of proprietary data.**

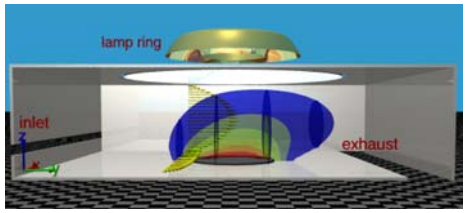


Iterative simulation-based design of CVD systems

CVD process operations leading to spatially non-uniform film growth



Simulation-based assessment of design and operation alternatives



Object-oriented CVD simulation tools for diagnosing factors responsible for non-uniformity

What is XML?

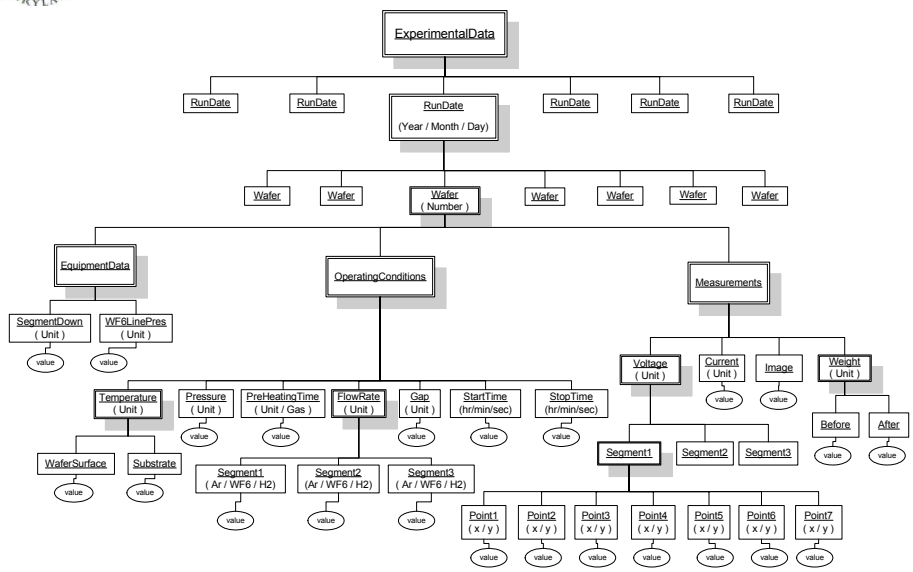
- XML: eXtensible Markup Language
- Generic syntax to mark up data with human readable tags in plain text format
- Standard format for computer documents, flexible enough to be customized for various data interchange applications (user-defined tags)
- Hierarchical tree-like data structure
- Validation against Document Type Declaration
- Separation of data representation and presentation/use

Semiconductor experimental data structure

Wafer number: w100102-03

- EquipmentData *(process diagnosis)*
  - Gas line pressure
  - Wafer position
- OperatingConditions data *(simulator input)*
  - Wafer/segment spacing
  - Segment gas flows
- Measurements data *(analysis, simulator validation)*
  - Initial wafer mass
  - Final wafer mass
  - Sheet resistance profiles

➢ Structure influenced by use
➢ Store raw data only



Address: http://www.isr.umd.edu/Labs/CACSE/A_team/IT/xml/PRdata.xml

Live Home Page | Apple | Apple Support | Apple Store | iTools | Mac OS X | Micro

```
<?xml version="1.0" ?>
<!--  moredata.xml  -->
<!--  XML format experimental data of wafer  -->
<!--  Fall, 2002  -->
<!DOCTYPE ExperimentalData (View Source for full doctype...)>
- <ExperimentalData>
 - <RunDate year="2002" month="09" day="12">
  - <Wafer number="w091202-04">
   + <EquipmentData>
   - <OperatingConditions>
    - <Temperature unit="C">
       <WaferSurface>300</WaferSurface>
       <Substrate>400</Substrate>
     </Temperature>
     <Pressure unit="torr">0.5</Pressure>
     <PreHeatingTime unit="min" gas="HF">5</PreHeatingTime>
     <Gap unit="mm">1</Gap>
    - <FlowRate unit="sccm">
       <Segment1F Ar="50" WF6="0" H2="0" />
       6="50" H2="0" />
       6="0" H2="50" />
```

Document begins with declaration that specifies XML version 1.0

Comments

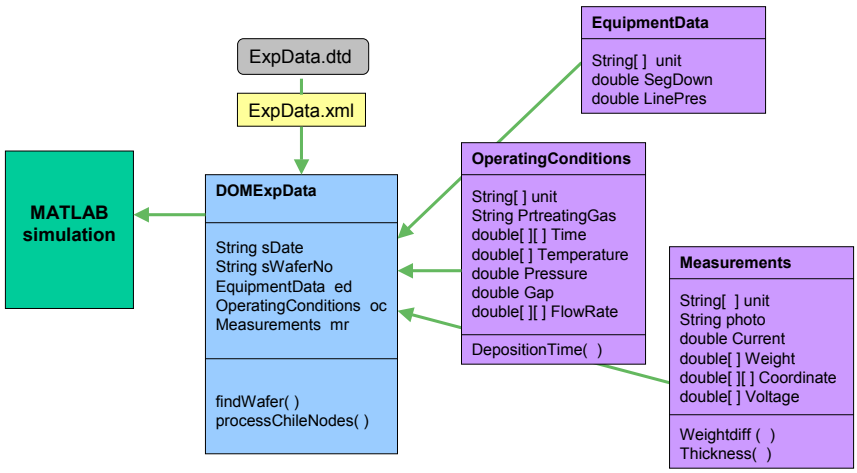
Document type definition (DTD) defines document structure and entities

Element RunDate contains three attributes: year, month and day

Root element ExperimentalData contains child element(s) RunDate

Child elements of element Temperature

Using the archived data



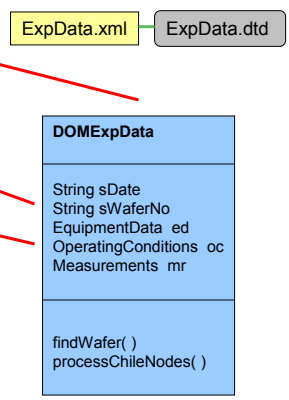
Reading data into a MATLAB session - Java methods

```
% download and parse XML; create Java object
url = java.net.URL('http://www.isr.umd.edu/Labs/CACSE/A_team/IT/xml/PRdata.xml');
WJO = DOMmoredata(url, 'w091202-06');

% display wafer number (Java object public field)
Wnumber = WJO.sWaferNo

% Java OperatingConditions object
JOC = WJO.oc;
% Java method to compute deposition time
dtime = JOC.DepTime

% Java Measurements object
JMR = WJO.mr;
 % Java method to compute net mass gain
dmass = JMR.WeightDiff
```



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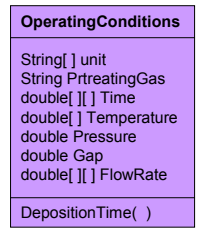

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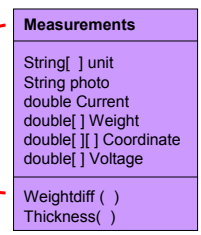
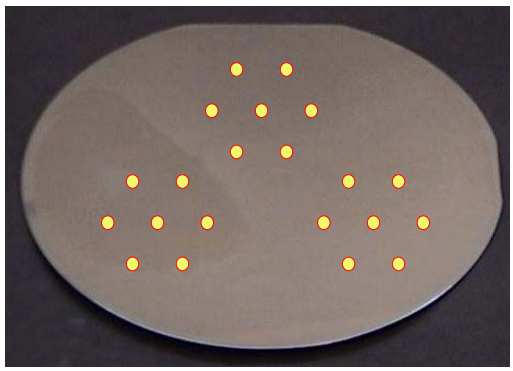


MATLAB application: Measurements branch

```
- <Wafer number="w091202-06">
  + <EquipmentData>
  + <OperatingConditions>
  - <Measurements>
      <Current unit="A">0.001</Current>
    - <Voltage unit="mV">
      - <Segment1R>
          <Point11 x="1" y="1">5.90</Point11>
          <Point12 x="2" y="1">6.91</Point12>
          <Point13 x="1" y="3">6.01</Point13>
          <Point14 x="2" y="3">4.70</Point14>
          <Point15 x="3" y="3">5.68</Point15>
```



- Wafer metrology data stored in OperatingConditions object after parsing
- Voltage measurements taken at 21 points on wafer surface
- Film thickness = ρ l / (4.53 V)

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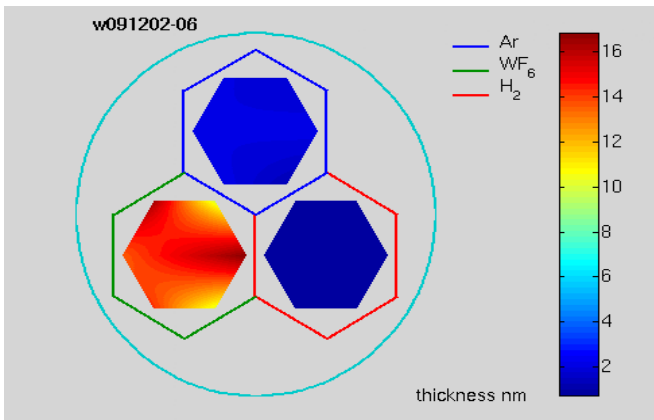
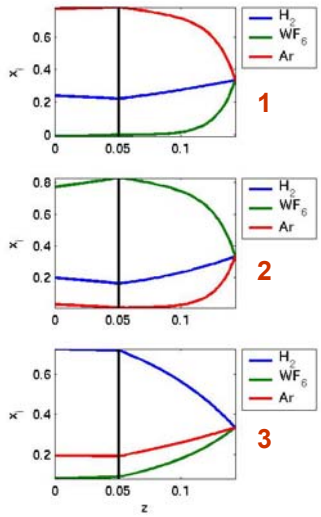
MATLAB application: Measurements branch

- Results from MATLAB function waferPlot(WJO)
- Feed conditions: pure Ar to segment 1, pure WF_6 to segment 2, pure H_2 to segment 3
- Q: why is W deposited in any of the segments?



MATLAB application: OperatingConditions branch

- Convert Java WJO object to MATLAB segsim (segment simulation) object
- Model transport through segments by Stefan-Maxwell equations including thermal diffusion
- Define segsim method to solve BVPs for each segment using a global spectral method (MWRtools)
- A: back-diffusion from common exhaust region to wafer surface, Si reduction by WF_6



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Conclusions

Initial success in developing an XML-based framework for on-line archiving and distributed simulation for semiconductor CVD manufacturing processes

Current work focuses on

- Simple data browsing techniques
- Integrating additional data: mass spec time traces, wafer maps, images, etc.
- Representing equipment design information suitable for simulators
- Thermo-physical property estimators
- Surface and gas phase reaction kinetics