Motivations

- 193nm lithography extension: double/multiple patterning
- EUV and other emerging lithography
- Much closer design and manufacturing interaction

Related SRC Tasks

- Task 2414 - Robust Standard Cell Design and Layout Regularity Study with Nanolithography (04/2013-03/2016)

Cross-Layer Synergistic DFM

- Shape/Electrical Optimization
  - Physical Design
  - DFM Cell Library
  - Mask Synthesis
  - Predictive Modeling, Hotspot Detection
- Var. Si-image Model
- Var. Electrical Model
  (Litho, CMP, etc.)
  Shape/Electrical Analysis
  (Timing, Power, ...)

Research Highlights

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<td>Litho Modeling, OPC, Variation</td>
<td>Variational lithography modeling</td>
<td>DAC06, ICCAD06, ICCAD07, SRC</td>
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<td>Analysis</td>
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<td>Litho Hotspot Detection &amp;</td>
<td>Data/machine learning; meta-</td>
<td>IICD09 BPA*, DAC11, TCAD11,</td>
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<td>Mitigation</td>
<td>classification; multi-level</td>
<td>ASPDAC12 BPA</td>
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<td>Double/Triple Patterning</td>
<td>Layout decomposition; early physical</td>
<td>IICAD08, ISP09, DAC09, ASPDAC10</td>
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<td>Lithography (DPL/TPL)</td>
<td>design optimization; deal with both LELE</td>
<td>BPA, IBM Research 2010 BPA,</td>
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<td></td>
<td>and SADP</td>
<td>ICCAD10, DAC11, ICCAD11 1BPA*,</td>
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<td>Standard Cell DFM &amp; Opt.</td>
<td>Total sensitivity based modeling</td>
<td>ISP010, DAC10, DAC11, ICCAD11</td>
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<td>and optimization; cell placement</td>
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<td>DFM Aware Routing</td>
<td>Systemic framework from global</td>
<td>DPC06, BPC, ICCAD06, DAC07,</td>
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<td>to detailed routing, dealing with</td>
<td>DAC08, ICCAD08, DAC09, FTEDA10,</td>
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<td>litho, redundant via, CMP,</td>
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<td>random defect, DPL, TPL</td>
<td>ICCAD12, SRC Inventor</td>
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<td>Emerging Lithography</td>
<td>E-beam throughput optimization</td>
<td>ISP011 BPA, ASPDAC13</td>
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Sample Results

- Standard cell library DFM tool kit
  - Litho/etch, etc
  - Environment + OPC
  - Doping/LE, strain
  - Monte Carlo

- DFM aware routing
  - Global Routing
  - Critical area minimization
  - Redundant via optimization
  - Lithography friendliness

Students & Technology Transfer

- Students involved and SRC companies they joined
  - Yongchan Ban (PhD’11, Intel), Ashutosh Chakraborty (PhD’10), Minsik Cho (PhD’08, IBM), Duo Ding (PhD’11), Jhih-Rong Gao, Katrina Lu (MS’08, SRC Scholarship, Intel), Joydeep Mitra, Xiaokang Shi (PhD’09, IBM), Gang Xu (PhD’07, Mentor), Xiaqing Xu, Jae-seok Yang (PhD’11), Bei Yu, Peng Yu (PhD’09), Kun Yuan (PhD’10)

- Technology transfer
  - DFM aware routing algorithms and methodologies widely adopted in industry (EDA companies and in-house EDA tools such as IBM and Intel)
  - DFM standard cell tool kit used by Freescale
  - Lithography hotspot detection algorithms and tools used by Mentor Graphics
  - Double/triple patterning layout decomposition and physical design a must for 22nm/14nm IBM, Globalfoundries, Mentor Graphics…
  - Open-sourced award winning BoxRouter
  - SRC sponsored patents on variational lithography modeling/PV-OPC and BoxRouter

- Many (20+) SRC liaisons: thank you very much!