Local Fix Based Litho-Compliance Layout Modification in Router

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Outline

● Lithography & OPC Introduction
● Previous Work – Prof. Y-W. Chang and D. Z. Pan
● Our Solution
● Conclusion & Future Work
Lithography Introduction (1)

- **Illumination**
  - Light source, \( \lambda \)
  - Condenser pupil
  - Condenser lens

- **Projection**
  - Mask/Reticule
  - Projection pupil
  - Projection lens
  - Photoresist wafer

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Lithography Introduction (2)

- Diffraction of Light

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Lithography Introduction (3)

- Impact
  - Gets serious as wavelength is comparable with feature.
  - 193 nm to expose 130nm → 90 nm → 65 nm?
**OPC (1)**

- OPC – Optical Proximity Correction
  - Add features to original shapes
  - Hammer Head (Mickey Ear), Line Biasing, Serif..
OPC (2)

- Post-Route Processing
  - After Wire Spreading/Widening, Via Doubling.
  - Before or after Dummy Metal fill?
- Pros
  - Low Cost compared with PSM or other techniques
- Cons
  - Unable to fix all bridge or pitch, Design convergence?
  - Pattern Selective
Previous Work (1)

- "Multi-level full chip gridless routing considering optical proximity effect", YW-Chang et al., ASPDAC-06
  - Gridless routing
    - Accurate for area utilization, esp. in DFM.
  - Using simple OPC rules
    - OPC cost is added in cost function
    - Reduction 11.3% features with 100% routability maintained. Very congested design
Previous Work (2)

- “RADAR: RET-Aware Detailed Routing Using Fast Lithography Simulations” David Z. Pan et al., DAC-2005

- EPE metric
- In courtesy of Pan.
Previous Work (3) RADAR Flow

- Initial design closure detailed routing
- Full chip fast litho simulation.
- EPE map display
- Routing window and blockage creation
- Wire spreading & ripup and reroute
- Re-simulate EPE hot spots if needed

Accept new route

EPE below threshold?

Keep old route

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Previous Work (4)

• Convolution to sum the Litho effect of neighbors

• In courtesy of Pan
Previous Work (5) RADAR

- Pros & Cons
  - Litho hotspot detect in Post Route Stage
    - Accurate
    - Speed determined by convolution engine.
  - Using EPE guided Ripup & Reroute to fix the hotspots.
    - **Timing Impact** due to Reroute
Our Solution (1)

- Adopt Pan’s solution.
- Improve
  - Hot Spot detection kernel. Two stage.
  - Apply Local fix → No Timing Impact
  - Various fixing guidance with weight to router.
  - Ripple out the error if unable to fix.
Our Solution (2)

● Two Stage Hot Spot detection
  ● Idea from Rule-based OPC v.s. Model-Based OPC.
    ● Rule-based OPC → Fast, inaccurate.
    ● Model-based OPC → Slow, accurate

Pattern Matching Litho hotspot detection ➔ Filter the false error by Convolution check

● Pros & Cons
  ● Overkill in 1st Stage, filter in 2nd Stage

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Lithography Hotspot

Litho Hotspot
Our Solution (3)

- Various fixing suggestions with weight

Choose one or several fixing solutions and added up, such that sum > 100%

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Local Fix Principles

- Fix the hotspot as LOCAL as possible.
- Don’t create new DRC violations.
- Pick up one of several possible solutions.
Local Fix example (1)

- Polygon Shift

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Local Fix example (2)

- Line End Extension

Hot Spot

Fix Guidance
Local Fix Flow

Full Chip Litho Hot Spots detection

Yes

Generate fix method

Fix Litho Hot Spots by choosing DRC-free solution

No

Done

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Local Fix Result (1)

- Bench Mark I
- Before Local Fix: DRC : 0
- Fix 6783 of 8414 suggested hotspots.
- After flcc fix: DRC : 0
- Fix Rate = 80.6%
- Partial fix 1529, 18.1%
Conclusion

● Hard to consider litho effect during routing stage
  ● Effect / Effort is too low if bind litho effect in routing engine.
  ● leave some room for post routing steps.
    ● Utilization Rate?

● How to create a smart Litho-Aware Local Fixing?
  ● Good Litho detection engine
  ● Fast & Effective correction selection algorithm
  ● Ripple out the error if failed
    ● 100% fixing guarantee?

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Future Work

● Implementation
● Automate Matching-Patterns generation
● Find good convolution algorithm
● Combine with other DFM in flow
  ● Wire Spreading
  ● Via Doubling
  ● Dummy Metal Fill
● G-Route & D-Route architecture change:
  DFM aware.. leave room for post processing …
Joke

Bush had something wrong with his brain and went to see a doctor.

After examination, the Doctor told him:

“You have two brains, Mr. Bush, your left brain and your right brain.”.

“Now your left brain has nothing right, and your right brain has nothing left”.

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