

Spatial Analysis of Ring Oscillator Devices

Term Project

6.780

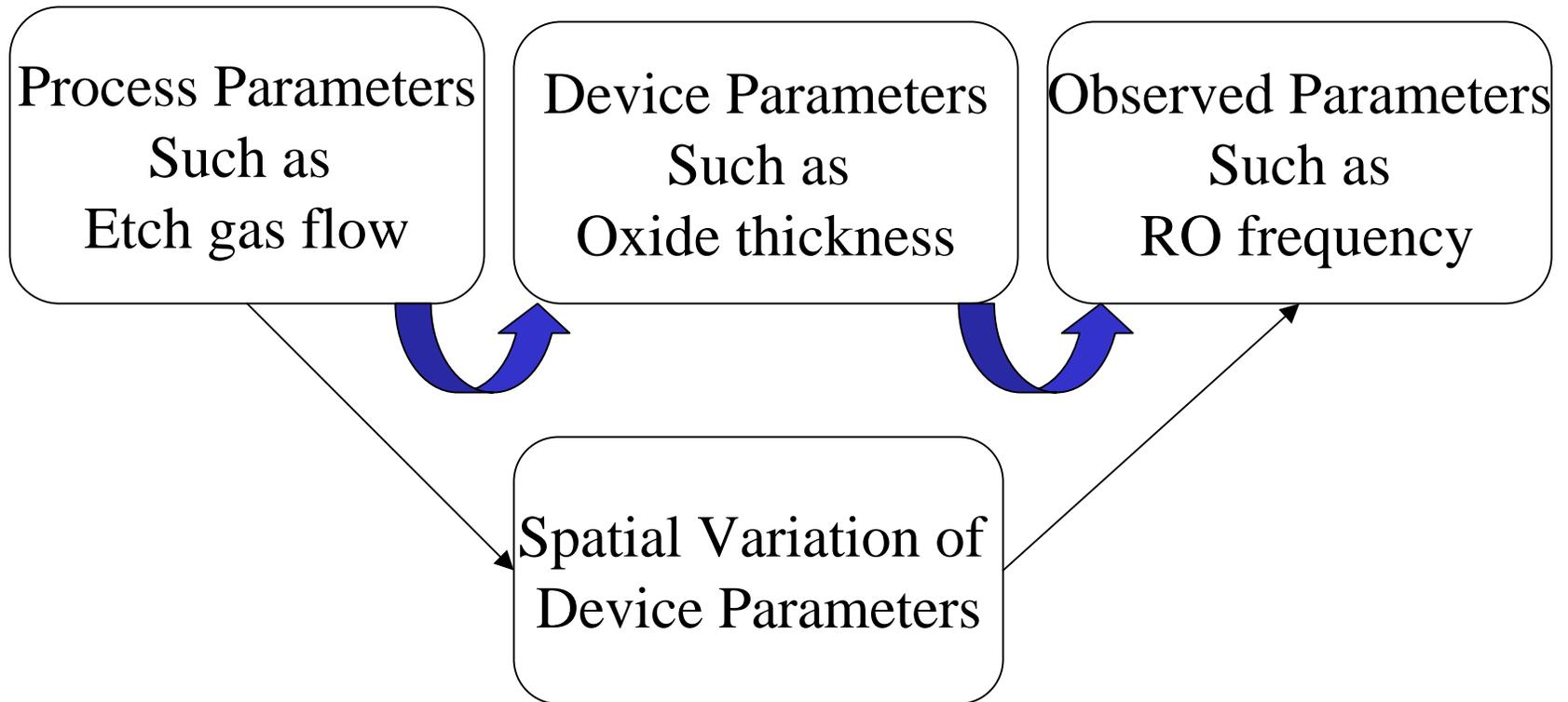
05/14/2003

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Overview of Talk

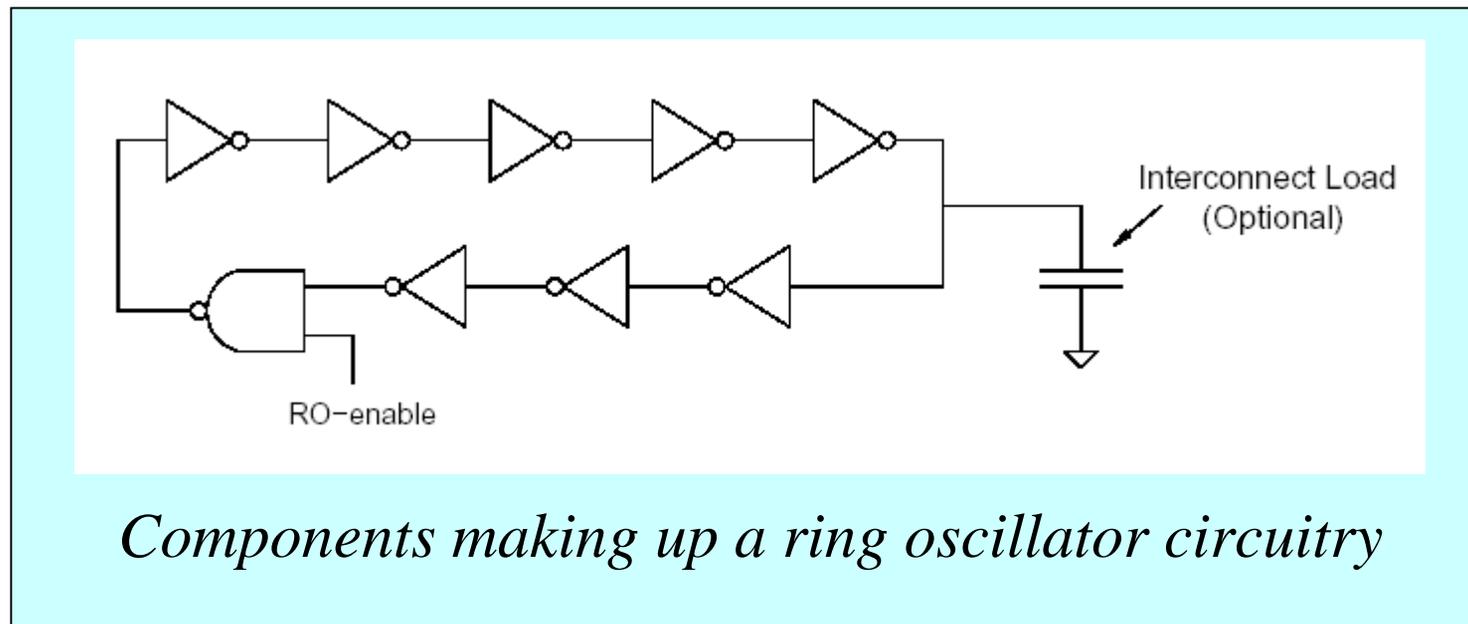
- Introduction
- Background of Dataset
- Spatial Model for RO Frequencies
- Spatial Analysis Results and Conclusions
 - Wafer level (Chip to chip)
 - Chip level (Within chip)
- Future Work

Introduction

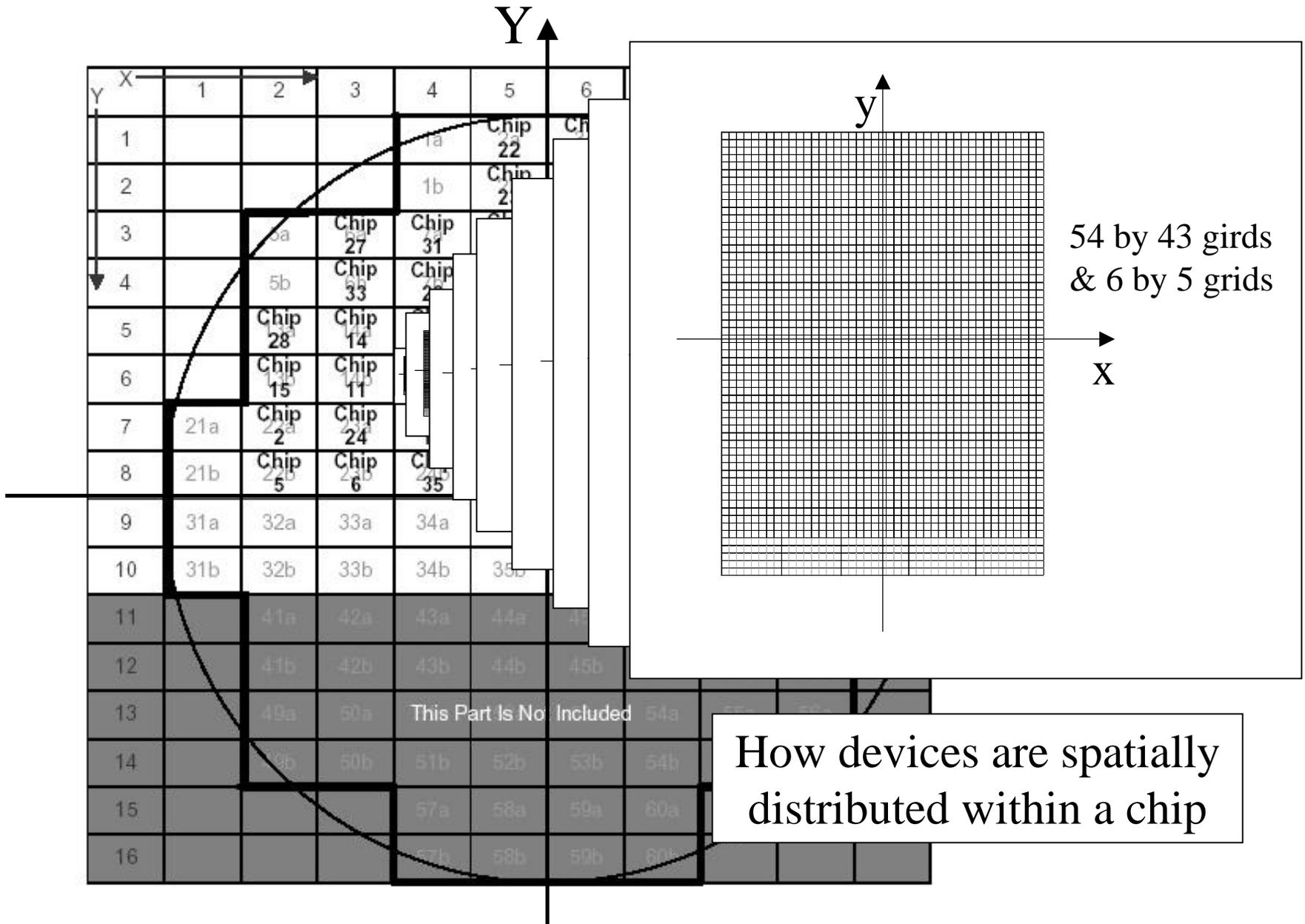


Background of Dataset

- 35 Chips fabricated on a single wafer using TSMC 0.25 μ m
- 45 different device structures on a single chip
- The chip architecture is designed to include *Front End Of the Line* (FEOL) and *Back End Of the Line* (BEOL) structures with ring oscillators



How chips are spatially distributed in a wafer



Spatial Model for RO Frequencies

Linear regression model

$$\hat{\eta}_i = a_i + b_1 x_{i1} + \dots + b_K x_{iK}$$

where

$$x_{i1} = X_i$$

$$x_{i2} = Y_i$$

$$x_{i3} = X_i Y_i$$

$$x_{i4} = X_i^2$$

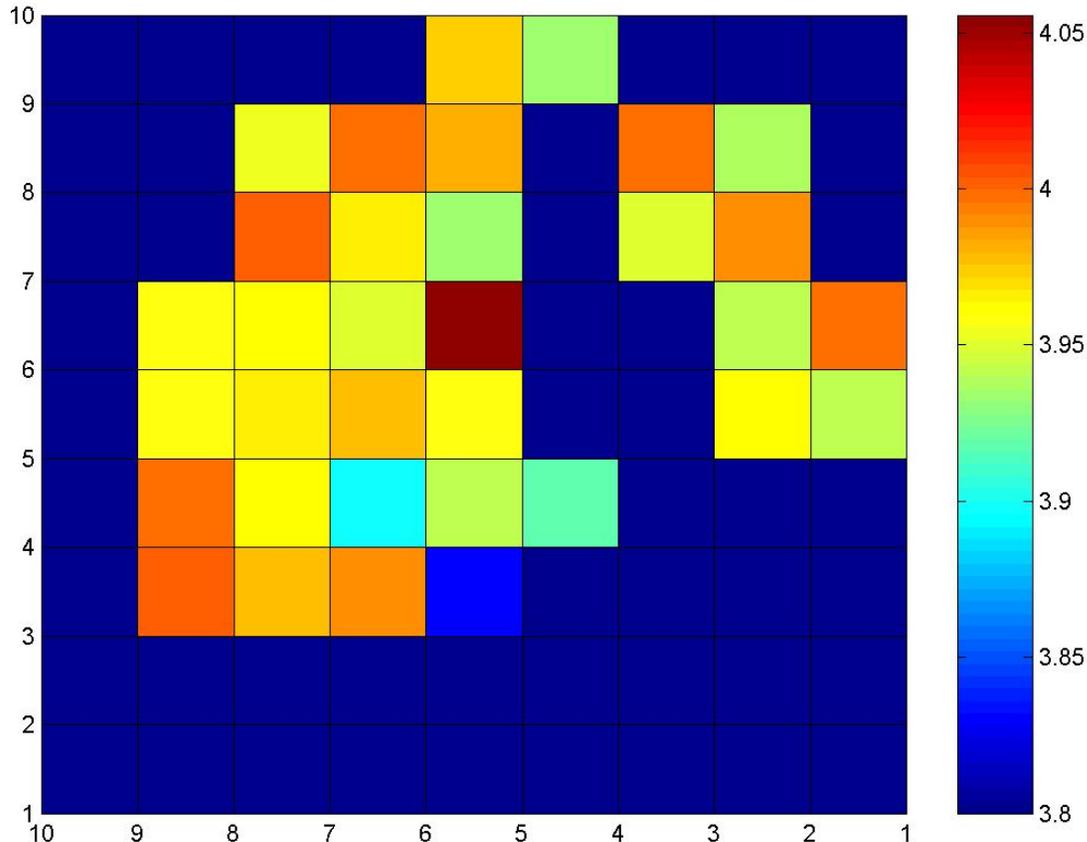
$$x_{i5} = Y_i^2$$

$$a_i = \text{Intercept}$$

$$\eta_i = \text{RO Frequency}$$

Statistical Tools: Matlab and Excel used to generate models

Spatial Analysis Results (Wafer Level)



How results are generated?

Individual types of devices in each chip are averaged

Best regression result is shown in this slide

Regression models:

R^2 values range from 0.04 to 0.22

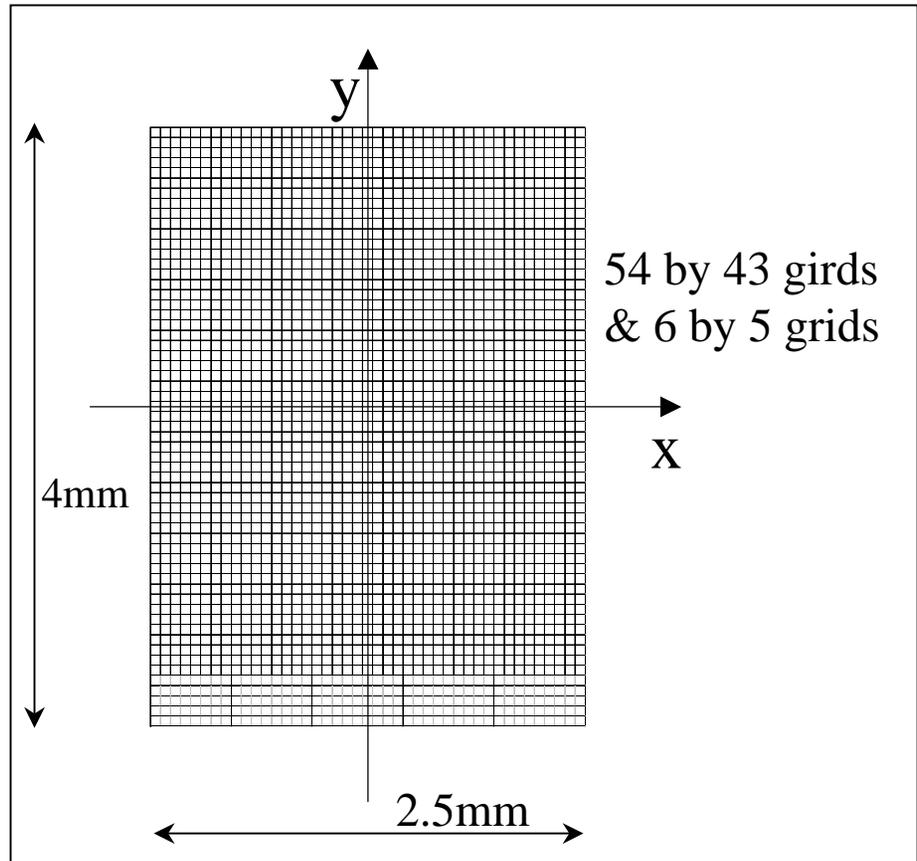
Mean Frequencies for Plane Cap for ILD by Spatial Location

Conclusion – Spatial Analysis (Wafer Level)

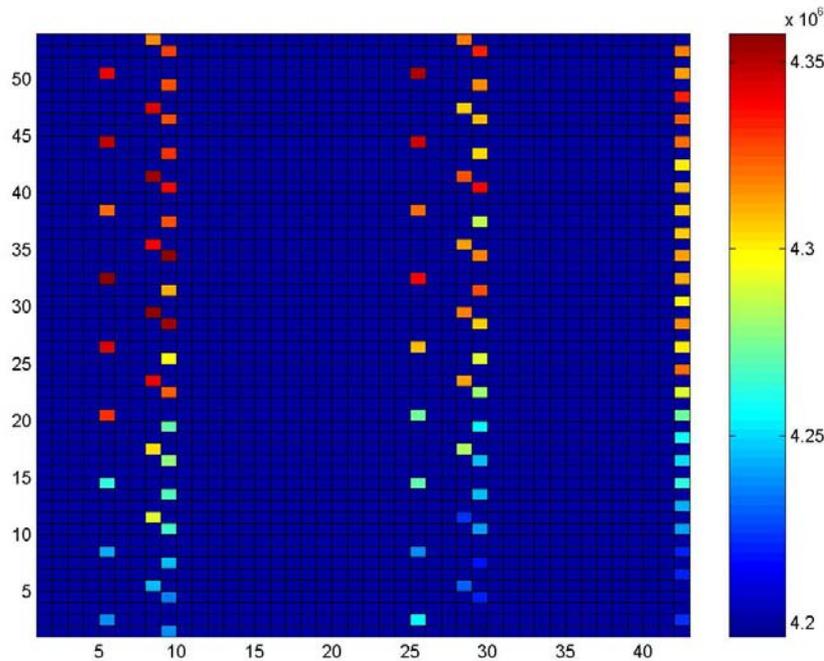
- No strong spatial dependence on wafer level for all individual devices structures
- Possible explanations for this behavior:
 - no strong spatial correlation
 - existence of non-linear terms
 - data is not well distributed to capture significant wafer level spatial effects

Spatial Analysis Results (Chip Level)

Total number of
permutations
(45 device structures
X 35 chips)



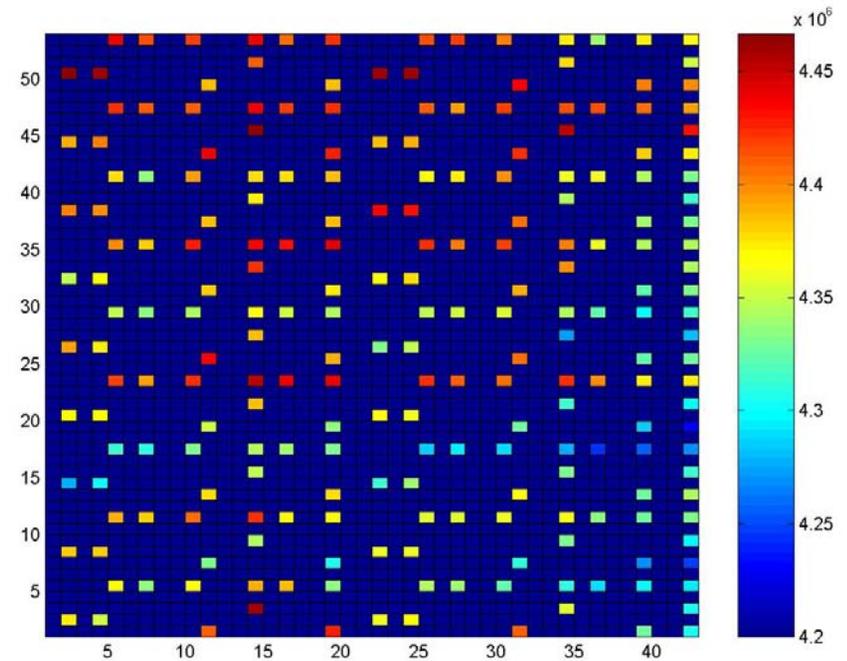
Spatial Analysis Results (Chip Level) – Chip 19



RO1_vertical by Spatial Location

Regression model:

R^2 value = 0.86

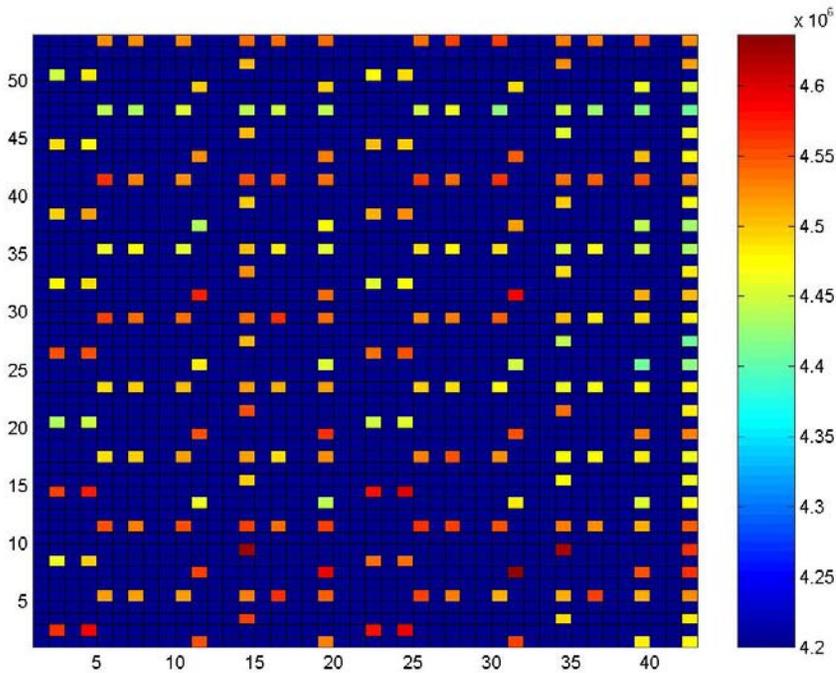


RO1_horizontal by Spatial Location

Regression model:

R^2 value = 0.49

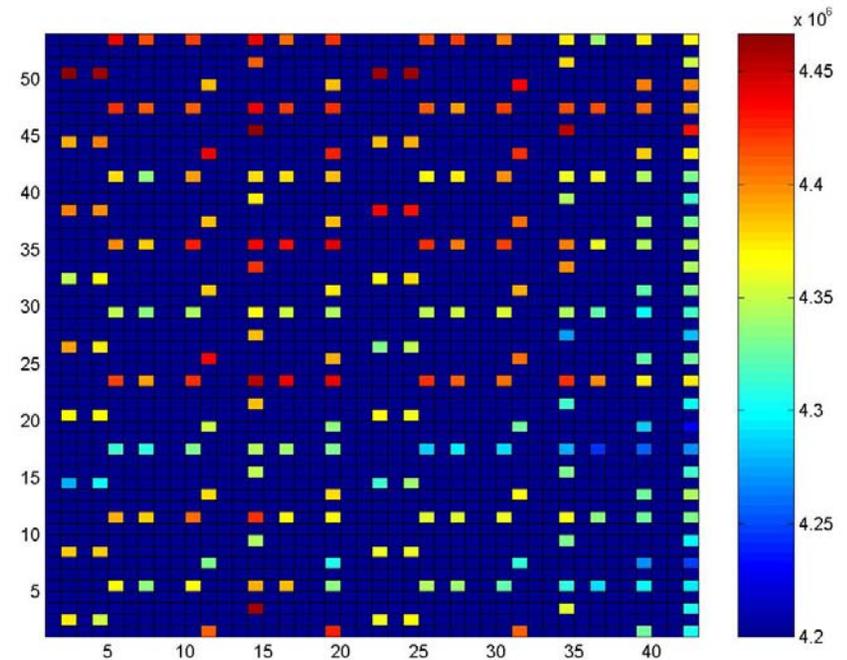
Spatial Analysis Results (Chip Level) – RO1_horizontal



*RO1_horizontal for Chip 11
by Spatial Location*

Regression model:

R^2 value = 0.24



*RO1_horizontal for Chip 19
by Spatial Location*

Regression model:

R^2 value = 0.49

Conclusion – Spatial Analysis (Chip Level)

- Stronger chip level spatial dependence as compared to wafer level spatial dependence
- Strong spatial dependence on selective device structures such as vertical structures
- Weak spatial dependence on particular chip for most devices such as Chip# 1, 3, etc.

Future Work

- Look for non-linear models to explain wafer level spatial variation
- Investigate why some device structures have strong chip level spatial dependence as compared to others
- Investigate why some chips have lower chip level spatial dependence for all the device structures
- Isolate the variation in observed parameters due to various device parameters taking into account the generated spatial models

Q & A