Courses in Optical Lithography by Chris A. Mack
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Introduction to Optical Lithography

(1 day class, or first day of a two day class)

1. Optics of Projection Tools

1.1. Diffraction

Purpose: The purpose of this section is to provide a simple description of diffraction and its relationship to imaging.

Objectives: Upon completion of this section, you will be able to:

- Describe the principle of diffraction
- Describe how a basic imaging system works
- Understand the impact of the mask on diffraction orders

1.2. Image Formation

Purpose: The purpose of this section is to describe how an image is formed.

Objectives: Upon completion of this section, you will be able to:

- Define numerical aperture and describe its effect on image formation
- Describe the concept of Fourier Optics

1.3. Mask Illumination

Purpose: The purpose of this section is to describe how masks are illuminated in lithographic imaging systems and how this illumination affects image formation.

Objectives: Upon completion of this section, you will be able to:

- Describe the effect of illumination angle on the diffraction pattern
- Define partial coherence
- Describe the impact of illumination on resolution
- Define Köhler illumination

1.4. Aberrations and Defocus

Purpose: The purpose of this section is to describe lens aberrations (including defocus) and how they affect the aerial image.

Objectives: Upon completion of this section, you will be able to:

- Describe aberrations in both geometrical and wavefront terms
- Understand the use of the Zernike polynomial
- Describe the causes of aberrations
- Describe how aberrations affect current lens designs

2. Standing Waves and Swing Curves

2.1. Standing Waves

Purpose: The purpose of this section is to describe how standing waves come about and how to reduce them.

Objectives: Upon completion of this section, you will be able to:

- Describe the basic principle of standing wave formation
- Describe the four ways to reduce the standing wave effect

2.2. Swing Curves

Purpose: The purpose of this section is to describe how thin film interference effects cause swing curves and how to reduce them.

Objectives: Upon completion of this section, you will be able to:

- Describe how thin film interference effects cause swing curves
- Describe the four ways to reduce swing curves

3. Photoresist Chemistry

3.1. Exposure and Absorption

Purpose: The purpose of this section is to describe the kinetics of photoresist exposure and absorption.

Objectives: Upon completion of this section, you will be able to:

- Define the major tasks and components of a photoresist
- Describe first order exposure kinetics
- Describe the Lambert and Beer laws of absorption
- Understand the definition and measurement of the resist ABC parameters

3.2. Thermal Effects

Purpose: The purpose of this section is to describe the how baking can lead to thermal decomposition in a photoresist.

Objectives: Upon completion of this section, you will be able to:

- Describe the major effects of photoresist baking
- Describe the consequences of photoresist thermal decomposition

3.3. Chemically Amplified Resists

Purpose: The purpose of this section is to describe the chemistry of chemically amplified resists and understand the lithographic consequences of this chemistry.

Objectives: Upon completion of this section, you will be able to:

- Describe the basis of “chemical amplification”
- Describe the impact of acid diffusion
- Describe the detrimental effects of acid loss

3.4. Development

Purpose: The purpose of this section is to describe the chemistry of photoresist dissolution.

Objectives: Upon completion of this section, you will be able to:

- Provide a simple mechanistic description of photoresist dissolution
- Understand the nature and possible causes of surface inhibition

Introduction to Optical Lithography, Day 2

(1 day class, or second day of a 2 day class)

4. Resolution and Depth of Focus

4.1. Why is Lithography Hard?

Purpose: The purpose of this section is to provide a broad overview of the goals and challenges of optical lithography.

Objectives: Upon completion of this section, you will be able to:

- Explain the difference between pitch resolution and feature resolution
- Understand why resolution enhancement technologies are used

4.2. Depth of Focus

Purpose: The purpose of this section is to describe the use of the focus-exposure matrix towards defining depth of focus.

Objectives: Upon completion of this section, you will be able to:

- Understand the importance of the focus-exposure matrix
- Define depth of focus
- Explain the nature of asymmetric focus responses

4.3. Resolution

Purpose: The purpose of this section is to define what is meant by resolution and determine the main variables that affect resolution.

Objectives: Upon completion of this section, you will be able to:

- Define Resolution using the simple Rayleigh criterion
- Define true manufacturing resolution
- Understand the difference between pitch and feature resolution

5. Linewidth Control

5.1. Overview

Purpose: The purpose of this section is to review the basic factors affecting linewidth control.

Objectives: Upon completion of this section, you will be able to:

- Describe the two approaches for improving linewidth control
- Understand the limitations linearizing the problem
- Understand why linewidth control is important to semiconductor device performance

5.2. Process Control

Purpose: The purpose of this section is to describe the process control and its relationship to resolution.

Objectives: Upon completion of this section, you will be able to:

- Describe the sources of focus errors, both random and systematic
- Use overlapping process windows to account for systematic process errors

5.3. Mask Error Enhancement Factor

Purpose: The purpose of this section is to define and understand the Mask Error Enhancement Factor (MEEF).

Objectives: Upon completion of this section, you will be able to:

- Define the MEEF
- Understand the basic causes and implications of a non-unit value of the MEEF

6. Resolution Enhancement Technologies

6.1. Off-axis Illumination

Purpose: The purpose of this section is to describe off-axis illumination and its impact on resolution and depth of focus.

Objectives: Upon completion of this section, you will be able to:

- Describe how off-axis illumination can improve resolution
- Describe how off-axis illumination can affect depth of focus
- Define “forbidden pitch”

6.2. Phase Shifting Masks

Purpose: The purpose of this section is to describe phase shifting masks and their impact on resolution and depth of focus.

Objectives: Upon completion of this section, you will be able to:

- Describe how phase shifting masks can improve resolution
- Describe how phase shifting masks can improve depth of focus
- Understand the sources and resolutions of phase conflicts

6.3. Optical Proximity Correction

Purpose: The purpose of this section is to define and understand optical proximity effects and their correction.

Objectives: Upon completion of this section, you will be able to:

- Explain the origins of proximity effects
- Describe the three basic approaches to optical proximity correction

7. Future Trends in Lithography