Fabrication of Micro-polarizer Array

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Outline

- Introduction for Polarization Imaging
- Fabrication of micro-polarizer
  - Positive photo-resist with wet and oxygen plasma dry etching
  - Negative photo-resist with Reactive Ion etching
- Concluding remarks
Introduction

- Importance about Light Polarization
  - What is light polarization
  - Human eyes detection

- System overview
  - Micro-polarizer Arrays using polymer films
  - Implementation to imaging chip
  - Applications
    - Underwater detection, etc
  - Advantages
    - Low power system
    - Real-time extraction of polarization
Choosing Polarizer

- Using commercially available polymer
  - Advantages: good proven data, cheap
  - Disadvantages: variable thickness

- Material
  - TECH SPEC™ Linear Polarizing Laminated Film
## Optical Test

### Polarisizing Material Transmission Characteristics

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>No Polarizer</th>
<th>Single Polarizer</th>
<th>Cross Polarizer</th>
<th>Extinction Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red LED (700 nm)</td>
<td>480 mW/cm²</td>
<td>190 mW/cm²</td>
<td>2 mW/cm²</td>
<td>40dB</td>
</tr>
<tr>
<td>Green LED (600 nm)</td>
<td>480 mW/cm²</td>
<td>180 mW/cm²</td>
<td>0.2 mW/cm²</td>
<td>60dB</td>
</tr>
</tbody>
</table>
Polarizer Thin Film Structure

Layers

- Polyvinyl Alcohol (PVA)
- Acetate Butyrate (CAB)
PVA Structure

- CAB Removal
  - Acetone Solution bath
PVA Thickness

- **Thickness of PVA**
  - 10~30 µm

- **Problem**
  - Non uniformity
Positive Photo-resist Masking

- Spin coating positive Photo-resist
  - Thickness: from $1 \, \mu m$ to $3 \, \mu m$ *

*Measured by Tencor Instruments™ Profilmeter
Positive Photo-resist Masking

UV light

- UV Photolithography*

* Performed by Kasper System™ 2001 Mask Aligner
Positive Photo-resist Masking

- Developer Etches away both masked PR and unmasked PVA
Positive Photo-resist Masking

- Oxygen Plasma Etching (Ideal)*

* Performed by Technics PlasmaEtch™ II Oxygen Plasma instrument
Oxygen Plasma Etching Rate Data
(PVA & Positive Photo-Resist)

Oxygen Plasma Etching Rate for PVA & Positive PR (300 Watts, 2 minutes)

Oxygen Plasma Etching rate for PVA
(80 Watts, O2:CF4 = 7.5:2.5)
Problems with Positive Photo-resist

- Developing Under-exposed PR

- Thickness
  - Multiple Layers: Un-uniform

- Developer
  - Can be used for wet etching of the PVA
  - Under-Exposing: Rough Surface
Problems with Oxygen Plasma Etching

Oxygen Plasma

- Oxygen Plasma Etching
  - Isotropic Etching
  - Vertical to Horizontal Etching Ratio:
    - 2:1 at 40W ~ 150 W Oxygen : CF4 = 7.5 : 2.5
Important factors

- The thickness of the photo-resist has to be relatively big comparing to PVA thickness
- Photo-resist has to have a different chemical structure from PVA
- An etching method that has less isotropic effects than oxygen plasma etching
Negative Photo-resist

- Material: Su-8 2000 series
  - Advantages: thickness, high aspect ratio (20:1)
- Developer
  - No significant effects on PVA
- Reactive Ion Etching (RIE)
  - Combination of O2, CF4 and Ar
  - The addition of Argon gas allows for more mechanical etching impact on sample
Negative Photo-resist Masking

- Adhesion
  - Humidity
    - Adhesion Promoter: Ti O2

Adhesion Promoter
- PVA
- CAB
Negative Photo-resist Masking

- Spin-coating Su-8

Diagram:
- Negative PR
- Adhesion Promoter
- PVA
- CAB
Negative Photo-resist Masking

- Pr Masks
- Negative PR
- Adhesion Promoter
  - PVA
  - CAB

UV light

- 96 micro-m
- 96 micro-m

- 40µm
- 20µm
- 300µm

- UV Exposure
  - Gradients
If the thickness of Su-8 is:

- 1 micro-m, the gradient is 0.05 µm
- 15 micro-m, the gradient is 0.75 µm
- 40 micro-m, the gradient is 2 µm
Negative Photoresist Masking

- PVA VS Su-8 RIE rate*: 3:1
- Anisotropic Etching

* Performed by Plasma Lab™ RIE Instrument
Conclusion

- Su-8 2000 negative photo-resist allows for high aspect ratio masks.
- Reactive Ion etching allows for very good anisotropic etching.
- Smallest dimensions that can be produced will be about 4 µm square.
- Refinement for the entire process will be needed.
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