CURRENT STATUS OF NANOIMPRINT LITHOGRAPHY DEVELOPMENT IN CNMM

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Outlines

I. PROCESS TECHNOLOGY

■ Single Step UV-NIL
  ■ UV-NIL using an Elementwise Patterned Stamp (EPS) in a Low Vacuum or Atmospheric Environment
  ■ UV-NIL for Uniform and Minimum Residual Layer
  ■ Step and Repeat UV-NIL
    ■ High Throughput Step-and-Repeat UV-NIL using a Large Area Stamp

II. APPLICATION TECHNOLOGY

■ Nano Wire Grid Polarizer
■ Photonic Band Gap Device

III. TOOL TECHNOLOGY

■ Single-Step UV-NIL Tool

IV. SUMMARY
Single step UV-NIL

UV-NIL using a elementwise patterned stamp (EPS) in a low vacuum environment
Schematic of UV nanoimprint lithography (UV-NIL)

- Press stamp
- Cure
- Remove stamp
- RIE

- Stamp
- UV curable resin
- Substrate
- Illuminate with UV light
- RIE
### Characteristics of UV-nanoimprint lithography

<table>
<thead>
<tr>
<th></th>
<th>Thermal type NIL</th>
<th>UV type NIL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resin</strong></td>
<td>Thermoplastic polymer</td>
<td>UV curable resin</td>
</tr>
<tr>
<td><strong>Stamp material</strong></td>
<td>Silicon, Nickel</td>
<td>Quartz, glass (transparent)</td>
</tr>
<tr>
<td><strong>Processing temperature</strong></td>
<td>$&gt; T_g$ (glass transition temperature)</td>
<td>Room temperature</td>
</tr>
<tr>
<td><strong>Processing pressure</strong></td>
<td>High (~ 30 bar)</td>
<td>Low (~ 1 bar)</td>
</tr>
</tbody>
</table>

- Advantages for mass production, multi-layer process, and step & repeat process
Recent studies on NIL

Nanoimprint lithography – Prof. Chou, Princeton University, 1995

- Imprint (Press stamp)
- Heating (150°C–250°C)
- Stamp
- Resist
- Substrate
- Remove stamp
- Imprint mold with 10nm diameter pillars
- 10nm diameter holes imprinted in PMMA
- 10nm diameter metal dots fabricated by NIL

RIE
Recent studies on NIL

5 UV-Imprint lithography

- University of Texas at Austin (Sreenivasan et al.), 1999
- Molecular Imprints Inc.
- Step & Flash Imprint Lithography (SFIL)

13 mm or 25 mm

Quartz Template

Release Layer

Planarization Layer

Substrate

Monomer

UV blanket expose

HIGH resolution, LOW aspect-ratio relief

Residual Layer

HIGH resolution, HIGH aspect-ratio feature
Motivations

- Step & repeat type UV-NIL using a small area (≤ 1 in.) stamp
  ⇒ Low-throughput
  (The imprint time is 2–3 minutes for each field and 10–20 minutes for a 4 in. wafer)
- Single step UV-NIL using a large-area stamp in a medium/high-vacuum environment
  ⇒ requires a vacuum-compatible system and UV curable resin
- For high-throughput manufacturing
  ⇒ We have developed new UV-NIL processes using a large-area stamp in a low-vacuum or atmospheric environment
Elementwise patterned stamp

Single-step UV-NIL using a large area flat stamp

Step-and-repeat UV-NIL using a small stamp

**Advantages**

- High-throughput
- Prevention of air entrapment
- Low-cost stamp
- Easy release
- Precise alignment for each field

In a low vacuum-pressure or atmospheric environment

UV-NIL using EPS

Elements with nanopattern

Channel
Elementwise patterned stamp
UV-NIL process using EPS

**Step I: Multi-dispensing**
- Nozzle
- Droplets
- Patterned elements at top

**Step II: Pressing EPS**
- Press
- Turning EPS round
- Wafer below stamp
- Patterned elements at bottom
- Producing vacuum (air out)

**Step III: UV exposure**
- UV
- Wafer below stamp

**Step IV: Releasing EPS**
- Separate
- Imprinted element
- Wafer
UV–NIL process using EPS

- Equipment - EVG620–NIL
  - Use 4 in. wafer
  - Vacuum hard contact mode

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>800 mbar</td>
</tr>
<tr>
<td>Exposure time</td>
<td>60 sec</td>
</tr>
<tr>
<td>Exposure intensity</td>
<td>36 mW/cm²</td>
</tr>
</tbody>
</table>

- UV curable resist
  - PAK01 (viscosity = 7 cps)
UV-NIL process using EPS

- 4 in. wafer with 9 successfully imprinted elements
- Residual layer thickness (RLT) distribution

Planarization layer

Imprinted element

Residual layer thickness (RLT)

A: 90 - 100 nm
B: 60 - 70 nm
C: 50 - 60 nm

A: 70 - 80 nm
B: 50 - 60 nm
C: 40 - 50 nm

Droplets
Air flow direction
UV–NIL process using EPS

- Imprint results

![70 nm lines](image1)

![50 nm lines](image2)
Single Step UV-NIL

UV-NIL using EPS and Additive Pressurization in an Atmospheric Environment

Process Technology
Single-step UV-NIL in an atmospheric environment

- **Elementwise Patterned Stamp (EPS):** avoid air entrapment
- **Additive Pressurization:** uniform residual layer thickness

Diagram showing:
- Element (field)
- EPS
- Pressurization
- Air pressure
- Dispenser
- 5 droplets/field
- Air out
Single-step UV-NIL in an atmospheric environment

Dispensing

Press

1st pressurization

2nd pressurization

Air pressure

secondary resist flow

additive pressurization
Imprint results

- Planarization layer (60 nm)
- Residual layer thickness:
  - 90-100 nm
  - 60-70 nm
  - 50-60 nm
- 50 nm lines
Step and Repeat UV–NIL

High Throughput Step-and-Repeat UV–NIL using a Large Area EPS
Step-and-repeat UV-NIL in an atmospheric environment

Selectively dispensing

Effective elements

Imprint I

Imprint II

Imprint III

Imprint IV

Patterned elements at bottom

Air

Step-and-repeat imprint
Step-and-repeat UV-NIL in an atmospheric environment

Step I
- Transparent backplate
- Wafer
- Wafer chuck
- Resin droplet
- EPS
- Dispensing nozzle

Step II
- Press
- Chamber

Step III
- Press
- Gas

Step IV
- UV
- Gas

Step V
- Imprinted element

Step VI
Step-and-repeat UV-NIL in an atmospheric environment

80 nm lines with a 110 nm pitch

50 nm lines

80 nm lines with a 110 nm pitch

Residual layer

Planarization layer

80 nm lines with a 110 nm pitch

50 nm lines

80 nm lines with a 110 nm pitch
Nanoimprint Lithography

Advantages of Nanoimprint Lithography

- High resolution
- Low tool cost
- High throughput
- Simple process

Process Flow (Nano Wire Grid Polarizer)

1. Aluminum Deposition
2. Resist Coating
3. Imprint (Heat & Pressure)
4. Demolding
5. Residual Layer Removing
6. Aluminum RIE
Nanoimprint Lithography

Development - Nano Wire Grid Polarizer

Contrast Ratio > 2,000,
Transmission > 83 % at $\lambda$ = 470 nm

Unpolarized Light

S-polarized Light

P-polarized Light

Pitch

50 nm Half-Pitch Stamp

Imprinted Polymer Pattern

Projection TV

Contrast Ratio > 2,000,
Transmission > 83 % at $\lambda$ = 470 nm
Application Technology

Photonic Band Gap Device
Nanoimprinting of Photonic Crystal Waveguides

Future vision of hybrid optical integration of an optical transceiver with silicon photonic components and conventional CMOS drivers

<SEM Image of Master>
Dimension
r = 150 nm
a = 400 nm

<SEM and AFM Images of Nanoimprinted Photonic Crystal Waveguide>
Dimension
r = 160 nm
a = 405 nm
Height = 335~340 nm
Completed Photonic Crystal Waveguide

Dimension: 7.7 X 13.5 μm

<Near Field Pattern of Photonic Crystal Waveguide>
Tool Technology

Single-step UV-NIL tool
UV-based Nanopatterning Equipment - CNMM

- Area: 4 inch Wafer
- Min. Feature Size ≤ 100 nm
- Chip-size Multi-Head Imprinting

- Nano-Precision Stage: 3nm
- 3-Axis Nano Leveling
- Overlay & Alignment
- UV Light Source
- Vibration Control

Nanolimprint Equipment

Flexure stage for parallelization

UV System
Imprinting Head
XYZ Stage
Vibration Isolator

Controller

Area: 4 inch Wafer
Min. Feature Size ≤ 100 nm
Chip-size Multi-Head Imprinting

Nano-Precision Stage: 3nm
3-Axis Nano Leveling
Overlay & Alignment
UV Light Source
Vibration Control

KIMM KAIST
Summary

- NIL has several advantages over optical lithography
  - High resolution (feature size ~ 10 nm)
  - low cost
- Challenging issues
  - Minimizing defects
  - Residual layer thickness control
  - 1× stamp inspection and cleaning
  - 10 nm scale overlay alignment
Thank You!