Ultrafast DPSS laser interaction with thin-film barrier stacks

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Overview

Introduction
Facilities
Results
Conclusions
Introduction: thin-film laser patterning

- Example: typical OLED layers optical properties

A single-laser wavelength will not be able to pattern all layers selectively.

An absorption coefficient of 1.E+5 cm\(^{-1}\) corresponds to a beam penetration depth of 100 nm.
Introduction: organics patterning using Excimer lasers

- Example: PEDOT:PSS and LEP removal from barrier foils
  - KrF Excimer laser (248 nm)

Single shot ablation of PEDOT and LEP on barrier is feasible
Introduction: organics patterning using Excimer lasers

- Example: PEDOT:PSS and LEP removal from barrier foils
  - KrF Excimer laser (248 nm)

Convenient process window for organics patterning
Clean removal of PEDOT/LEP
No debris or flakes are observed

Flexible OLED devices incorporating Excimer laser patterning have been demonstrated. *Applied Optics 2013 (under review)*

Detailed surface analysis after laser patterning.
*Applied Surface Science 2013 (article in press)*
Introduction: inorganics patterning using Excimer lasers

- Example: (inorganic) barrier layer patterning on metal contacts

The photochemical nature of the process does not allow for layer selectivity.
Introduction: inorganics patterning using DPSS lasers

- Example: (inorganic) barrier layer patterning on metal contacts

Goal is to study the influence of the wavelength and the pulse energy on the ablation mechanism

An absorption coefficient of $1.0 \times 10^5 \text{ cm}^{-1}$ corresponds to a beam penetration depth of 100 nm
Ultrafast laser set-ups at TNO and imec

Coherent ps laser (Talisker)
TimeBandwidth ps laser (Duetto)
Amplitude Systems fs laser (Satsuma)
OVERVIEW

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Results SiN on MAM / ps 355nm

- **Step 1: power scan / single pulse**
  - To determine the ablation threshold of the SiN on MAM
  - Find threshold for damage of the sub layers
  - To see the behavior of ablation mechanism(s) as function of laser pulse energy

Photo-chemical assisted ablation
Laser fluence higher than 90 mJ/cm²

Photo-mechanical assisted ablation
Laser fluence < 90 mJ/cm²

Threshold SiN removal 60 mJ/cm²
Results SiN on MAM / ps 355nm

- **Step 2: photomechanical process optimization**
  - Complete SiN layer removal without introducing damage to the underlying layer
  - Single shot process seems to be unstable
  - Improve laser patterning “process window” by tuning the pulse to pulse distance (P2P)

![Graph showing depth vs. distance](image)

- Selective removal of SiN on MAM
- Consistent SiN removal BUT slow process

p2p distance: 24 → 16 → 8 → 1μm
Results SiN on MAM / ps 1064nm

- **Step 1: power scan / single pulse**
  - To determine the ablation threshold of the SiN on MAM
  - Find threshold for damage of the sub layers
  - To see the behavior of ablation mechanism(s) as function of laser pulse energy

**Threshold SiN on MAM**

- 1064nm, F=566mm, W₀ ~70μm
- \[ y = 9803.8x + 27194 \]
- \[ R^2 = 0.9875 \]

**Results**

- Threshold SiN removal: 64 mJ/cm²
- MAM micro-cracks above 150 mJ/cm²

**Photomechanical ablation**

- Large particles (debris)
Results SiN on MAM / ps 1064nm

- **Step 2: photomechanical process optimization**
  - Complete SiN layer removal without introducing damage to the underlying layer
  - Large particles: cleaning method needed: e.g. N$_2$ blowing

After cleaning

Consistent SiN removal AND fast process
Step 1: power scan / single pulse

- To determine the ablation threshold of the SiN on ITO
- Find threshold for damage of the sub layers
- To see the behavior of ablation mechanism(s) as function of laser pulse energy

Threshold SiN removal 106 mJ/cm²

Challenging to remove the SiN layer completely

Photo-chemical assisted ablation over complete fluence range
Results SiN on ITO / ps 1064nm

- **Step 1: power scan / single pulse**
  - To determine the ablation threshold of the SiN on ITO
  - To see the behavior of ablation mechanism(s) as function of laser pulse energy
  - Find threshold for damage of the sub layers

Threshold SiN removal 120 mJ/cm²

Photomechanical assisted ablation of SiN on ITO, providing a clean bottom interface

Complete SiN removal
No ITO damage
Discussion

- Not always beneficial to select a laser wavelength which shows the highest absorption for the (inorganic) layer to be removed.

An absorption coefficient of 1.E+5 cm\(^{-1}\) corresponds to a beam penetration depth of 100 nm.
Overview

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Conclusions

- **Ultrafast DPSS laser interaction with thin-film barrier stacks**

- **Influence of laser wavelength and pulse energy on the ablation mechanism**

- **Photomechanical versus photochemical assisted thin-film removal**
Acknowledgement

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