Development of the Flexible Surface Light Source using Luminous Array Film Technology

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Outline

1. Basic structure for Deep UV flexible surface light source with “Luminous Array Film (LAFi)” technologies
2. Fabrication process and device configuration for flexible characteristics
3. Improvement of the UV emission power and the life time
4. Performance of the UVC surface light source for a sterilization application
5. Summary
Prototype roll-up display by LAFi technology

Prototype 1 x 1-m display in I-Zone, Display Week 2013 at Vancouver, Canada

Display Application of LAFi

Display film:
- 1024 x 1024 mm,
- 320 x 320 pixels
- Thickness < 1 mm
- weight = 2 kg

Basic structure of Luminous Array Film (LAFi)

- Luminous tubes
- Films with electrodes
- MgO layer
- Phosphor Layer
- Discharge gas

1 mm
Issues of LAFi structure for DUV light

Cross section of the LAFi for display

- Color emission
- Front plastic film
- Front electrodes
- Adhesive layer
- Glass tube
- Phosphor layer
- Back electrodes
- Back plastic film
- Ne + Xe gas

- Front and back plastic film with electrodes and adhesive layer absorb UVB and UVC light
- Film material and adhesive material deteriorate by UV light
- Glass tube material of the bolo-silicate absorb UVC light
Basic structure for DUV emission

Cross section of the DUV luminous tube and the array structure

- Backside electrodes apply AC electrical field on the discharge gas in the glass tube, and DUV light emits only to front side.
- Electrode film and adhesive material are protected by reflecting the UV light with widely formed phosphor layer in bottom of the tube.
- AC driving pulse provide a stable and uniform discharge in the tube.
Transmittance of the glass wall

- Absorption of UVC by the glass wall was reduced by ultra thin glass tube formation technique.
- Reflection of UVC by the glass wall was very little because of low dispersion at the no phosphor area of the glass tube.
- UVC output was achieved with low cost glass material.
Fabrication Process of LAFi

1st step
Glass formation

2nd step
phosphor layer formation

3rd step
Exhaust and gas filling

4th step
Aging and selection

5th step
Back substrate formation

Last step
Arraying and adhere

Bolo-silicate glass is formed as designed size

Discharge gas

Exhaust

Ne + Xe

Final sealing

Pre-sealing

Simple process of the luminous tube without electrode formation

- External electrodes
- Luminous tubes
Configuration for the bendable array

- Selectable substrate; the solid plate or the flexible film
- The tube gap, the adhesive and insulation layer is important
UV emissions spectrum by typical three phosphors

- Several phosphor materials were tested by making a small size LAFi light source
- Single-band phosphor is expected to focus on a particular application
- UVC broadband light provides a several new applications
Variation of UV-LAFl

- Surface size is designed by the tube length and the tube arrangement
- Long tube of over 20cm is available
- These design flexibilities provides many advantages for UV applications
- Flexible film substrate is available
Improvement of UV emissions power

- Miss-matching of the impedance between the drive circuit output and the gas space was reduced by optimizing the insulation layer and the inverter circuit.
- By these optimization, the high UVC emission of 200 mW (4 mW/cm²) was achieved with 8 x 6-cm surface light source.
Life test results and life control

The 8 x 6-cm light sources with two types of UV phosphors were tested in two driving condition.

- The life time varies according to the phosphor material.
- The life time is controllable by controlling emission power with pulse duty ratio control technique.
Sterilization by UV-LAFi with broad band UVC phosphor

- High speed sterilization
- 99.999% of sterilization rate within 10 sec
- High sterilization efficiency with UVC broad band phosphor

Irradiation energy for 99.9% inactivation with 254 nm emission by Low-pressure Hg lamp

<table>
<thead>
<tr>
<th>Name of a bacteria</th>
<th>UVC irradiation for 99.9% inactivation</th>
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<tbody>
<tr>
<td>Bacillus subtilis (spores, NBRC 3134)</td>
<td>20.3 mJ/cm²</td>
</tr>
<tr>
<td>Escherichia coli (NBRC 3972)</td>
<td>9.8 mJ/cm²</td>
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Advantage of UV-LAFi with broadband UVC phosphor

- The shape of the emission spectrum of broadband UVC phosphor is very similar to that of sterilization curve
- Diffusion light by surface light source provides a shadow free lighting

![Graph showing emission spectrum and sterilization curve comparison](image)
Summary

✓ A flexible light source technologies using Luminous Array Film (LAFi) realized a new mercury free flexible surface deep-UV light source.

✓ We developed several wavelength and size of DUV-LAFi and improved emission power to spread there application field.

✓ UVC light source for sterilization provides very high performance against to strong bacteria.

✓ LAFi is the best device for large area surface light source in DUV light applications.