June, 2009

As you may have noticed, our newsletter has grown in the past few months. This month we have added a section from KSU’s Technology Transfer Department. This section will highlight a Liquid Crystal Institute patented technology that is available for licensing. This month the technology is a method for generating color, whose inventor is LC Chien. Professor Chien is also the subject of our monthly faculty profile. For easier navigation, we have provided the following links that allow you to “jump” to a particular section in this newsletter.

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CLEANROOM NEWS

LCI cleanroom staff will be scheduling 1-2 days of shutdown early in August for some equipment movement and thorough room cleaning. We will give 1-2 weeks notice for this to allow for planning purposes.

An Ocean Optics Spectrometer is being installed in the standard assembly area. This will allow for quick cell gap measurements during and immediately after cell assembly efforts. All parts are on site, but waiting for an operating system and software to be installed on the controlling computer. This should be completed by mid July.

The MRC sputter coater located on the 1st floor (“MRC Room”) is once again running with the original larger Leybold mechanical pump. The pump has been rebuilt and repaired. We are currently looking into the possibility of upgrading the unit to pulsed DC operation, which would allow deposition of ITO in the system. Further information on this upgrade will be provided next month.

The new high end assembly area has been completed, in the alcove next to the cleanroom air shower. The Asymtek A402 XY Dispenser has been reinstalled in this space (the A403 Dispenser is still in the original assembly area), and the Fusion UV Source and Dymax UV Source have been moved to this area as well. This area is initially being used by one of the IPP member companies for more complicated assembly tasks.

The Brewer GX100 Large Area Spincoater has been returned to the LCI fully operational, after service at Brewer. Please inquire with Doug Bryant if you have interest in use of this tool.
The GenVac Aerospace SC1 ion-assisted e-beam coater is currently operational for metal or insulator coatings, but not for ITO. GenVac has agreed to help troubleshoot and repair the custom ion gun. A new power supply for one of the turbo pump controllers is on order. The ion gauges have been replaced, and staff will continue to look at upgrading the safety interlocks, likely in late July, depending upon interest in the machine.

If there are particular pieces of equipment that are of interest to you, or if you would like to see particular capabilities added to the room, please contact Doug Bryant.

**PROCESS NOTES: BARRIER COATINGS**

Barrier coatings can be used in liquid crystal devices to prevent shorting between the two substrates. Alternatively, these films may be referred to as insulation layers, passivation layers, dielectric layers, or ITO top coat. All of these names generally describe the same materials. A different barrier layer is often used between the ITO and glass substrate to prevent sodium ion migration from the glass—this will not be discussed here (but will be a future Process Notes topic).

Most liquid crystal devices operate at relatively low voltages (<25 volts for most types). But because of the small gaps between substrates (1-10 microns), the field strengths are relatively high. Because the polyimide alignment layer is thin, there is little to prevent a hard particle from causing a short between the two ITO surfaces. Localized defects such as small particles, spikes in the ITO layer, etc. can cause higher electric fields which can also lead to arcing. By coating a thin layer on top of the ITO conductor that has high dielectric strength, shorting can be prevented in most cases. The layer should be thin to avoid much of an increase in driving voltage for the device due to the added layer thickness.

The best barrier coating is a thin layer of SiO2 (often as thin as 200-300 angstroms), vacuum deposited by e-beam evaporation or sputtering. These films are very hard, can withstand very high electric field strengths, and are completely transparent. However, this is not practical if there is not an appropriate deposition system on site—it can be cost prohibitive.

An alternative to vacuum deposited barrier layers is to use a spin-on barrier layer. The simplest barrier layer material is tetra-ethyl-ortho-silicate (TEOS, often used for sol-gel applications), which can be converted to SiO2 as follows:

\[
\text{Si(OC}_2\text{H}_3\text{)}_4 \rightarrow \text{SiO}_2 + 2\text{O(}\text{C}_2\text{H}_5\text{)}_2 \\
\text{at elevated temperature; and}
\]

\[
\text{Si(OC}_2\text{H}_3\text{)}_4 + 2 \text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4 \text{C}_2\text{H}_5\text{OH}
\]
The bake temperatures necessary to complete this reaction, however, are typically 400-500°C. These temperatures can affect the resistivity of ITO layers, and at the upper end are approaching softening points for soda lime glass, but offer good substitutes to vacuum deposited SiO2.

Films that are not completely converted to SiO2 may still be suitable for use as a barrier layer, however. Zhang (ref 1) has shown the change in film refractive index vs. bake temperature for spin-on type and sputtered type barriers (TEOS type)—see Figure 2. The spin-on films show the characteristics of Si2O3 (index = 1.55) at lower temperatures, decreasing with bake temperature until fully converted (the index of fused silica is 1.46). The change in index for the sputtered films is more likely due to densification of the film with higher temperatures.

![Figure 2. Change in index vs. bake temperature (deg C) for spin-on (sol-gel) and sputtered SiO2 layer](from Zhang)

Similar to TEOS, a titanium-based material, tetra ethyl ortho titanate (TEOT) can also be synthesized. TiO2 has a much higher refractive index (~2.0). Merck has marketed the TEOS and TEOT materials in solution (ZLI-2132 is TEOS, ZLI-1857 is TEOT) as a “2-bottle system” for adjusting refractive index of the barrier layer for index matching (see Table 1). The materials are thinned with anhydrous isopropanol for spincoating. Experience at the LCI has shown that the Ti based material especially is very sensitive to moisture. A white TiO2 precipitate will form if standard isopropanol is used.

<table>
<thead>
<tr>
<th>Parts TEOS (ZLI-2132)</th>
<th>Parts TEOT (ZLI-1857)</th>
<th>Film index after 400-500°C bake</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1.4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>1.9</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 1. Tuning of refractive index by mixing Si- and Ti-based components (from Merck data sheet)

Several materials suppliers have introduced barrier layers with lower bake temperatures. Nissan Chemical supplies several barrier layer materials that have recommended cure temperatures of 300°C. TEOS and TEOT are used in some of these mixtures, as well as similar components (tetra methoxy silane, etc.) and aluminum based compounds (aluminum nitrate nonahydrate) which can form an alumina barrier. The lower cure temperatures are likely designed to fit more easily with standard LCD processing, rather than indicate a complete conversion to SiO2, TiO2 or Al2O3.
The LCI uses the Merck materials, as well as several Nissan barrier materials. If you have interest in discussing further, please contact Doug Bryant.

References

LCI NEWS

Leading Edge Liquid Crystal Technology-Based Company Holds Board Meeting in Northeast Ohio
Crystal Diagnostics has partnerships with NEOUCOM, Kent State

Crystal Diagnostics, a high-tech company with strong and strengthening ties to Northeast Ohio held its regular Board of Directors meeting at the Northeastern Ohio Universities Colleges of Medicine and Pharmacy (NEOUCOM) and Kent State University on June 24, 2009. The award-winning company was formerly known as Pathogen Systems, Inc., or PSI, and now does business under the Crystal Diagnostics name.

Crystal Diagnostics, a Delaware corporation doing business in Colorado and Ohio, licensed technology born in the labs of NEOUCOM and Kent State to develop a device that tests water samples for the presence of harmful biological pathogens. The prototype device recently underwent its first field test in California. Numerous government and industry leaders have expressed interest in the product when it comes to market in quantity.

The company is in the process of signing an agreement to locate a significant portion of its business operations in Kent State University’s Centennial Research Park. Crystal Diagnostics also conducts R&D work in an Applied Research Laboratory on the campus of NEOUCOM. Last year the state of Ohio awarded NEOUCOM with a $3 million Wright Project grant to further the development of the partnership with Crystal Diagnostics and Kent State University.

“NEOUCOM is proud to be working with our partners at Crystal Diagnostics and Kent State University to develop a device that has such strong market potential in water quality control, and even global health initiatives,” says Walter E. Horton, Jr., Ph.D., Vice President for Research at NEOUCOM. “As this company grows the impact on the local economy will be substantial.”

“The collaboration with the Kent area’s research partners will be critical in taking this product and our business to the next level,” says Bunting.

New Faces at LCI
Professor Hiroshi Yokoyama joined us on July 1 as the Ohio Research Scholar and Professor of Chemical Physics. His office is in Room 215 LCM and his lab space will be in Room 149.

Recent Talks by Robin Selinger
Invited talk: "Modeling Liquid Crystal Elastomers"
Gordon Research Conference on Liquid Crystals
New London, NH
June 17, 2009
Invited talk: "Modeling Liquid Crystal Elastomers"
Hougen Symposium on Frontiers of Liquid Crystals
Madison, WI
April 24, 2009

Recent CPIP Ph.D. Defenses
Oleg Pishnyak, "New Electro-Optical Applications of Liquid Crystals: from Beam Steering and Tunable Lenses to Negative Refraction and Field-Induced Dynamics of Colloids"
Clinton Braganza, "High Dielectric Constant Materials Containing Liquid Crystals"

Recent Masters Thesis Defense
Nithya Venkataraman, "Photosensitive Cholesteric Liquid Crystal Materials"

Upcoming Events
July 8 and 10, 2009 - 1st NSF-OTKA Symposium for Complex Fluids
Eger, Hungary: http://www.lci.kent.edu/crelic_ires/symposium.htm
September 24-26, 2009 - 5th International Liquid Crystal Elastomer Conference – 2009 - Liquid Crystal Institute, Kent State University, Kent, Ohio, USA: http://ilcec2009.lci.kent.edu/

TECHNOLOGY TRANSFER

Featured Kent State University LCI Technology
From the Office of Technology Transfer and Economic Development, Kent State University
www.techtrans.kent.edu (Please visit the “For Industry” section)

KSU.350 - Polymer and Blue Phase Liquid Crystal Composites for Field-Induced Color (FIC)
Inventors: Dr. L.C. Chien (faculty) and Shin-Ying Lu (student)

This polymer-stabilized blue phase mode technology is an eco-friendly technology that can help display companies reduce their environmental impact and deliver cost savings as well as improve color displays. Our Kent State inventors have demonstrated a new electro-optical device for field-induced color (FIC) based on a polymer-stabilized blue phase (PSBP) liquid crystal display.

The color tuning is reversible and with a wide color range capable of covering the visible spectrum. Due to the advantages and ability of controlling the electrically-switched colors, one can fabricate devices for application without alignment layers, color filter, and polarizers.

This invention includes better options for formulating materials, processes, and fabrication of polymer-stabilized blue phase liquid crystal devices that can provide improvements for electrically-tunable color displays. It offers improved transmissive displays through greater light efficiency; improved reflective displays through brighter color; and improved optical filters and new generation electro-optical devices and active optical elements.

Advantages include energy savings through light efficiency; fast switching; reversible color tuning; brighter color; better temperature stability at operation range; and better control and manipulation of optical properties - without alignment layers, color filters, and/or polarizers.
Licensing Information Contacts:
Gregory B. Wilson, Associate Vice President, Economic Development and Strategic Partnerships greg.wilson@kent.edu, 330-672-0704
Charmaine Streharsky, Ed.D., Licensing Coordinator for Technology Transfer cstrehar@kent.edu, 330-672-3553

FACULTY PROFILE

Liang-Chy Chien
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Statement of Interest
The focus of my work is development of novel liquid crystal materials, polymer composites and elastomers for applications in energy storage and conversion, actuators and sensors, reflective and flexible displays, spatial light modulators and lenses with switchable focal length.

Current Lab Activities
• Developing high birefringence liquid crystal materials for fast switching spatial light modulator
• Developing polymer dispersed, modified and stabilized liquid crystals for flexible displays
• Developing high dielectric complex fluids and composites for high density capacitors
• Developing single substrate color reflective cholesteric LCDs
• Developing color reflective polymer-stabilized blue phase LCDs
• Developing fast-switching blue phase LCDs
• Developing high dielectric complex fluids and composites for high density capacitors
• Developing organic and polymeric photovoltaics
• Developing photochromic and electrically switchable liquid crystal polymers and elastomers for sensors and actuators
• Developing compensation films for wide viewing angle LCDs
• Developing non-contact liquid crystal alignment materials and methods

CV / website  http://www.lci.kent.edu/PI/Chien.htm

Application interests
• Reflective liquid crystal displays
• Flexible liquid crystal displays
• Fast switching displays
• Fast switching optical devices, including switchable gratings and lenses
• Wide viewing angle displays
• Low power reflective displays
• High density and fast pulse charging and discharging capacitors
• Organic and polymer solar cells
• Artificial muscles
• Sensors and actuators

**Interests in potential industrial interactions**
- Research/Development topics
  - I’d be glad to collaborate with industrial partners in applications of liquid crystals and polymer composites or anything within our research interests
  - Lab facilities capable of chemical aspect of the preparation of LC and polymeric materials
  - My lab has capabilities for physical aspects of the characterization of LC devices
  - Topics that could be addressed as consultant

**Current Graduate Students**
- Clinton Braganza
- Shin-Ying Lu

**Book Chapters**

**Refereed Journals**

Shin-Ying Lu
Ph.D. Candidate
Liquid Crystal Institute &
Chemical Physics Program
330-672-1526

**Long Term Interests**
- Liquid crystal based optical device.
- Flexible displays for electronic paper.
Simulation with finite differential method and Monte Carlos method.

**Current Research Projects**
- Electrically tunable color based on polymer stabilized cholesteric liquid crystals and blue phase. The device is aim to used as reflected displays or color filters.
- Carbon nanotube doped nematic liquid crystals.

**Interest in short term projects for a company**
- Design of liquid crystal device for optical and display applications.
- Characterizations of Physical and optical properties of liquid crystals.
- Modeling with finite differential method and Monte Carlos method. I’m familiar with Matlab and C++.

**Link to CV**
[http://sites.google.com/site/shinyinglu/](http://sites.google.com/site/shinyinglu/)