March, 2008

CLEANROOM NEWS

Process Spotlight: Liquid Crystal Alignment Layers, Part II
Last month, we discussed the basic concept of alignment layers, and discussed how polyimides have become the predominant material used for liquid crystal alignment. This month we will discuss some basic properties of polyimides, and how they relate to device performance.

Why we need different polyimide formulations
The most important thing to realize about modern polyimides is that they have become highly engineered chemicals, designed for optimal performance in LCDs. The basic polyimide structures have been modified to best achieve defect free, temperature stable films, with somewhat “tunable” pretilt angles, electrical properties, and cure temperatures. Blending of different polyimide materials has also resulted in improved performance. For more in-depth detail of the specific chemistries involved, the references from Nissan Chemical referenced at the end of this article are helpful. In the simplest terms, a polyimide is generally formed by reaction of a dianhydride and diamine—the actual structure of each moiety can vary, depending upon desired properties. The actual chemical structure of commercial polyimides is usually considered a trade secret, although Japan Synthetic Rubber (JSR) has been somewhat open about this. Kent State University also owns a patent portfolio donated by DuPont that outlines significant information about polyimide structure, chemistry, and synthesis, including that related to the standard PI-2555 polyimide. (These patents are available for licensing).

Pretilt angle and different LCD modes
At first glance, it might appear that the pretilt angle induced by polyimide alignment layers would be unimportant, as long as it is small. However, it is actually quite important to stabilize switching performance in many LCD modes. TN cells require a small (~1 deg.) pretilt angle to break the degeneracy between left-hand and right-hand twist configurations for a given rub. Without this, reverse-twist disclinations appear in the cell, hindering performance (note that a small amount of chiral dopant is usually added to prevent reverse-tilt disclinations, which appear when the device is switched). In super-twist nematic (STN) displays, higher pretilts (4-8 degrees typical) are required to prevent stripe defects (where the helix “tips over” instead of untwisting). Pretilt angle also can have a large effect on viewing angle of LCDs. Individual polyimides usually have a small range of tunability of pretilt with rub strength, so chemically distinct materials are used for TN vs. STN devices, in most cases.

Electrical properties—voltage holding ratio and residual DC
The electrical properties of polyimides are very important, as well. Voltage holding ratio (VHR) of a display is defined as the percent retention in RMS voltage across a pixel within one frame time. It is very important for active matrix (TFT) displays, and is indicative of the amount of ionic contamination in a display. Similarly, residual DC (RDC) is a measurement of the amount of charge trapping at display surfaces, resulting in a recurring DC voltage on a pixel after the addressing voltage is removed (usually measured in mV). In both cases, the polyimide material can have a large effect, based on its ability to trap charges, and its general ion permeability.
Cure temperatures and percent imidization
Cure temperatures for polyimides are typically over 250°C for complete imidization. However, in many cases, these temperatures are not well suited to device fabrication. Color filter materials were the biggest impetus in achieving lower cure temperatures, as cure temperatures as low as 200°C could damage early color filter materials. As a result, there was a big drive to develop suitable materials that could be cured at 180 degrees C. Researchers discovered that curing a particular polyimide at a lower temperature that that required for full cure (imidization) was acceptable, as long as the polyamic acid precursor was stable and would not degrade device performance. Most of today’s “low” cure temp (<220°C) materials can actually be cured at higher temperatures and achieve different end properties (usually much higher pretilts).

Blends of preimidized and polyamic acid types
In general, preimidized (PI) polyimide types have good electrical (VHR) properties, and perform better with rubbing, while polyamic acid (PAA) types have better coating (adhesion, solvent systems for defect free coatings) properties and somewhat lower RDC. As it turns out, it is possible to blend these two types to achieve the “best of both worlds”. Researchers at Nissan have indicated that they have developed blends that separate during coating/cure, so that the PAA type material is concentrated near the glass surface, while the PI material is more prevalent at the film surface. This combination gives better performance than either material could by itself (see table below). In particular, RDC is greatly reduced using blends compared to either material on its own.

<table>
<thead>
<tr>
<th>Polymide</th>
<th>Tilt Angle (deg.)</th>
<th>VHR (%) at 90°C</th>
<th>RDC (V) at 120 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI-D</td>
<td>2</td>
<td>46</td>
<td>1.0</td>
</tr>
<tr>
<td>PI-F</td>
<td>6</td>
<td>86</td>
<td>1.6</td>
</tr>
<tr>
<td>PI-D + PI-F</td>
<td>6</td>
<td>85</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table 1. Influences of the mixing of the two polyimides, PI-D and PI-F, on LC-cell properties (from ref. 1 below, Nissan Chemical, SID 2000)

The LCI has numerous polyimide materials available for use, including those for TN, STN, active matrix, and VA mode cells. If you would like further information about the capabilities of the LCDRF, please contact Doug Bryant.

Some resources to learn more about polyimides:
2. “Physical Properties of Liquid Crystals—Description of Measurement Methods,” Merck publication, undated. (definitions and measurement methods for RDC, VHR,
5. Japan Synthetic Rubber (JSR) website: http://www.jsr.co.jp/jsr_e/pd/lc_pd.shtml#lc_a

EQUIPMENT UPDATE
Several tools in the LCDRF will be undergoing maintenance and upgrades, or have recently completed maintenance:

The MRC 603 III Sputter Coater has undergone several repairs in the last month. The DC power supply was repaired, and an external monitor added to replace the failed internal user interface monitor. Additionally, the gas controls were adjusted to proper calibration, and a loose cable was reseated to allow
for appropriate automatic operation of the ion gauge controller. The unit is temporarily down to address a vacuum leak in the system, but should be operational again by mid-March.

Dr. Qihuo Wei’s Oxford 80+ reactive ion etcher (RIE) system was installed early in October. An Oxford engineer will return in a few weeks for process training. Standard processes on this tool will be etching of Si, SiO2, and silicon nitrides. Other processes are possible using the SF6 and CHF3 gases (along with Ar or O2).

The Oriel Mask Aligner has undergone lamp replacement / alignment and stage planarization. LCI staff have now used the mask aligner to fabricate multilayer patterned coatings with 3 micron feature sizes.

The Technics PlanarEtch II plasma etcher is currently down. No work is planned on this machine in the next month. If you have interest in using this machine, please contact Doug Bryant; if there is a need for it, we can bump this up in priority.

The Clean Air Systems Wet Bench has been gutted and is being rebuilt for maximum efficiency in working with 6” and 7” glass. Kevin Ballard, and undergraduate cleanroom assistant, has been working to redesign the work surface, and prepare mechanical drawings. Design phase for this work is nearly complete, with actual installation scheduled for late winter.

LCI NEWS

Crawford named Dean at University of Notre Dame
Congratulations to Gregory Crawford who has been named Dean of the College of Sciences at the University of Notre Dame in Indiana, effective July 1, 2008. Dr. Crawford is currently Dean of Engineering at Brown University. He graduated from Kent State University in 1991 with a degree in Chemical Physics.

New Faces at LCI
Dr. Alexander Petrov will be a Visiting Scientist from 3/3/08 - 4/25/08 working with Tony Jakli. He is the director of the Institute of Solid State Physics, Bulgarian Academy of Sciences.

Kexuan Li is a visiting student working with Dr. Deng-ke Yang. March 3 - Dec. 31, 2008

Recent publications:
Robin L. B. Selinger, Badel L. Mbanga, and Jonathan V. Selinger, "Modeling liquid crystal elastomers: actuators, pumps, and robots"
Proceedings of SPIE Vol. 6911
Link... doi:10.1117/12.768282

Yong-Kyu Jang and Philip Bos, “Optimization of the White state director configuration for perfectly compensated Pi-cell devices”

Yong-Kyu and Philip Bos, “Comparision and analysis of off-axis color shift properties of compensated liquid crystal devices”

Recent presentations:
Prof. Robin Selinger, Liquid Crystal Institute, Kent State University, "Modeling liquid crystal elastomers: actuators, pumps, and robots"
Feb. 19, 2008, 21st annual workshop, Center for Simulational Physics, Univ. of Georgia, *Invited talk*
Prof. Robin Selinger, Liquid Crystal Institute, Kent State University, "Rubber That Moves: Modeling Liquid Crystalline Elastomers"

**Upcoming Presentations**
March 28, 2008, Condensed Matter Seminar, Syracuse University,
Prof. Robin Selinger, Liquid Crystal Institute, Kent State University, "Simulation studies of orientational order and topological defects in curved geometries"

April 3-4, 2008... two talks at the Univ of Nebraska at Kearney,
Prof. Robin Selinger, Liquid Crystal Institute, Kent State University
1. Talk for science community: "Modeling Liquid Crystal Elastomers"
2. Talk for general audience: "How Things Bend and Break"

April 8, 2008... Physics colloquium at Yeshiva University
Prof. Robin Selinger, Liquid Crystal Institute, Kent State University, "Finite Element Simulation of Liquid Crystal Elastomers"

May 18-23, 2008, SID International Symposium, Los Angeles,
Mitya Reznikov, Bentley Wall and Philip J. Bos, “Mono-domain alignment of the SmC liquid crystalline phase for analog display applications”
E. Dorjgotov, A. Bhowmik, P. Bos, “Liquid crystal etalon device for reflective display”
Yi Huang, K.H. Kim, J.K, Jang, H.S. Kim and Philip Bos, “Dynamic simulation of Pi-cell liquid crystal displays with transverse field”

**APS March meeting contributed talks**
Robin Selinger, Jonathan Selinger, and Alex Travesset, "Orientational order and topological defects on curved surfaces"
Jonathan Selinger, Robin Selinger, Christopher Spillmann, Jawad Naciri, B. R. Ratna, "Electrically induced twist in smectic liquid-crystalline elastomers"
Badel Mbanga, Jonathan Selinger, Robin Selinger, "Finite element studies of the soft elastic response in liquid crystal elastomers"
N. Scott Weingarten and Robin Selinger, "Atomistic simulation studies of plastic deformation and dislocation patterning as a function of temperature"
Lena Lopatina, Andrew Konya, Jonathan Selinger, Robin Selinger, Alex Travesset, "Simulating defect structures in nematic liquid crystal shells"
Jake Fontana, Peter Palfy-Muhoray, Nicholas Kotov, Ashish Agarwal, “Measurements of the electric susceptibilities of Au nanorods at optical frequencies”
Piotr Lesiak, Michele Moreira, Peter Palfy-Muhoray, Nicholas Kotov, Ashish Agarwal, “Z-scan measurement of oriented Au nanoparticle suspensions”
Timothy Sullivan, Pushkar Dahal, Peter Palfy-Muhoray, “Pattern morphology and dynamical scaling in the Cahn Hilliard model”
Xiaoyu Zheng, Peter Palfy-Muhoray, Michael Shelley, “Angular momentum transport in complex fluids”
Chad Wickman, Christina Haas, Peter Palfy-Muhoray, “Writing and representation in liquid crystal physics research”
Israel Lazo Martinez, Peter Palfy-Muhoray, “Determination of the refractive indices of liquid crystal elastomers”
Sabrina Relaix, Michele Moreira, Peter Palfy-Muhoray, Michel Mitov, “Varying the optical properties of cholesteric liquid crystals”
Upcoming LCI Seminars
March 19, 2008 at 3:00 p.m.
Prof. Mark Warner, Cavendish Laboratory, University of Cambridge, UK, "Non-linear processes in dyes and nematic photo-elasticity”

March 24, 2008 at 4:00 p.m.

March 26, 2008 at 3:00 p.m.
Prof. Alexander G. Petrov, Director of the Institute of Solid State Physics, Bulgarian Academy of Sciences, “Liquid Crystal Physics and the Physics of Soft Matter”

April 2, 2008 at 3:00 p.m.
Prof. Vladimir M. Agranovich, The NanoTech Institute, The University of Texas at Dallas, and Institute of Spectroscopy, Russian Academy of Science, "Negative refraction, polaritons and negative group velocity"

April 9, 2008 at 3:00 p.m.
Prof. Sasha Govorov, Department of Physics, Ohio University, “Optical properties of coupled semiconductor and metal nanocrystals: Exciton-plasmon interaction and nonlinear effects”

April 16, 2008 at 3:00 p.m.
Prof. Matthew A Glaser, Department of Physics, University of Colorado, “Nanophase segregation and frustration: chirality, splay, and curvature in bent-core smectics”

April 23, 2008 at 3:00 p.m.
Prof. Robert Austin, Department of Physics, Princeton University, Title: TBA

April 30, 2008 at 3:00 p.m.
Prof. Paul Goldbart, Department of Physics, University of Illinois at Urbana-Champaign, Title: TBA

Please let us know if you would like more detailed information about any activities at the LCI.

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