MULTIPHYSICS SOFTWARE, A VERSATILE, COST-EFFECTIVE R&D TOOL AT SHARP

Supports lab's multidisciplinary research and product development activities

By **GARY DAGASTINE**

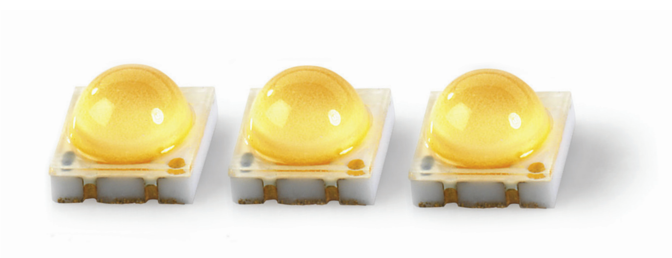

FIGURE 1: LED modules from Sharp (www.sharpleds.com).

TODAY'S ELECTRONICS PRODUCTS are sophisticated, highly integrated systems that may contain technologies as diverse as processors, communications chips, analog and passive components, light and power sources, displays, imagers, microelectromechanical systems (MEMS), and other components.

This wide range of technologies and the many interactions within and among them mean that product developers must draw on multiple scientific and engineering disciplines right from the outset of a project to meet functionality, quality, cost, and time-to-market goals.

Nowhere has this multidisciplinary approach taken root more firmly than in the R&D laboratories of Osaka, Japan–based Sharp Corporation. Sharp is one of the world's largest producers of televisions and liquid crystal displays and is a major force in LED lighting systems, solar cells, multifunction business machines, and a variety of other electronics-based products.

Sharp's global R&D presence includes laboratories in Japan, which is the global headquarters for R&D, as well as in Oxford, England; Camas, Wash.; and Shanghai, China. The mission of each laboratory is to develop technology that can be used in Sharp products, and while each lab works on roughly the same research themes—displays, health, energy, and lighting—each has its own unique capability and tailors its activities to support Sharp's regional businesses.

A case in point is Sharp Laboratories of Europe (SLE), Sharp's wholly owned affiliate in Oxford, with approximately 100 employees whose primary focus is to conduct R&D on electronics hardware and devices. The lab has active projects in display technology, semiconductor devices, lighting, health, and energy systems. SLE-developed technology has gone into Sharp's mobile phones, smart cards, personal computers, laptops, and automotive displays. (A selection of some of the lab's work can be seen at Sharp's Humans Invent website, at www.humansinvent.com.)

"A common feature of much of our work is its multidisciplinary nature, as reflected by the broad range of scientific specialties across our research staff, including materials scientists, chemists, physicists, optical designers, electronic engineers, and software developers," says Chris Brown, research manager for SLE's Optical Imaging and Display Systems Group.

Brown says the multidisciplinary trend goes hand in hand with changes in the type of R&D done in the lab. "Ten years ago, for example, our main research themes were based on improving component technologies, in particular, displays and optoelectronic devices such as semiconductor lasers. Activities tended to be driven by depth of knowledge in just one technical specialty, such as optics or electronic circuit design. More recently, though, there has been a shift in focus to systems or products as a whole, such as health systems and energy systems. By their nature, these activities are broader, and the research is driven by understanding how all the parts fit together," he says.

Brown says SLE uses COMSOL Multiphysics® in a number of projects across the lab, for purposes ranging from early-

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> —CHRIS BROWN, RESEARCH MANAGER, SHARP LABORATORIES OF EUROPE'S OPTICAL IMAGING AND DISPLAY SYSTEMS GROUP

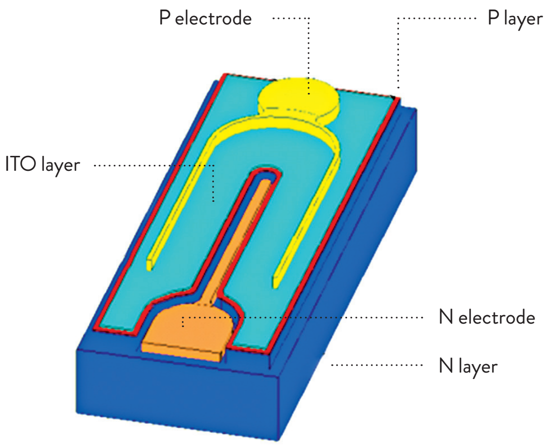

FIGURE 2: Structure of an LED chip.

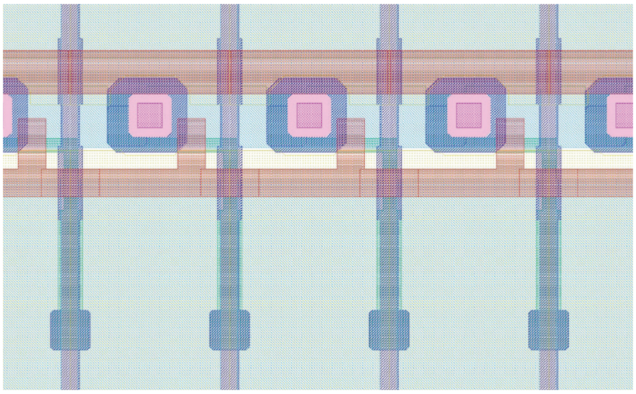

FIGURE 4: Structure of an LCD pixel, as drawn in an ECAD software.

stage research to product development. The main areas and some typical projects include LED devices, displays, labs-on-a-chip, and energy systems.

» LED LIGHTING

SHARP IS A major supplier of LED devices for lighting products (see Figure 1), and SLE supports Sharp's LED business by providing technical analysis and design modifications to improve the performance of its LED devices.

One example is optimization of LED electrode designs for improved wall-plug efficiency. A major issue with LED devices is that high operating temperatures can cause a reduction in the efficiency at which they convert electricity to light. The relationship between optical efficiency and temperature in an LED is not linear, however, meaning that any hot spots in the LED chip will disproportionately reduce the efficiency of the entire device.

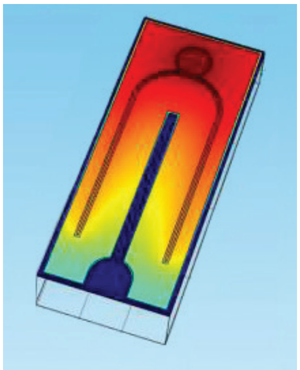

FIGURE 3: Simulation results of the surface electric potential.

The key goal, therefore, is to create a uniform temperature distribution. This is done by designing the LED's electrodes so that no hot spots occur. The resulting uniform temperature distribution will also tend to maximize heat dissipation from the LED chip and will result in a lower average temperature.

The structure of a typical LED chip is shown in Figure 2, with a COMSOL Multiphysics simulation of the LED shown in Figure 3. Multiphysics simulation of the LED's electrical and thermal performance allows the electrode design to be optimized. The lab originally used specialized LED design and simulation software for this project, but it was limited in functionality and didn't offer multiphysics analysis capability.

"Now we also use LiveLink™ *for* SolidWorks® in COMSOL Multiphysics to simplify the process of design translation and minimize the risk of translation errors," Brown says. "The gradually increasing complexity of our simulations means we must take into account multiple physics-based processes. By allowing multiphysics simulation of electrical and thermal aspects, we can achieve a much more accurate match between simulation and experimental data, and as a result, we are able to optimize LED designs for improved performance and reduced time to market."

» DISPLAY TECHNOLOGY

SLE ALSO PROVIDES technical support to Sharp's displays business. The broad goals are to improve the image quality and reduce the power consumption of LCD displays used in Sharp products ranging from smartphones to televisions. A detailed understanding of the electrical and optical performance of the LCD displays—particularly the electrical characteristics of the LCD pixels (see Figure 4)—is critical to achieving these goals.

Within its overall design and simulation environment for electronic circuit design, SLE uses the AC/DC Module to extract the parasitic resistances and capacitances of the electrical wiring inside the LCD. Here, the key feature

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> —**CHRIS BROWN**

is the meshing capability of COMSOL Multiphysics.

“We previously tried to use parasitic extraction tools from several traditional ECAD software packages but none was able to successfully cope with the large aspect ratio of the thin-film, large-area structures used in LCDs,” says Brown. “The versatility and degree of control over the meshing procedure in COMSOL have allowed us to successfully analyze these structures for the first time.” (See Figures 5 and 6.)

Brown also says the software’s ECAD Import Module lets researchers transfer layout designs from ECAD software quickly and without error, enabling them to explore the effects of design modifications to a degree not possible otherwise. That’s because the only alternative is to hand-calculate the capacitances between wires using simple linear design equations.

The shape of the wiring in the LCD makes this quite complicated, however. In the past, SLE’s researchers have had to make a number of simplifications when using this method. “Hand calculations of capacitance are correct to a first order but aren’t really of any use when trying to optimize or improve designs,” Brown says.

» MICROFLUIDIC LAB ON A CHIP

BESIDES PROVIDING technical support for existing products, SLE is also engaged in creating business opportunities for Sharp in new markets.

In the health care arena, SLE is leading the development of so-called lab-on-a-chip systems. These leverage Sharp’s manufacturing expertise with the thin-film transistors traditionally used in the LCD industry. The goal is to develop palm-size diagnostic tools for doctors, nurses, and other health care professionals that will let blood be tested in a matter of minutes, compared with the hours or days it can take today.

The enabling technology is known as digital microfluidics and involves the precise control and manipulation of fluids on the submillimeter scale using microelectronic circuits. Figure 7 shows the structure of a microfluidic array.

Droplets of fluid, such as biological fluids or other test reagents, can be

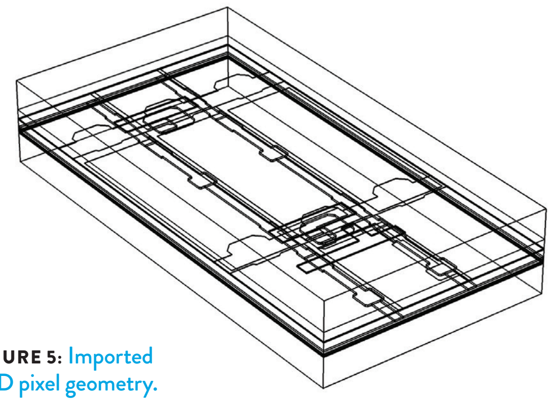


FIGURE 5: Imported LCD pixel geometry.

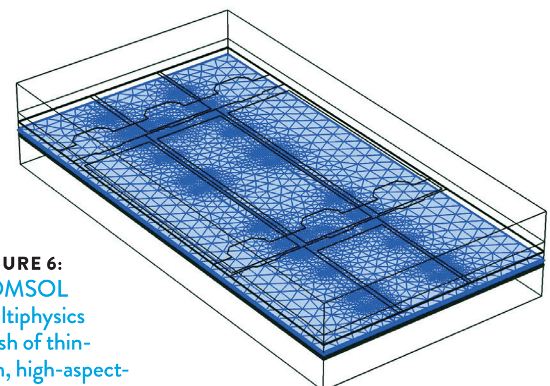
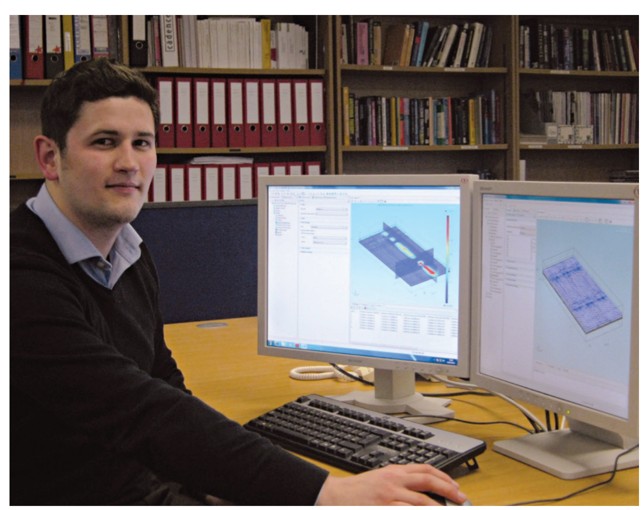


FIGURE 6: COMSOL Multiphysics mesh of thin-film, high-aspect-ratio structures.



Researcher Matthew Biginton using COMSOL Multiphysics to simulate LCD pixel capacitances.

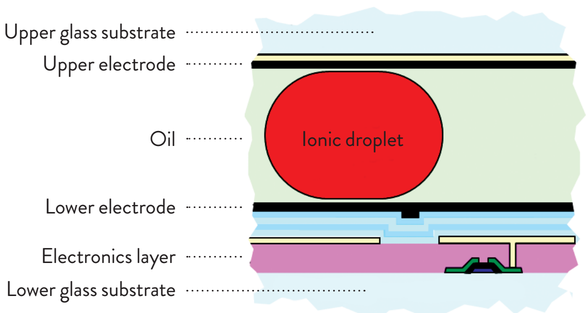


FIGURE 7: Structure of a microfluidic array.

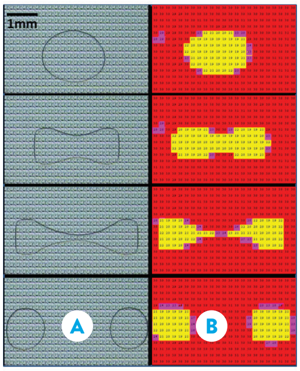


FIGURE 8: Manipulation of droplets on microfluidic array. Left-hand column shows photographs of a droplet being split into two parts; right-hand column shows the corresponding output signals from sensors in the array.

From left: Sarah Mitchell, Senior Researcher, LED; Adrian Jacobs, Research Supervisor, Microfluidics; Pamela Dothie, Senior Researcher, Microfluidics.

moved around the array by applying voltages to the upper and lower electrodes. Sensors in the electronic layers detect the presence of the droplets, providing accurate closed-loop control (see Figure 8).

Brown says SLE has used COMSOL Multiphysics as a research tool to investigate the interactions between the fluid layer and the electronics. "For example, we have modeled fluid flow at the input ports of the array, enabling us to design fluid-input structures to get the droplets onto the array in the right place with minimum fluid-input volumes," he says. "This modeling ability gives us a more accurate starting point for experimental work, hence reducing the number of design iterations required, which in turn helps us to reduce R&D prototyping time and cost compared with simple hand calculations."

The laboratory achieves a similar benefit when modeling the interactions between the droplets or particles in the fluid and the electronic sensors in the array. "In this case, we were interested in investigating impedance changes as droplets or particles in the fluid pass between a pair of electrodes," Brown says. "The simulation output is a range of likely impedance values, and this can be used as the basis of a specification for designing sensor circuits to detect the presence of the droplets or particles."

» ENERGY SYSTEMS

SLE IS ALSO engaged in the development of new energy storage systems and sustainable heating and cooling. An important R&D target is to optimize the performance of heat exchange components so as to achieve high heat-transfer efficiency and minimize system size and weight. This work has involved both the optimization of existing heat exchange components and the design of new ones.

"We have simulated the fluid dynamics of cooling fluids in air-conditioning systems and achieved an efficiency improvement of 30 percent with a new system," Brown says. "We use COMSOL because this is inherently a multiphysics problem, given the need to link the gas and liquid flows in the system to thermal transfer in the solid components."

» FLEXIBLE, COST-EFFECTIVE USE OF SOFTWARE

SLE APPLIES THE same rigorous approach to the purchase, configuration, and use of its tools as it does to its R&D explorations.

Given the diverse range of projects for which COMSOL Multiphysics is used, each research group has its own license and associated specific modules. A member of the research staff in each group is tasked with becoming an expert user and is responsible for the installation and maintenance of that group's license. SLE's use of COMSOL has grown over the last five years, having started out in the LED area and expanded to the other research themes by way of internal recommendations, Brown says. Ten research staff members across the lab are now trained in its use.

"The way our projects and teams are structured means that we need the flexibility for several researchers across the lab to be using the software simultaneously, if need be. As each team has started to use it, we have found the easiest and least costly course to be to simply dedicate a high-end PC workstation in each group to COMSOL," says Brown.

"The multidisciplinary nature of our research activities at SLE will continue in the future, and as such we expect COMSOL Multiphysics to continue to play an important role, both as a research tool and as a product development tool," Brown adds.