UCF Students Earn Outstanding Student Paper Award from SID

By Ruidong Zhu with Jenny Donelan

The growing popularity of augmented-reality (AR) applications, coupled with the challenges posed by creating optimal displays for these devices, prompted a student research team at the University of Central Florida to develop new materials to support AR technology. In order to improve the ambient contrast of AR systems, and also to reduce their size, the students created a “smart” liquid-crystal film and polarizer that can potentially be used in automotive head-up displays (HUDs) as well as AR head-mounted devices (HMDs). At Display Week 2017, authors Ruidong Zhu, Haiwei Chen, Guanjun Tan, and Professor Shin-Tson Wu from the University of Central Florida, as well as collaborators Tamas Kosa and Pedro Coutino of AlphaMicron, Inc., in Kent, OH, received the Best Student Paper Award from SID for their 2016 paper “High-Ambient-Contrast Augmented Reality with a Tunable-Transmittance Liquid-Crystal Film and a Functional Reflective Polarizer.” See Fig. 1.

Seeking Solutions in Ambient Light

Sunlight readability is an obvious problem for mobile displays and head-up display devices. The displayed images can easily be washed out by strong ambient light. Researchers at UCF have been tackling this problem for decades, and the issues have become even more challenging with the emergence of AR and automotive displays. Zhu’s team of graduate students at UCF, under the direction of Wu, decided to tackle this problem with a “smart dimmer” and a functional reflective polarizer. Wrote Zhu: “Our LC film (we call it a smart dimmer) works similarly to transition sunglasses (the kind that automatically darken in response to light). To develop it, we doped some dichroic black dyes to our LC host. Without voltage, the transmittance for unpolarized light is about 76 percent. As the voltage increases, the transmittance decreases gradually. At 8 volts, the transmittance reaches ~26 percent.”

The new film’s transition time is only a few milliseconds – much faster than that of transition glasses. For practical applications, Zhu explained, a sensor can be added to the LC smart dimmer. When the ambient light is strong, the voltage will be turned on so that the film darkens, reducing the transmission of the high ambient light. If the ambient light is weak, then no voltage is applied and the LC smart dimmer will become highly transparent.

The team also developed a functional reflective polarizer, which works to optically combine the ambient light and the display images. Similar to a polarizing beam splitter (PBS), it transmits one polarization and reflects the other. However, compared to a PBS, it is smaller and its design process is truly flexible. These features will help minimize the thickness and weight of the optical systems. Wrote Zhu: “We can design the transmittance and reflection band of the functional reflective polarizer for other alternative applications; one example we showed in our paper is to help people with color-vision deficiency.”

Overcoming Challenges

The most challenging aspect of this project was to achieve a wider tunable transmittance range, which required dye materials with a higher dichroic ratio. With help from their industrial collaborator, AlphaMicron, the UCF researchers say they were able to get “the best dichroic dye material on the market” and incorporate it into their device. “However,” wrote Zhu, “we still need to increase the transparency state to above 80 percent and the dark state to below 10 percent. We need to develop better materials and device approaches, especially lightweight and conformal smart dimmers.”

As for developing the functional reflective polarizer, the biggest challenge was tuning the reflection band to mitigate color-vision deficiency. The UCF group spent a great deal of time evaluating commercially available products and comparing their performances to provide direction and inspiration. They also performed a number of simulations to determine the optimal reflection band. They are still looking for an industrial company to manufacture the functional reflective polarizer.

Zhu said his team realized it was making potentially important discoveries when it measured the transmittance and response time of the smart dimmer and found out it had the leading tunable transmittance range on the market and was 100 times faster than commercial transition glasses.

Real-World Applications

In the real world, the smart dimmer can be used for all scenarios in which high ambient contrast is required; for example, transparent displays, smart watches, pilot goggles, etc. Collaborator AlphaMicron is already commercializing this technology for ski goggles. As for the (functional) reflective polarizer, it can be used for scenarios in which polarization recycling is required, such as display backlighting. At the same time, the reflective polarizer can be used as an optical combiner for optical see-through systems. Moreover, by carefully designing the transmittance curve of the functional reflective polarizer, the sensor can help people with color-vision deficiency.

When these two components are combined, they should be an excellent match for augmented-reality systems, wrote Zhu. He added that the team is also trying to incorporate the technologies in other applications, such as transparent displays.

Another future direction involves dividing the smart dimmer, a single-pixel device, into several segments so that it can be used to selectively dim a bright area locally without affecting the see-through aspect of surrounding or adjacent areas. For example, when a user is driving into the sun, just the bright area of the automotive see-through display could be dimmed while the high transmittance is retained for the rest of the field of view.

Ruidong Zhu received his B.S. in electronics science and technology (optoelectronics) from Harbin Institute of Technology, Harbin, China, in 2012. He is currently working toward a Ph.D. at the College of Optics and Photonics at the University of Central Florida. From 2014 to 2015, he served as the president of the IEEE Photonics Society Orlando student chapter.