Skin like Plasmonic Full Color Displays

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Imagine a flexible, thin, low power, full color display that can wrap around columns, be made into any shape and dynamically show image or video content. We have developed technology enabling this called eskin display, a full color thin film plasmonic display that can replace static paper based and conventional LCD and LED digital signage.

Opportunity

- Reflective display - low power consumption - no backlight
- Surface changes color: eliminates need for RGB subpixels, increasing resolution three fold
- iPhone 6+ retina display has 401 ppi, ours is capable of 1814 ppi
- Capable of displaying video (< 10ms switching time)
- Fabrication compatible with flexible substrates: can be made into wearables, flexible displays

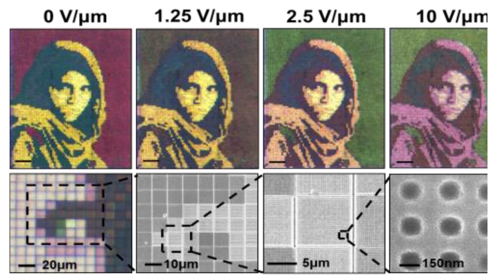

Fig. 1. Preliminary full-color display based on liquid crystal tunable nanostructured plasmonic surface. (D. Chanda et. al., (Featured Article) *Nature Communications, Vol. 6, pp. 7337, June 2015*).

Impact Summary

Imagine improving a display's resolution threefold with the same back panel technology already in mass production. By implementing state of the art liquid crystal and plasmonics research, the color reflected from the nanostructured surface can be tuned across the visible spectrum as a function of voltage. By using nanoimprint lithography (NIL) and flexible polymer substrates, the engineered plasmonic surface allows complete LC reorientation and maximum overlap between plasmonic fields and LC, enabling large tunability across the entire visible spectrum for the first time. This eliminates the need for static color filters and the standard subpixel display architecture. Along with pixels close in size to the optical resolving limit, the display has demonstrated an astonishing 1,814 dots per inch (DPI) as compared the 401 DPI of the iPhone 6s Plus retina display, a 452% improvement.

The preliminary work appeared as a featured article in the June 2015 issue of Nature Communications

Business Potential

The out of home (OOH) advertising industry attempts to reach consumers when they are away from home (70% of the time). It consists mainly of digital, print, airport/shelter signage. Static signage is still widely used in public spaces and accrues $12+ billion annually. Digital signage accounts for $22+ billion, making the OOH market total $34+ billion, growing at single digit to 40%. The downside of the current digital signage is that the displays are rigid, consume lots of power (500 W/ m2), generate lots of heat and is expensive to install and maintain. Hence, a huge opportunity exists for a display that is low powered, high resolution and flexible and can work like the static signage but can show dynamic creatives and video. Our display technology is low power, high resolution, flexible and compares in features and characteristics to magazine print. This allows us to tap into the digital as well as static signage market, making this a huge disruptive opportunity. Such a thin film reusable display technology will have immense impact on society in terms of creatives, energy saving and low material consumption.

Technical Background

Fundamental Principles of Imprinted Plasmonic Surface based Color Generation. When excited with incident light at a resonant frequency, a nanostructured plasmonic surface produce localized and/or propagating surface plasmons, the fields of which penetrate tens of nanometers into the surrounding medium. The tightly focused evanescent fields of the surface plasmon resonance (SPR) are extremely sensitive to the surrounding medium's dielectric constant. By using nematic LCs, the dielectric constant in the region of the plasmonic field can be modulated by the LC's order parameter, which in turn is controlled through an external electric field. This changes the effective index experienced by the metasurface and shifts the spectral location of the plasmonic absorption. If performed in the visible spectrum, this results in a voltage controlled, color tunable reflective surface.

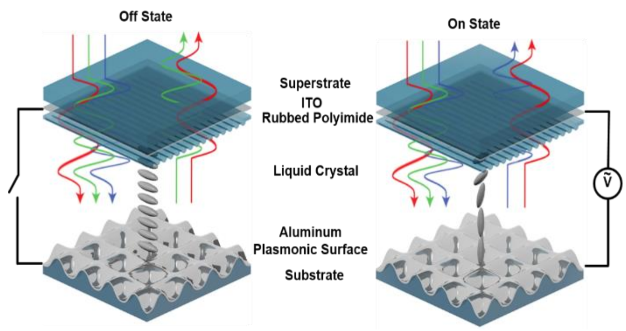

Figure 1 | Liquid Crystal Tunable Plasmonic Surface. a, Schematic of nanostructured plasmonic surface-liquid crystal cell with impinging white light. Light transmits through the superstrate and liquid crystal layers to interact with the reflective plasmonic surface. The metasurface selectively absorbs light while reflecting the rest back out of the device. The wavelength of this absorption depends on the liquid crystal orientation near the interface which in turn depends on the voltage applied across the cell. **b,** Voltage across the cell reorients the liquid crystal and changes the wavelengths of absorbed light.

In the preliminary work done, a LC tunable plasmonic reflective pixel where color of a nanostructured surface is changed continuously as a function of applied voltage. Using nanoimprint lithography (NIL) and flexible polymer substrates, the engineered surface allows complete LC reorientation and maximum overlap between the plasmonic fields and LC, enabling large tunability across the entire visible spectrum for the first time (unpublished). While significant in demonstrating the potential of LC tuned plasmonics displays, this was achieved with an angle dependent unoptimized structure without a dark state. A novel angle independent, flexible, thin film reflective plasmonic surface display using LCs to simultaneously achieve dynamic color tuning and grey states (generalized dark state) is being researched. The implementation of dynamic pixels which can cover color and grey space will reduce the need for multiple subpixels, thereby eliminating layered processing steps, increasing resolution, and decreasing cost. Using NIL to produce the plasmonic structure over large areas, we can bypass expensive and tedious electronbeam (EBL) or deepUV lithography techniques used in fabricating many previously reported plasmonic devices. Fig 1 a,b shows shows an illustration of the preliminary LC-plasmonic coupled system fabricated.