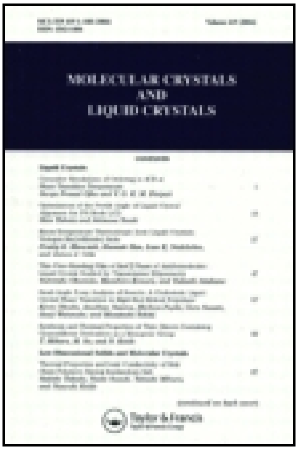

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Non Conventional Approaches to Reflective Color Displays

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Non Conventional Approaches to Reflective Color Displays

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Emissive displays use additive color synthesis provided by two dimensional Red Green Blue pixels arrays; reflective displays would use the subtractive color synthesis from primary Cyan Magenta Yellow colors: several attempts show that photographic like structures using 3 active superposed color layers constitutes a very challenging objective. Beside the transflective mode compromise, most current attempts concern black and white or bicolor reflective displays, as well as reflective micro displays for image projectors.

After reviewing these technologies, we consider some new approaches to reflective color displays, including the direct color synthesis using physical colors generation such as light dichroic reflection, diffraction and scattering.

Keywords: bicolour displays; emissive displays; reflective displays

1. NEED FOR REFLECTIVE COLOR DISPLAYS (RCD)

Definition – or comparison – for RCD would be 'Living Color Photography', including low thickness and in some cases, flexibility. Identified needs concern mainly PC, cellular phones, digital cameras, games image displays…street advertising, paper replacement (e-books, e-newspapers..), future wall TV…Required sizes are comprised from cm^2 to tens of m^2; RCD have to be readable and show a high contrast at full sun. They would include an intrinsic memory in order to limit their power consumption.

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2. CURRENT DISPLAYS COLOR TECHNOLOGIES

Three pixel parameters have to be simultaneously controlled in real time for creating a living colored image:

- *Hue*: pure colors are defined by their frequency (except for purples which are combinations of extreme blue and red) from 380 to 770 nm.
- *Saturation*: shades between a pure color and white.
- *Luminence*: emitted or reflected light intensity.

Emissive displays such as CRT, electroluminescent/plasma/back lighted LCD use the additive color synthesis, i.e., the addition of light rays: RGB emissive pixels form a planar array with spacing lower than the eye resolution and independently controlled intensities on a black background. Contrast vanishes at high ambient illumination, except at larger power consumption.

Reflective colored displays of fixed images such prints and paints use the subtractive color synthesis (subtractive optical absorption from ambient white light): pixels are colored in their volume by mixing CMY pigments volume deposited on a white substrate. Photography uses 3 superimposed CMY controlled absorption layers. The contrast and legibility increase when ambient illumination increases. Living images would need that the pigment volume mixing in each pixel could be controlled in real time, which is not currently obtained.

In waiting a solution, the current compromise adopted by most display suppliers [1] is the so called 'transflective mode' applied to transmitting colored LCD displays: a semitransparent backmirror is used as a reflective mirror for the front ambient illumination and as semi-transparent plate for the backlight. The consequence of this 'reflective mode additive color synthesis' is that intensity of each of the RGB color is divided by 3 (one third of the display surface devoted to each of them), with the results of dull colors and low contrast in the reflective mode and backlight power consumption increase in the transmitting mode.

Nevertheless, very efficient reflective modes for image projection are demonstrated with fast reflective black and white microdisplays such as Liquid Crystals On Silicon (LCOS) [1] and Digital Light Processor (DLP) of Texas Instruments [2] associated with color-intensity temporal multiplexing; color additive synthesis and image fusion are performed by the vision memory.

3. NEW APPROACHES TO REFLECTIVE COLOR DISPLAYS

Most displays companies are working on this RCD strategic and very challenging domain. Many different materials, physical principles and technologies are competing:

- LC, PDLC, functional polymers, liquids, powders...
- Electrooptics, Electrophoresis, Electrostastics, Electrochromism, Electrowetting...
- Generation of physical colors: light diffraction, interferences, scattering...
- Direct color synthesis...

The corresponding displays are currently black and white, or bi-color (some possible extensions to multicolor displays), sometime flexible, with high contrast (>50%), and intended to be use as 'electronic paper.'

3.1. Current R&D

Some examples are given in the following published R&D results:

- SONY dichroic colored PDLC [3] "LIBRIé" e-paper
- E-INK (Philips an Toppan Printing) Electrophoretic [4] e-paper
- GYRICON MEDIA, Xerox electrophoretic [5] e-paper
- PEAS in PODS, Oji Paper Corp electrophoreric [6] e-paper
- PAPYRON (Holland) Electropheric [7] e-paper
- MFPP (Mobile Fine Particles Display) [8] Kogakuin. Univ./Nagaoka Univ./Stanley
- CANON Electrostatic [9] e-paper
- SIPIX (Kyuushu Univ./Bridestone) liquid powder electrostatic [10] e-paper
- NTera Electrochromic [11] e-paper
- PHLIPS Electrowetting [12] e-paper

3.2. Advanced/Future R&D

It is interesting to consider Mother Nature approaches for researching original concepts, principles and materials which could be applied to new RCD.

For instance, Chameleon changes its skin color by selective opening of surface pores which contain different colored pigments [13]: why to not use the very new artificial muscles materials (Electro Active Polymers) [14] for producing colors changes? Their maximum induced strain reaches 100%, comparable to the blue/red frequencies ratio. Recorded diffracting gratings in this deformable medium could generate variable colors; the angle of view could be enhanced through three dimensional diffraction structures: this is already the case for the magnificent blue Morpho butterfly wings [15].

Note that the company IRIGDM (now QUALCOM) [16] has proposed the IMOD concept of interference color generation using electrostatic activated membranes which create variable light resonant gaps with the silicon substrate.

Other physical color generation principles have already been presented:

- KENT DISPLAYS [17] proposed a subtractive color synthesis display using three independent and superimposed transparent cholesteric LC layers, each of them being in charge to control the reflection of one of the three CMY primaries.
- BROWN University [18] has experienced the selective CMY reflectance of double holograms recorded in PDLC with diffraction efficiency controls.
- JET PROPULSION [19] lab. has demonstrated variable physical color generation using evanescent plasmon modes at the electrooptic crystal/glass prism interface.

Special deep blue and red colors in ancient stained glasses are recently understood to be due to gold and copper nanospheres surface plasmons modes [20]: why not use asymmetric nano particles dyes orientation and light polarization plane rotation for direct color generation?

4. CONCLUSION

The research domain of the Reflective Color Display is fully open as demonstrated by some of the multiple approaches presented in this review. It is possible that the next color synthesis mode in reflection could be the direct mode "HIS," in which Hue, Saturation and Intensity would be independently controlled.

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