Electronic Supplementary Information

Video 1:

The video of the response of 100 μm-thick display medium with 3 μm, 2.5 % (w/v) (i.e., 1.68 × 10^9 particles/mL) red PS particles when applying 25 V_{RMS} (i.e., electric field strength of 0.25 MVm^{-1}), 500 kHz on the direct driving electrode pattern "NCTU".

Electrophoresis and dipole-dipole interaction forces:

The electrophoresis force is calculated from the charge of 2.6 × 10^{-18} C per particle[2] when applying 2 MVm^{-1}.

$$F_{electrophoresis} = qE = 2.6\times10^{-18}[\mathrm{C}]\times2\times10^{6}[\mathrm{Vm}^{-1}] = 5.2\times10^{-12}[\mathrm{N}]$$

In comparison, the dipole-dipole interaction for forming particle chains from a 3 μm (r = 1.5 × 10^{-6} m), 5 % (d = 6.7 × 10^{-6} m) particle suspension can be estimated from Eq. (3) by using 78.5 as ε_l and assuming the Clausius-Mossotti factor to be 0.5. The Clausius-Mossotti factor, describing the degree of polarization, is frequency dependent with a value between -0.5 and 1.

$$F_{dipole-dipole} = \frac{24\pi r^6 \varepsilon_l \left(\frac{\tilde{\varepsilon}_p - \tilde{\varepsilon}_l}{\tilde{\varepsilon}_p + 2\tilde{\varepsilon}_l}\right)^2 E^2}{d^4}$$

$$= \frac{24\pi\times(1.5\times10^{-6}[\mathrm{m}])^6\times(78.5\times8.85\times10^{-12}[\mathrm{Fm}^{-1}])\times(0.5)^2\times(2\times10^6[\mathrm{Vm}^{-1}])^2}{(6.7\times10^{-6}[\mathrm{m}])^4}$$

$$= 296.2\times10^{-12}[\mathrm{N}]$$

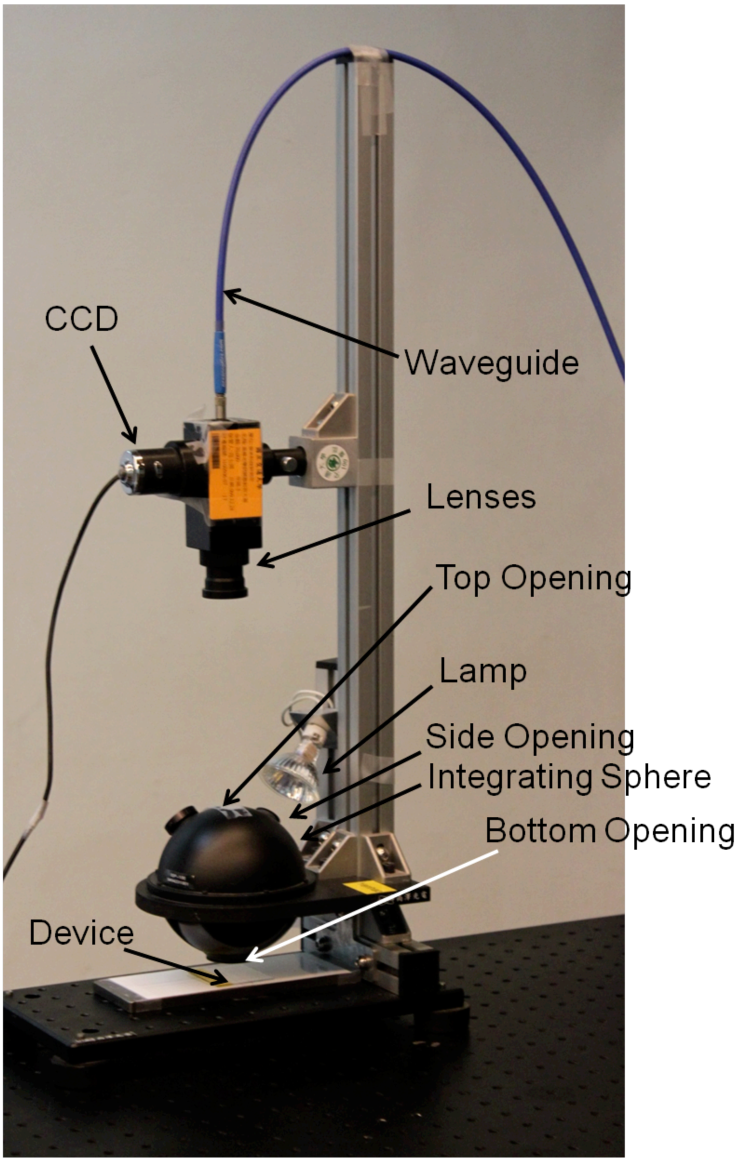

Fig. s1 The apparatus for reflectance measurements. The tested device was placed underneath the bottom openings of the integrating sphere. An incident light from the 50 W halogen lamp transmitted into the integrating sphere through the side opening. The light was first evenly diffused in the integrating sphere and then shone to the device through the bottom opening. The light reflected from the device passed though the integrating sphere and was focused by the lenses positioned above the top opening of the integrating sphere. A portion of the focused reflected light was colleted to an optical waveguide connected to the spectrometer, while the rest was acquired by the CCD that was used to observe and position the device. A proper background with a high or low reflectivity was placed under the device to reflect or absorb, respectively, the incident light passing through the device. The value of measured reflectance of the apparatus was calibrated using standard specimens. In this study, the reflectance was analyzed at the wavelength of 550 nm.

Electronic Supplementary Material (ESI) for Lab on a Chip

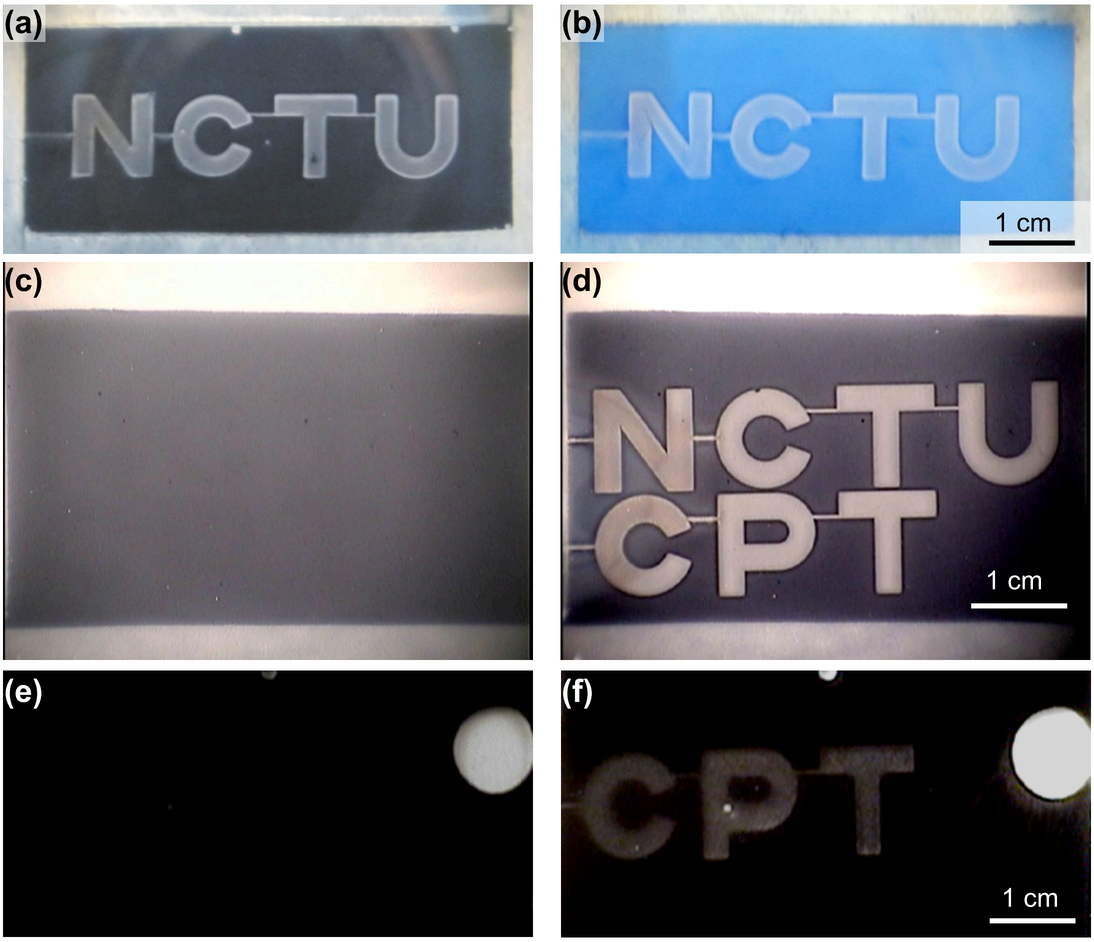

Fig. s2 Demonstrations of different display medium materials. (a) and (b) 100 μm-thick display medium containing 3 μm, 5 % (w/v) black and blue PS particles dispersed in glycerol and driven by a 0.5 MVm^{-1}, 10 kHz electric field. (c) and (d) 100 μm-thick display medium containing 3 μm, 2.5 wt% black PS particles dispersed in 4 % (w/v) PNIPAM (Poly(N-isopropylacrylamide)) aqueous solution and driven under 0.45 MVm^{-1}, 500 kHz. By tuning the temperature, the viscosity of the liquid is altered. Particle chains would be formed at a lower viscosity and then stabilized at a higher viscosity. (e) and (f) Low cost 100 μm-thick display medium containing 10 % (w/v) laser printer toner particles and 20 cSt silicone oil driven by 1 MVm^{-1}, 150 Hz. Because the toner particles were charged in silicone oil, DC electric fields were used to move the toner particles from the bright state to the dark state by electrophoresis.

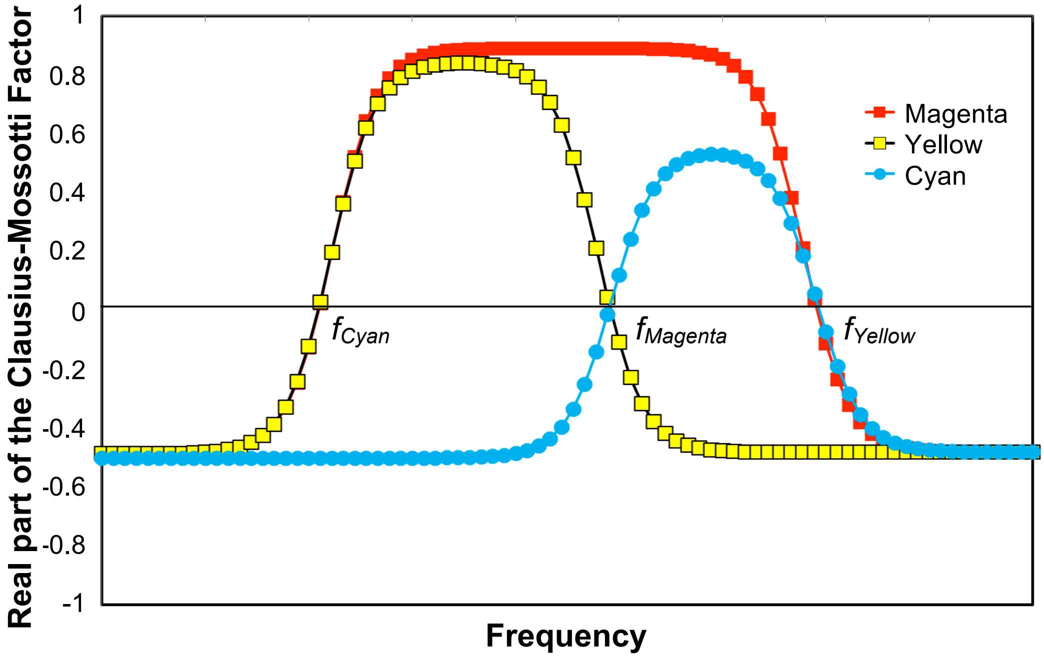

Fig. s3 Proposed color PCDs with a mixture of three groups of particles in the display medium. With properly designed core-shell particle structures, each particle has two non-polarized cross-over frequencies which overlap with one of the cross-over frequencies of the other two particles. For example, one of the cross-over frequencies of magenta and yellow particles overlap at f_{Cyan} that can be used to polarize cyan particles and show red color from the mixture of magenta and yellow. The grey scale can be achieved by tuning the applied electric field strength and frequency. Similarly, magenta and yellow particles are polarized at $f_{Magenta}$ and f_{Yellow} to display blue and green, respectively. Combined frequencies can be applied to drive multiple particles simultaneously.