Electronic Supplementary Material (ESI) for Lab on a Chip

1. Cell Phone as Photodetector

We evaluated suitability of a smartphone camera as photodetector (Casio Commando), and compared its light sensitivity with other more expensive detectors. For this, we took images of 10 greyscale standards (Labsphere) and compared intensities in each image (intensity I = 0 is black while the maximum value I = 255 for the Commando's 8-bit color depth is white). A flatbed desktop scanner (HP Scanjet N6310, 12-bit color depth) and an SLR camera (Canon EOS T3i, 22-bit color depth) were used for sensitivity comparison. Fig. S1 illustrates the mean intensities of the greyscale regions in each image, with all imaging devices showing a linear response. The differences in intensities are due to the reflectance of the paper as the surface absorbs a portion light while reflecting the rest. The light collected by the cell phone and SLR cameras is the reflected component of ambient light, while the scanner uses an internal light source that is substantially brighter, yielding higher intensity values. Overall, these results demonstrate that sensitivity of a smartphone camera is comparable to a SLR camera or a desktop scanner when sufficient ambient light is present. In the following studies we use the Casio smartphone and aim to improve reproduction of sample images and the accuracy for data quantification.

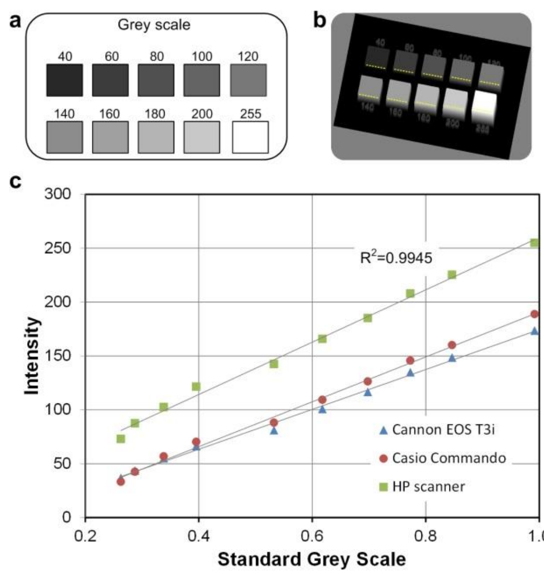

Fig. S1: (a) Greyscale images for camera sensitivity test. (b) Three dimensional surface intensity plot of the greyscale images. (c) The smartphone camera response compated with responses of a high-end Canon EOS T3i SLR camera and an HP desktop color scanner.

2. Color Space Conversion

Conversion of the smartphone camera image data into the CIE 1931 color space involves three steps, in which the color space terms are derived from the conventional RGB values.

First, the nonlinear sRGB values obtained from the smartphone image must be converted to linear RGB values using the following equation:

$$C_{linear} = \left(\frac{C_{srgb} + 0.055}{1.055}\right)^{2.4} \quad \text{(S1)}$$

where C_{srgb} stands for R_{srgb}, G_{srgb}, and B_{srgb}, and C_{linear} indicates R_{linear}, G_{linear}, and B_{linear}.

Then, the linear RGB values can be converted to tristimulus values *X*, *Y*, and *Z* using the following equation:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R_{linear} \\ G_{linear} \\ B_{linear} \end{bmatrix} \quad \text{(S2)}$$

Finally, the chromaticity values *x* and *y* are obtained from the tristimulus values by

$$\begin{cases} x = \frac{X}{X+Y+Z} \\ y = \frac{Y}{X+Y+Z} \end{cases} \quad \text{(S3)}$$

The new color space specified by *x*, *y* and *Y* is represented in a 2-D chromaticity diagram. The pure colors are located on the boundary curve from blue (380nm) to red (700nm), while all the mixed colors, such as yellow and pink, are represented within the area enclosed by the curve. The position of a point on the diagram indicates the chromaticity of the corresponding color.

3. Ambient Light Compensation

Fig. S2 illustrates the red channel intensities of the reference chart regions photographed at 5000K fluorescent light as compared to other light conditions, such as sunshine, shade, smartphone LED, and 3500K fluorescence light. As is illustrated in Fig. S2*a*, the measured intensities at one light condition I_1 can be mapped to another I_2. The high coefficient of determination ($R^2 > 0.99$) indicate excellent linearity of the fits, proving that the reference color chart can be used to compensate the intensity differences caused by ambient light changes.

We calibrated the test strips responses and the corresponding 3-D fitting model using a 5000K fluorescent light source, and ran detection tests under other light conditions. By building the compensating equations in the red, green, and blue pixel channels, RGB intensities of any imaged sample can be mapped to the 5000K exposure, and the corresponding chromaticity values can be calculated.

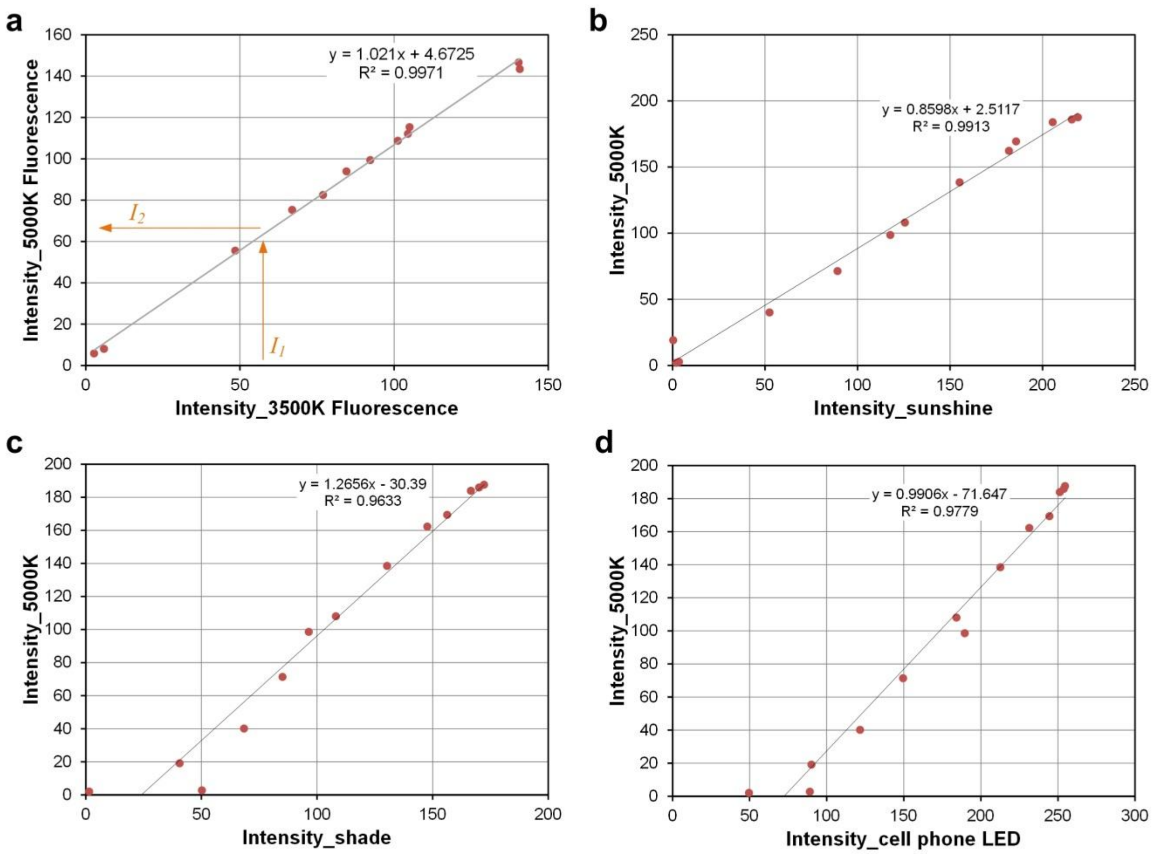

Fig. S2: The linear relationship of the reference chart intensities between the 5000K fluorescent light and (a) 3500K fluorescent light, (b) sunshine, (c) shade, and (d) smartphone LED. The color intensities of the sample can be substituted to the fitted curve to derive the corresponding intensities at which the device was calibrated (5000K).