Investigation of the influence of the ambient temperature on the luminance and the chromaticity coordinates of OLEDs

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CIE International Standard S 025, which currently only includes inorganic LEDs, is to be extended to organic light emitting diodes (OLEDs). For this purpose, standard testing conditions, such as the ambient temperature, are being defined. Similar to inorganic LEDs, the ambient temperature is to be 25 °C; a random tolerance interval of +/- 5 °C is, however, being discussed, which is four times larger than that of inorganic LEDs in comparison. For this reason, it will be necessary to check whether these temperature variations really lead to an acceptable change in the electric and optical behaviour of OLEDs or whether the temperature tolerance interval has to be reduced.

Procedure:
To check the influence of the ambient temperature, the OLED was operated in an air-conditioned testing chamber with a direct current power supply unit in the circuit of which a measuring resistor had been added to measure the current indirectly. At the same time, the voltage was measured in parallel to the OLED (four-point measurement). The temperature was recorded with two thermistors which were placed around the OLED and whose resistance was also recorded. Since the OLED was to be operated horizontally, a mirror had to be placed in the chamber at a 45° angle of the main beam direction of the OLED, so that the camera was able to observe the OLED through an inspection window in the lateral wall of the air-conditioned testing chamber.

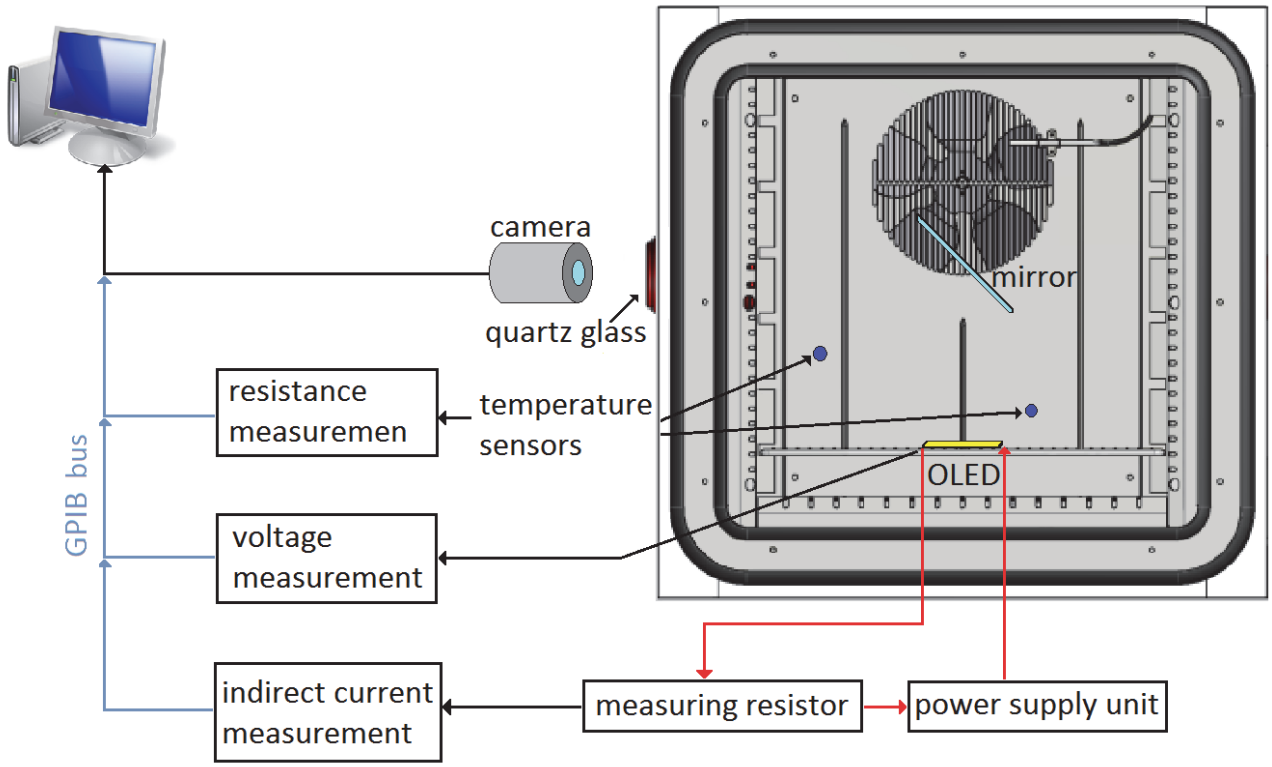

Figure 1: Measurement set-up with air-conditioned testing chamber

The measurements were carried out in compliance with S 025. For example, a measurement was only completed and new parameters set when the voltage across the OLED only varied within a defined range.
The characterization of the OLED began at an ambient temperature of 25 °C.
The temperature inside the air-conditioned testing chamber was then varied from 31 °C to 19 °C, and the electro-optical properties of the OLED under test were measured. A final measurement at 25 °C provided information on possible wear effects.

Analysis:
The camera records a colour picture in the CIE-RGB format. Using a transformation matrix, these chromaticity values can be converted into the chromaticity values X, Y and Z as defined by the CIE. The recorded chromaticity value Y, which is identical to the luminance, is hereby particularly important.
Since the picture recorded by the camera located next to the OLED also detects the black area around the OLED, values below a defined threshold value were eliminated. The remaining chromaticity values were averaged to obtain a chromaticity which is proportional to the mean luminance. Its relative deviation from the first chromaticity value determined at 25 °C is plotted in the diagrams below.
At the same time, the relative deviation of the voltage value from the first recorded voltage value is determined.

From the calculated chromaticity values X, Y and Z, it was, in addition, possible to determine the temperature dependence of the standard chromaticity coordinates x and y that are typical of the CIE standard chromaticity table. The relative change in these quantities is also plotted in a diagram.

Results:
Figure 2 shows the relative change in the luminance of two OLEDs normalized to an ambient temperature of 25 °C as a function of the temperature. When the ambient temperature changed by up to 10 °C, the luminance changed by more than 3 % in certain cases. Depending on the materials properties of the OLED, the relative luminance may increase or decrease when the ambient temperature rises. Moreover, the voltage decreasing across the OLED also changes with the ambient temperature. Hereby, it turned out that the conductivity of the OLEDs under test increases when the temperature rises.

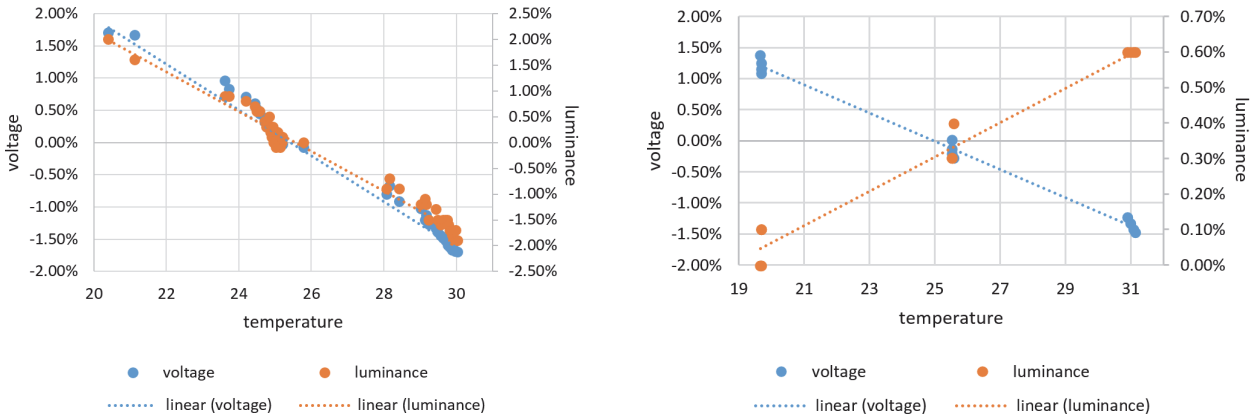

Figure 2: Change in voltage and luminance when varying the ambient temperature

The conclusion to be drawn is that a smaller tolerance interval for the ambient temperature must be selected if the objective is to achieve low measurement uncertainty when characterizing OLEDs.

Considering, in addition, the chromatic behaviour of OLEDs when varying the ambient temperature, one obtains the graphic represented in Figure 3. It shows that the x standardized chromatic coordinate changes by 0.001 in the event of a temperature change of up to 10 °C, the y coordinate even changing by more than 0.002. The statement, according to which a smaller tolerance interval must be selected when a low measurement uncertainty is desired, also applies here. More than 20 OLEDs in total were measured; in principle, all of them exhibited similar dependence on the temperature.

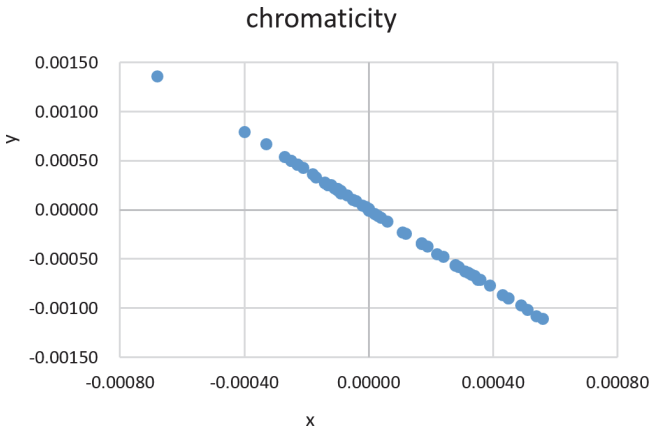

Figure 3: Change in chromatic coordinate

Outlook:

In the evaluations above, the flow velocity of the air stream in the air-conditioned testing chamber was kept constant as changes in the air stream are non-negligible – as shown in the diagrams below.
In Figure 4, the OLED was subjected to a variable air stream. As a result, the luminance varies by 0.5 %, the voltage even by 1 %.
The graphics represented in Figure 5 clearly show that a stronger air stream cools down the OLED so much that the values for the luminance and the voltage correspond to those obtained at a temperature which is 5 °C lower.

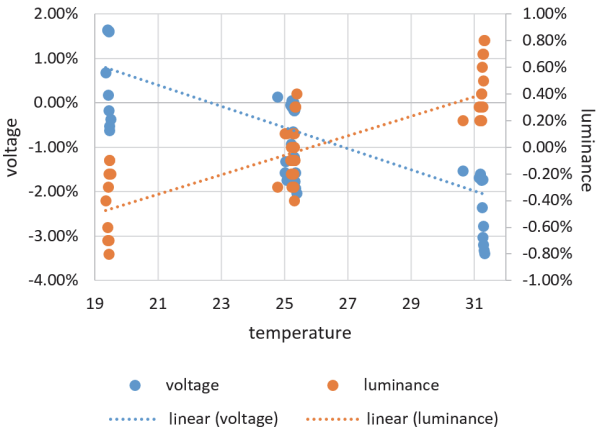

Figure 4: Fluctuation at varying air stream

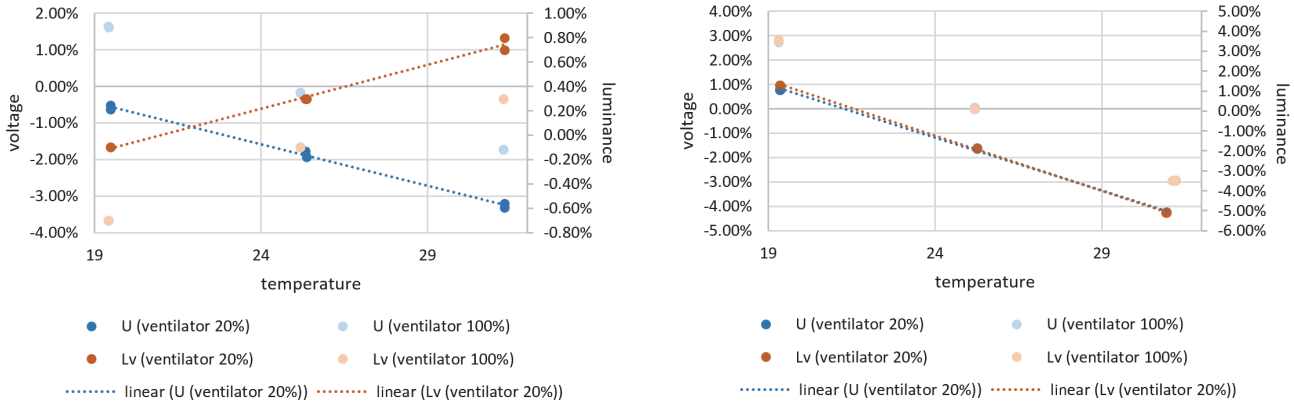

Figure 5: Influence of the air stream on the voltage and the luminance of an OLED

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