The “C” in CIMPS

CIMPS: Controlled Intensity Modulated Photo Spectroscopy

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02/2021

CIMPS

Intensity modulated photocurrent spectroscopy (IMPS) and intensity modulated photovoltage spectroscopy (IMVS) are main characterization techniques in the field of photoelectrochemistry and photovoltaics. In IMPS (IMVS), light illumination is used as an excitation (sine-wave excitation) signal and induced photocurrent (photovoltage) in a solar cell or a photoelectrode is measured as a response signal. In IMPS/IMVS, determining correct intensity of the illuminated light is crucial as it is involved in calculating impedance and other transfer functions of the system under investigation.

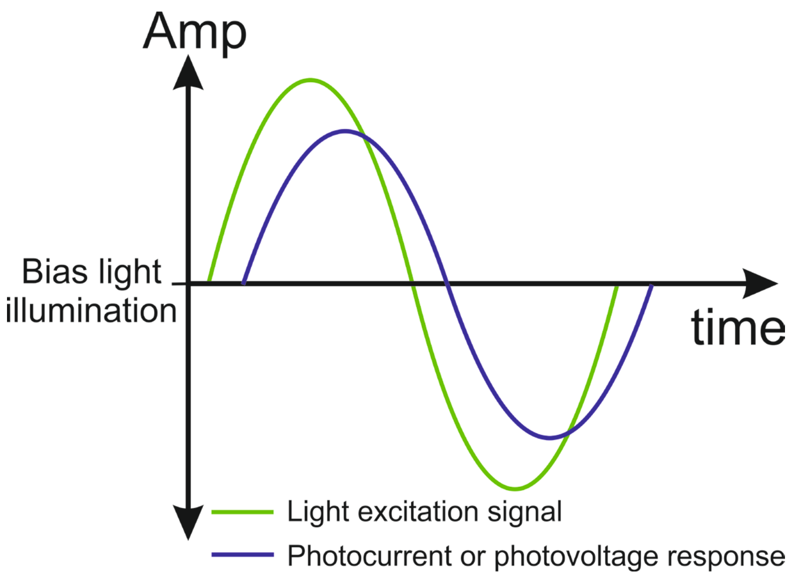

Fig. 1: Light sinewave excitation and photocurrent/photovoltage response signal measurement for IMPS/IMVS measurement. An accurate IMPS/IMVS is only possible with an outstanding control on the light intensity. Here, the bias light illumination must be higher than the amplitude of light excitation signal.

Traditional IMPS/IMVS

In traditional IMPS/IMVS, current input to operate an LED is used as an indicator of light intensity. The illumination intensity before the illuminated photoelectrode/solar cell is not verified. This approach to IMPS/IMVS measurement is faulty as it has many drawbacks and may lead to erroneous results. The drawbacks of using “current input to an LED” as an indicator of light intensity are listed and discussed below.

1. Non-linearity
2. Thermal drift
3. Phase shift
4. Aging effect

Non-linearity: The relation between the current input to an LED and intensity of produced light is not linear. Fig. 2 shows the increase in light intensity of an LED with increase in the input current to the LED. It is clear that the light intensity is not linear with input current and linearity can be assumed only at very small current range with acceptable error margin.

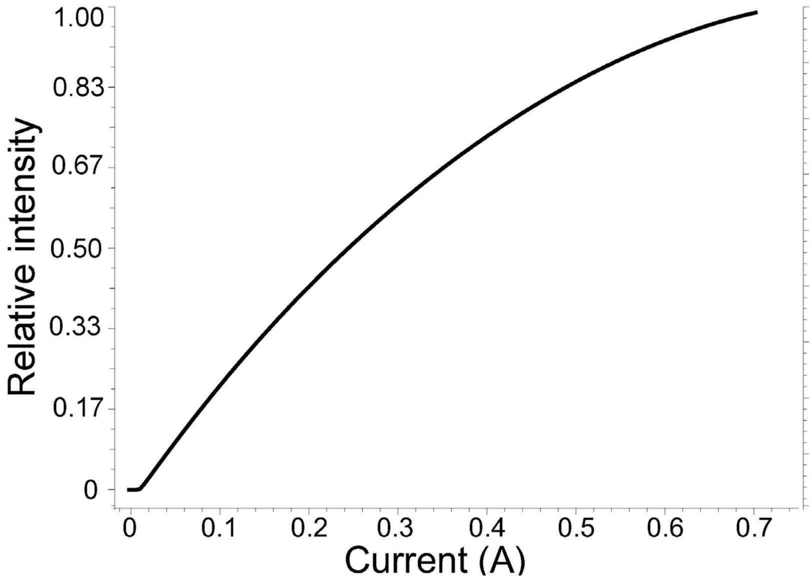

Fig. 2: LED light intensity as a function of input current to LED.

Thermal drift: During operation, the LEDs temperature increases, decreasing the efficiency of the LED and reducing its light output. Fig. 3 illustrates the change in light intensity output of an LED with time. The light intensity decreases with time for a constant input current of 0.7 A. An external heat management cannot effectively eliminate this affect as the thermal drift takes place between light emitting chip and housing (substrate) of the LED.

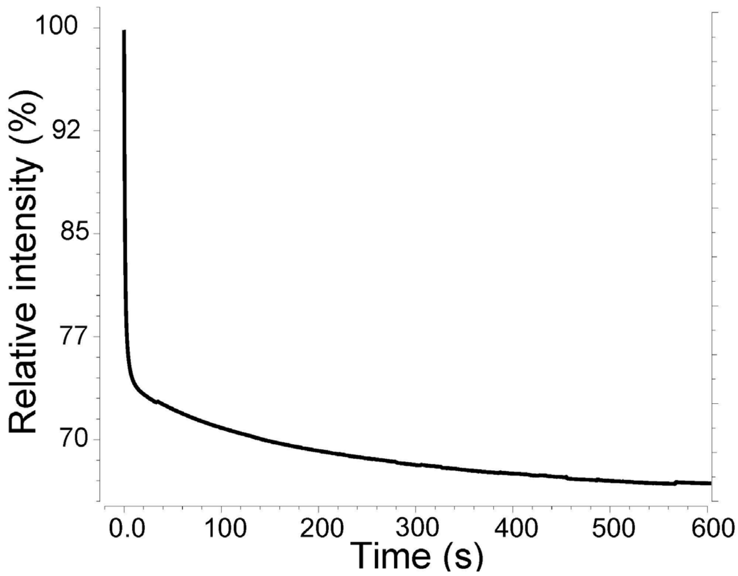

Fig. 3: Change in light intensity output of an LED with time. The drop in light intensity is due to the internal heating of the LED during operation.

The rate, with which the light intensity decreases, varies for different input currents. This further complicates the correlation between the light intensity and input current.

Phase shift: There is delay between the current input to the LED and the light generation by the LED. This delay causes an additional phase shift in the traditional IMVS/IMPS measurements. The phase shift to the light sine wave changes with the bias light intensity. The phase shift increases with an increase in frequency of sine-wave excitation.

Aging effect: The light generation efficiency of an LED decreases with aging. This effect also causes change in light intensity at low frequencies (long measurement time) leading to erroneous results.

CIMPS – a photoelectrochemical system

CIMPS stands for "**Controlled** intensity modulated photo spectroscopy". Zahner's CIMPS system contains an active feedback system which eliminates the previously described drawbacks by directly and continuously controlling the light intensity of the LED. The feedback system is built around a calibrated sensor which is placed before the system under investigation. This sensor ensures that the illumination intensity to the system under investigation is always the same as that of defined value in the Thales software. Fig. 4 compares the schematics of a traditional IMPS/IMVS setup with Zahner's advanced CIMPS systems.

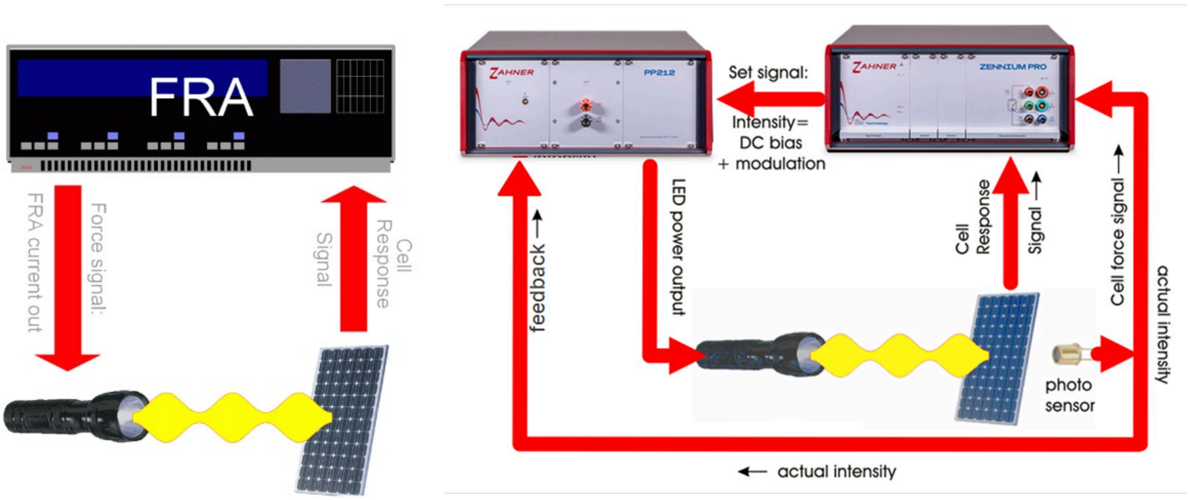

Fig. 4: Schematics of a tradition IMPS/IMVS setup and Zahner's CIMPS/CIMVS setup with feedback loop for controlled light illumination.

With the active feedback system the long warm-up times are not necessary, as the feedback system always ensures that the light intensity stays constant. This is especially beneficial for the LEDs with wavelength in UV light range as the lifetimes of these LEDs are very less so the wastage of illumination time during the warm-up time can be avoided with the CIMPS system.

Exceptional intensity control enables accurate IMPS/IMVS (or CIMPS/CIMVS) measurements. Fast Fourier transformation (FFT) is also used in real time to ensure that the light sine-wave is precise and consist of single frequency without artefacts. This exceptional control on light intensity is also used to carry out detailed IPCE (Incident photon to current efficiency) measurement. For calculating the maximum internal efficiency or IPCE, an IMPS measurement is carried out in a frequency range where the phase shift between the excitation and response signal is zero ensuring absence of non-Faradic processes. This provides the true IPCE values for the system under investigation. Such a measurement is not possible by the traditional IPCE setup (with mechanical/electrical chopper). Further information about IPCE measurement is available in CIMPS-IPCE.