Fiber-tip nanothermometer based on up-conversion nanocrystals for electrolysis cells

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Characterisation of *Proton Exchange Membrane Water Electrolysis* (PEMWE) cells requires the knowledge of the state variables such as concentrations, temperatures, and pressure inside the cell. For example, information about the temperature at the catalyst layer will help to better parametrize reaction kinetics and understand degradation mechanisms. However, PEMWE cells are operated under strong compression forces to obtain the required contact pressure. The resulting closed setups make it difficult to determine the state variables inside the cell and often only averaged values obtained from the cells inlet and outlet are available, although strong gradients inside the cell can be expected. To overcome this issue by providing a suitable sensor, we developed a novel, miniature fibre-tip sensor for proof-of-concept nanothermometry inside PEMWE cells as outlined in the following.

The Boltzmann population of the Stark energy levels of rare earth ions in crystalline hosts provides a temperature dependent emission. This feature allows to measure temperature optically [1]. In particular, Er^{3+}:Yb^{3+} co-doped $NaYF_4$ UC-NCs can conveniently be excited around 980 nm with standard laser diodes and emit via up-conversion in the green wavelength regime. This green emission features multiple narrow lines whose relative intensities allow (after a proper calibration) to compute the NC temperature [2]. We used an optical approach [3] in combination with simple dip-coating to attach UC-NCs to the 230 µm fiber facet of the output of a 2-to-1 multimode fiber splitter, see Fig. 1 (a). The splitter separates the incoming excitation radiation provided by a standard 976 nm laser diode and the backward propagating green emission from the UC-NCs, which is read-out by a USB-spectrometer. The UC-NCs have a core/shell structure with an average core size of 14 nm and a shell thickness of around 1.5 nm, see Fig. 1 (b) for a TEM image. The relative Er^{3+}:Yb^{3+} doping concentration is around 1:10. The sensor has been calibrated by controlled heating of the fiber tip from 50 °C to 90 °C for various integration times of the data acquisition via the USB-spectrometer. At a constant sensitivity of 0.81 %/K, an integration time of 10 s or 150 s yielded a temperature resolution of 1.0 mK or 0.2 mK, respectively, see Fig. 1 (c). In preliminary experiments, we used the fiber-tip sensor for in-situ temperature measurements in PEMWE cells, see Fig. 1 (d). In our contribution, we will present the development and calibration of the sensor as well as its application in the PEMWE cell.

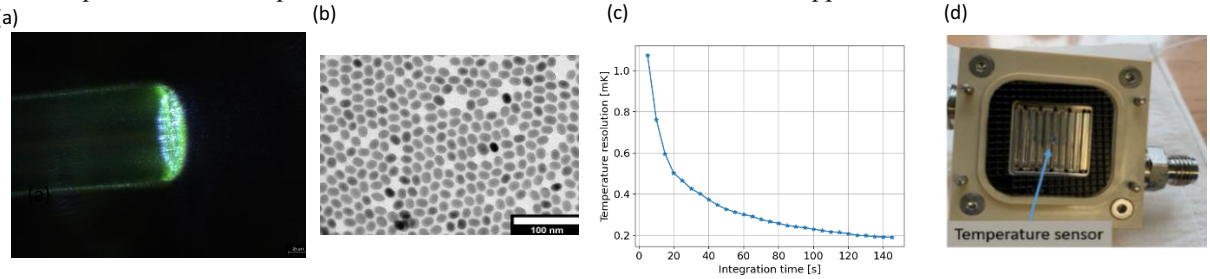

Fig. 1 (a): Microscopy image of the fiber-tip (diameter: 230 µm) with attached UC-NCs and their characteristic green emission. (b): TEM image of the used UC-NCs with an average core size of 14nm. (c): Absolute temperature resolution of the sensor in dependency of the integration time. (d): PEMWE with drilled entrance hole for the fiber-tip sensor.

Literature

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