

# Laboratory of Applied Electrochemistry



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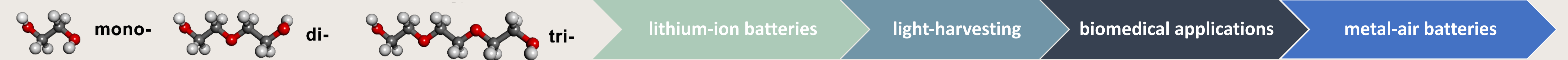
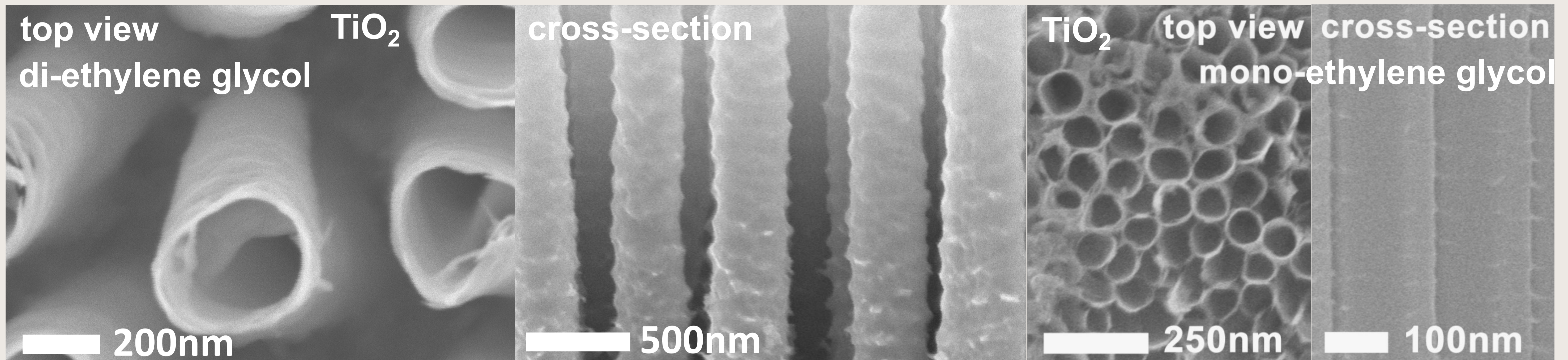
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## Introduction

Anodization is a powerful tool to control the structure of electrochemically active materials, among which self-organized TiO<sub>2</sub> nanotubes are of high interest in various fields such as lithium-ion batteries, biomedical applications, light-harvesting and electrochromic devices.<sup>1-3</sup> Our group is strictly specialized in the synthesis of nanotubes on metals such as Ti, Fe, Nb, Ta and Zr leading to the formation of nanotubular TiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, Nb<sub>2</sub>O<sub>5</sub>, Ta<sub>2</sub>O<sub>5</sub> and ZrO<sub>2</sub>. Beyond nanostructures formation, we seek to impart a variety of functions in functional materials including charge storage,<sup>3-5</sup> proton conduction,<sup>1</sup> damage detection and light harvesting. For instance, a unique one-dimensional (1D) geometry offers high-volume expansion tolerance and applications without binders and conductive additives which is strictly related to battery applications. We try to understand how the nanotubular structures composed of one or many components may store Li<sup>+</sup>/Na<sup>+</sup>, by using *in-situ* techniques such as *in-situ* Raman spectroscopy.<sup>4</sup> We look at the structural fingerprints that may shed a light on fundamental aspects of energy storage. Our research is highly interdisciplinary represented by a variety of scientific disciplines including, chemistry, engineering and physics.

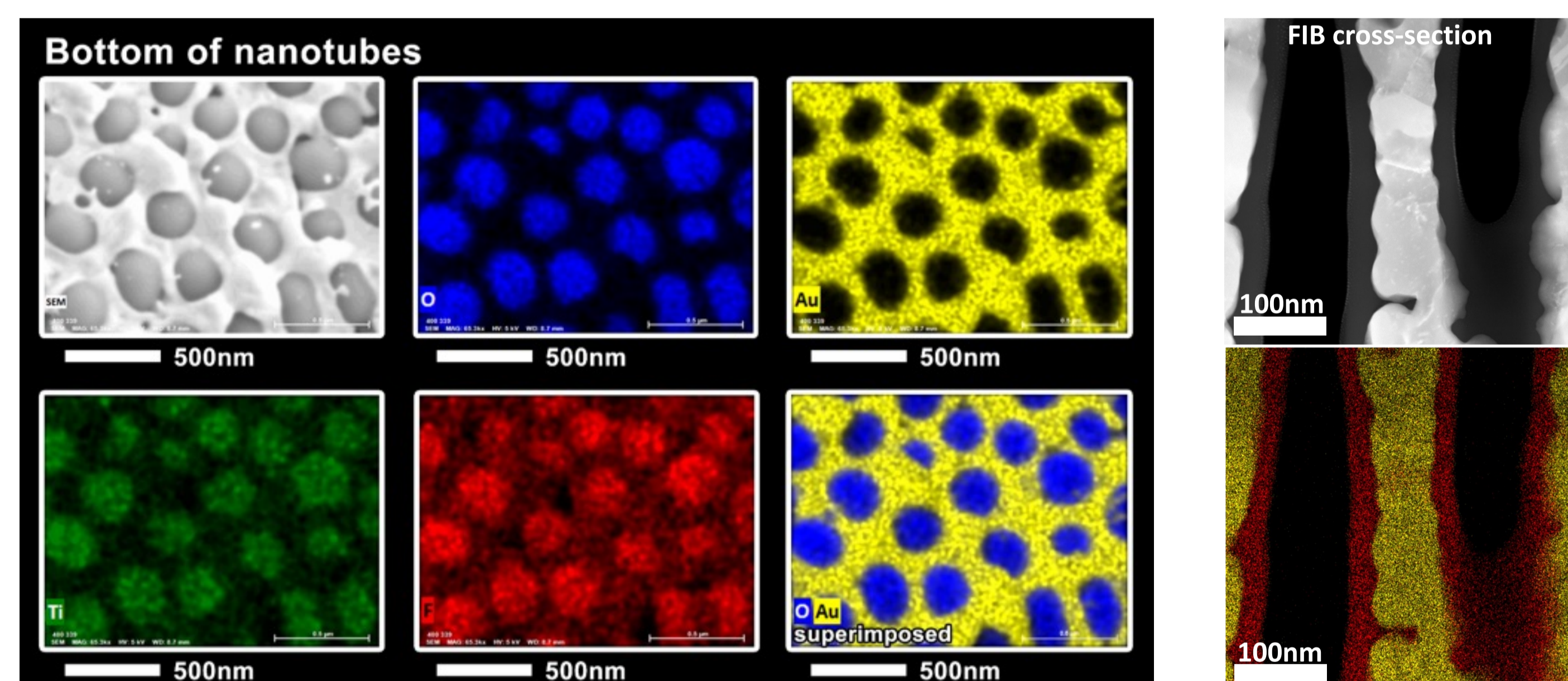
## Synthesis of anodic nanostructures - anodization



## Applications:

### PLASMONIC MATERIALS

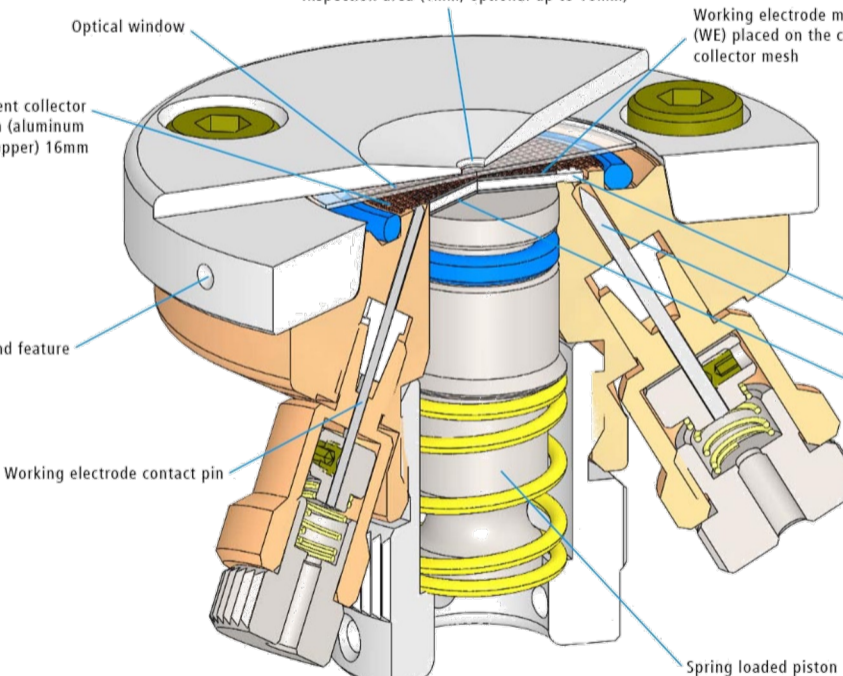
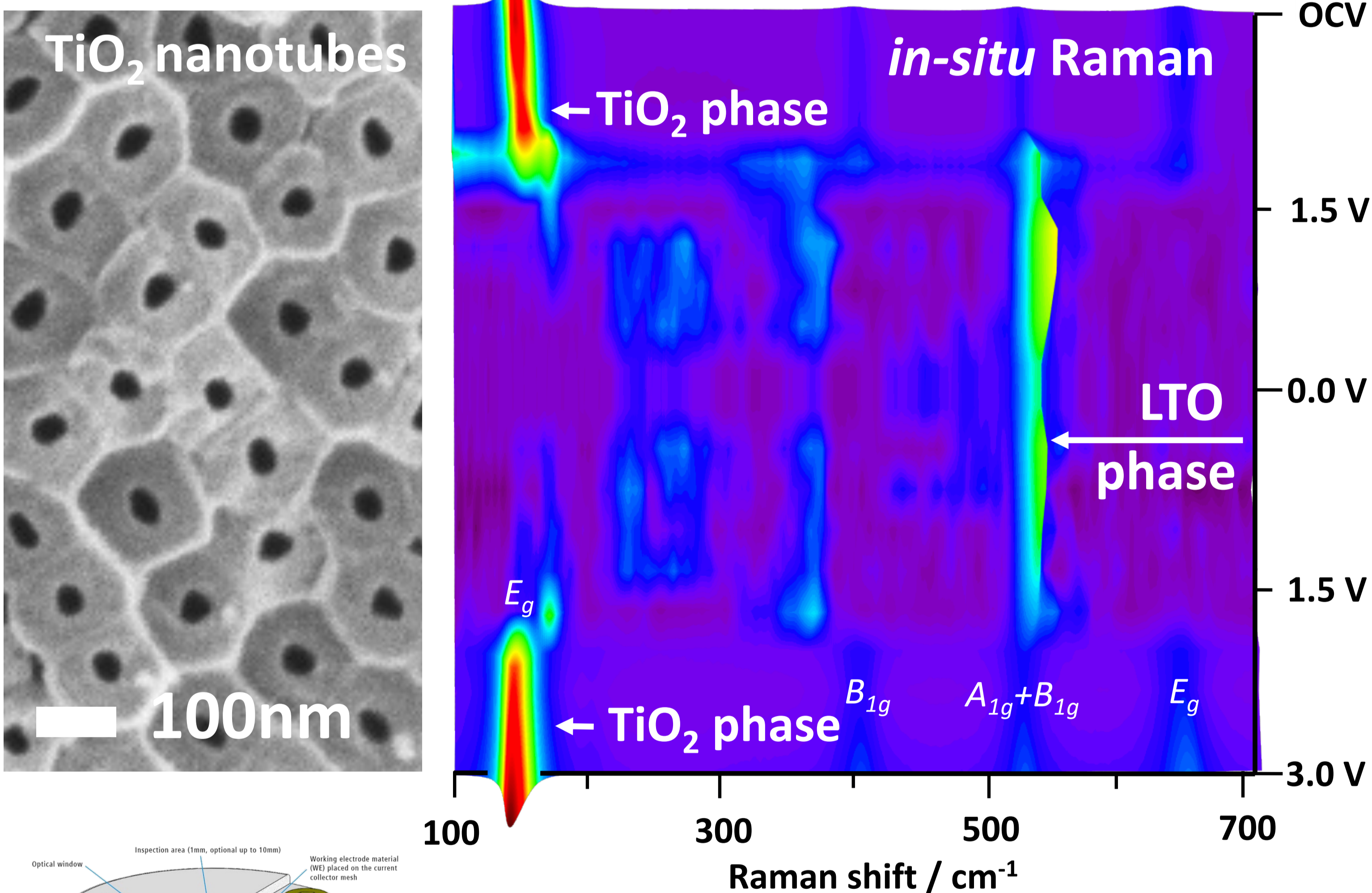
TiO<sub>2</sub> nanotubes modified with Au through electrodeposition process.



Gold nanostructures were grown in anodic TiO<sub>2</sub> nanotubes by means of the electroreduction of Au<sup>3+</sup> species from a potassium dicyanoaurate electrolyte. The primary location of the electroreduced gold is in the gap between nanotubes, resulting in the formation of a gold/titania interface at the outer shell of the nanotubes. Surface plasmon resonance evaluated by finite-difference time-domain modelling (FDTD).

### LITHIUM-ION BATTERIES

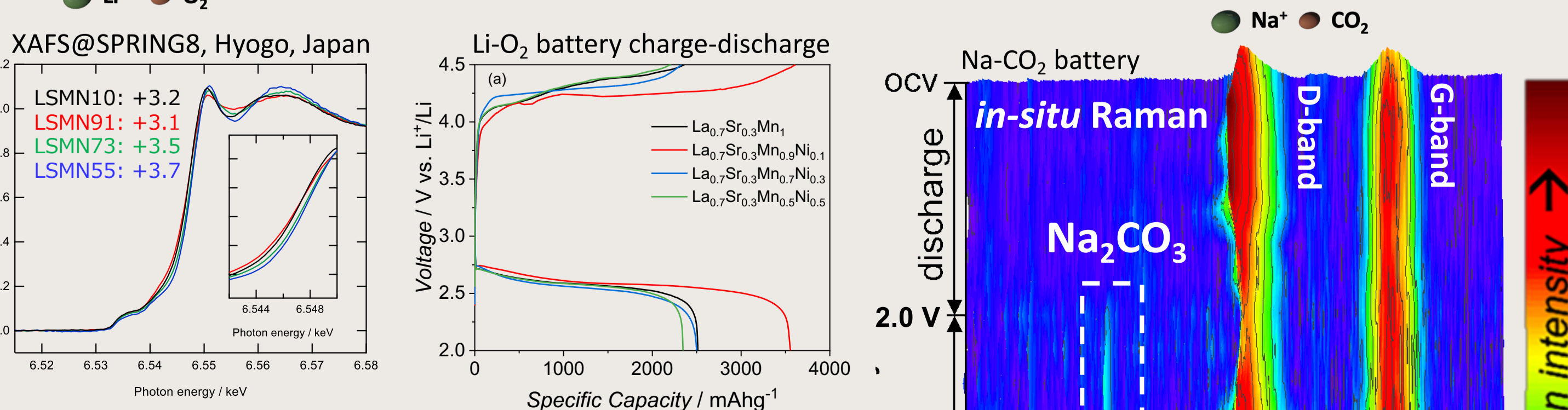
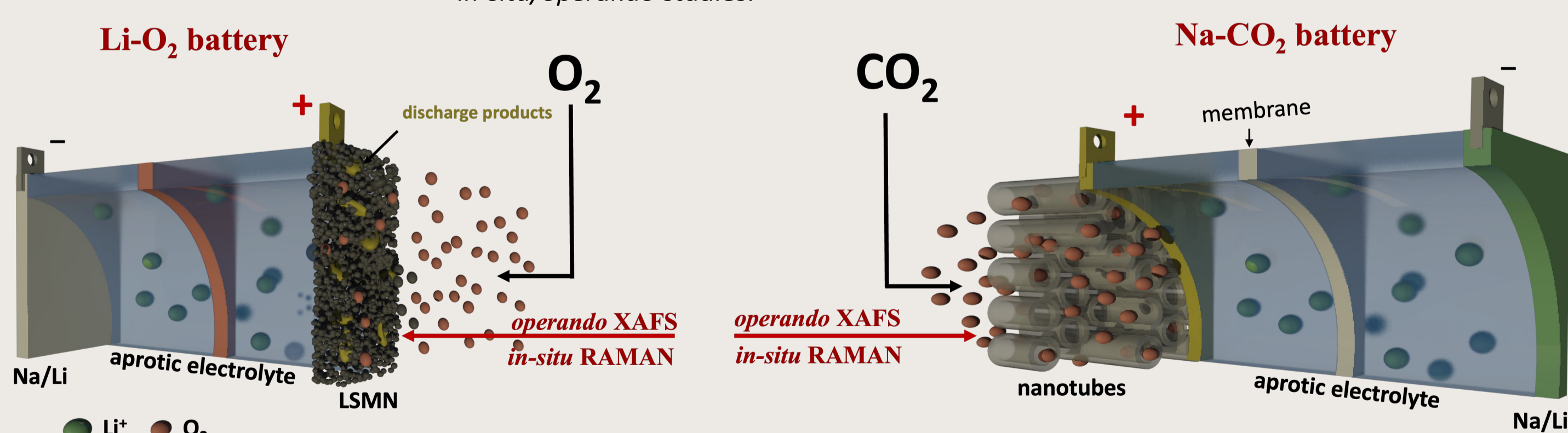
Intercalation-type TiO<sub>2</sub> nanotubes, *in-situ* Raman studies.



*In-situ* Raman spectroscopy was used for a better fundamental understanding of Li<sup>+</sup>/Na<sup>+</sup> storage in anodic TiO<sub>2</sub> nanotubes.<sup>4</sup> The structural fingerprints were correlated with the electrochemical data on differential capacity plots of  $d(Q-Q_0)/dE^{-1}$ . Real-time measurements revealed that the nanotubes had undergone two major phase transformations with increasing lithium content, disclosing the sequential steps of a lithium intercalation type of storage.

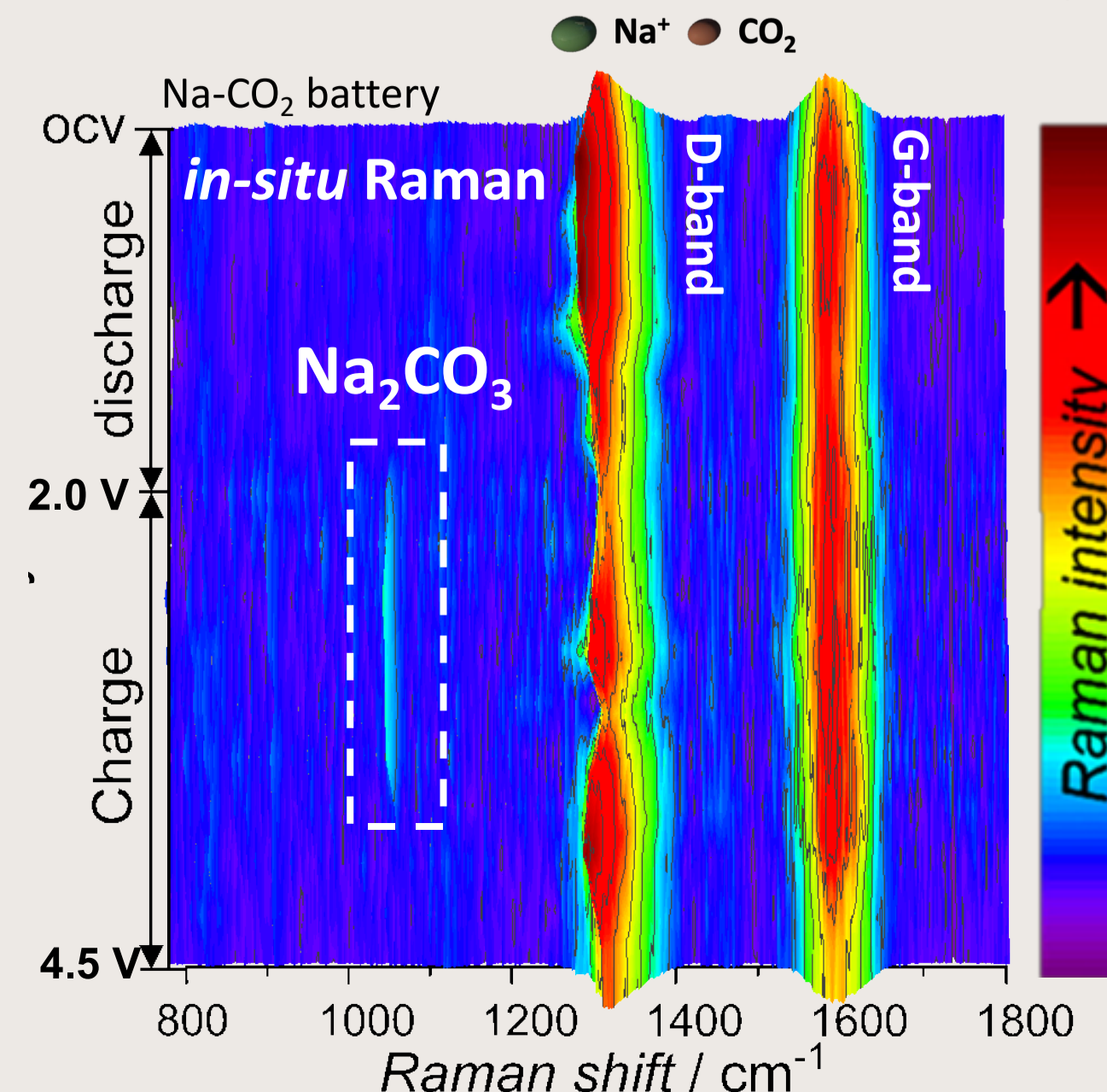
## metal-air, Li-O<sub>2</sub> and Na-CO<sub>2</sub> type batteries, *in-situ/operando* studies.

### NEXT GENERATION OF BATTERIES



Normalized Mn K-edge X-ray Absorption Near Edge Structure spectra obtained at SPRING8 synchrotron radiation facility, Hyogo, Japan. Charge-discharge profile for Li-O<sub>2</sub> battery.

Li-O<sub>2</sub> and Na-CO<sub>2</sub> batteries are the next-generation energy storage devices considered as a possible replacement for classic lithium-ion systems available on the market today.<sup>3</sup>



## Research areas

Fundamental understanding of the growth of anodic nanotubes on Ti, Fe, Nb, Ta, Zr. Modifications of NT. *In-situ/operando* studies of electrochemical reactions in batteries: metal-air, Li-O<sub>2</sub>, Li-CO<sub>2</sub>, Na-O<sub>2</sub>, Na-CO<sub>2</sub>

**CO<sub>2</sub> CAPTURE**  
CONVERSION OF ATMOSPHERIC CO<sub>2</sub> INTO ENERGY STORAGE IN Na-CO<sub>2</sub> BATTERY

POLAND: Damian Kowalski (Project Lead)

JAPAN: Yoshihiko Aoki

TURKEY: Fatma Denizli

**EIG CONCERT JAPAN**

**PROJECT PARTNERS:**

- University of Warsaw, Poland (Project Lead)
- Hokkaido University, Japan
- Acibadem University, Turkey

## Funds

- OPUS 28** National Science Centre research grant no. 2024/55/B/ST4/02569, "Integrated CO<sub>2</sub> conversion and energy storage in aprotic Li battery" (ongoing).
- OPUS 20** National Science Centre research grant no. 2020/39/B/ST4/02548, "Alkaline air battery" (ongoing).
- OPUS 11** National Science Centre research grant no. 2016/21/B/ST5/03387, "Noble-metal and semiconductor core-shell structures for plasmonics, catalysis and photovoltaics" (completed).
- OPUS 6** National Science Centre research grant no. 2013/11/B/ST4/02151, "1-D polymer solar cell with nanotubular architecture - a fundamental understanding of exciton diffusion pathways" (completed).
- EU PROJECT EIG CONCERT JAPAN** Coordinator for international project Poland-Japan-Turkey grant no. 20/70/CO<sub>2</sub>capture/2024 "Conversion of atmospheric CO<sub>2</sub> into energy storage in Na-CO<sub>2</sub> battery" (ongoing).
- Joint Research Project between Poland and China NAWA-MOST** "Research and development of key technologies for constructing Zn-CO<sub>2</sub> batteries" (ongoing).

**References:** [1] D. Kowalski et al. *Angewandte Chemie* 2009, 48, 7582-7585, [2] D. Kowalski et al. *Chemical Communications* 2010, 46, 8585-8587, [3] S. Sajeev et al. *RSC Applied Interfaces* 2025, 5, 7696-7703, [4] M. Vincent et al. *ACS Applied Nano Materials* 2023, 6, 6528-6537, [5] L. Fadillah et al. *ACS Appl. Mat. Inter.* 2023, 15, 52563.