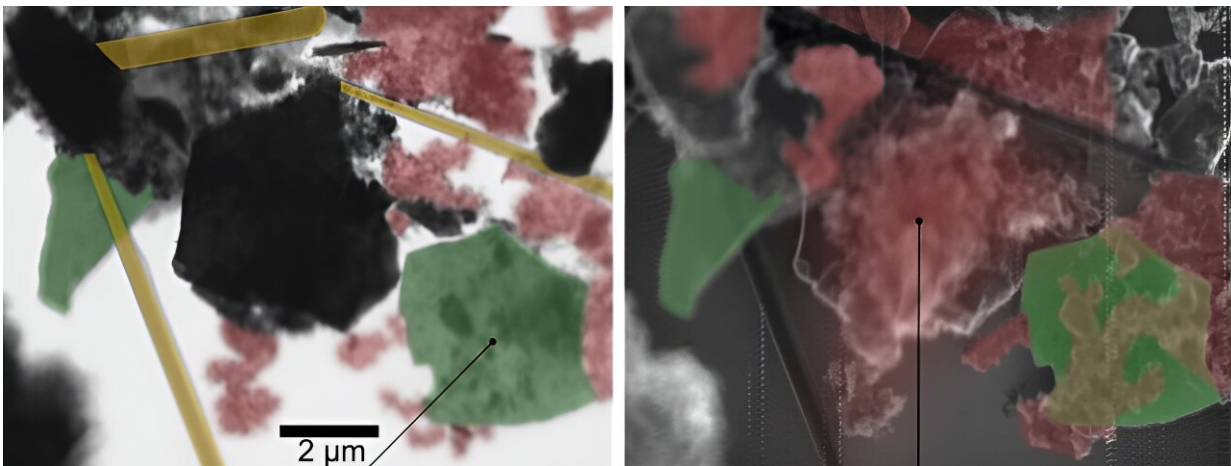


# MXenes for energy storage: Chemical imaging more than just surface deep

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Scanning X-ray images of a dismantled Li-ion battery with cycled MXene electrode (green), electrolyte/ carbonate species (red) and separator (yellow). The Transmission (bulk-sensitive) image is on the left, the electron yield (surface-sensitive) image on the right. Credit: HZB

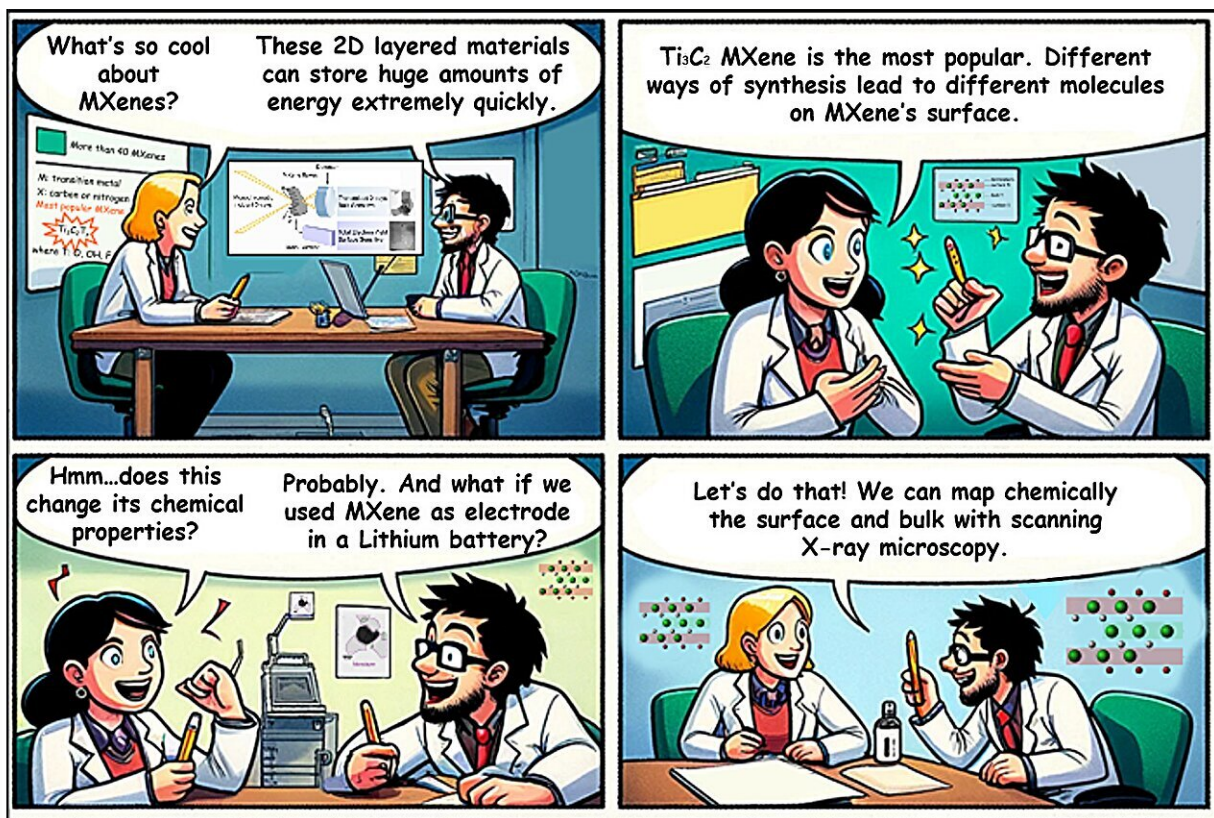
A new method in spectromicroscopy significantly improves the study of chemical reactions at the nanoscale, both on surfaces and inside layered materials. Scanning X-ray microscopy (SXM) at MAXYMUS beamline of BESSY II enables the investigation of chemical species adsorbed on the top layer (surface) or intercalated within the MXene electrode (bulk) with high chemical sensitivity.

The method was developed by a HZB team led by Dr. Tristan Petit. The scientists demonstrated, among others, first SXM on MXene flakes, a material used as electrodes in lithium-ion batteries. The paper is [published](#) in the journal *Small Methods*.

Since their discovery in 2011, MXenes have gathered significant scientific interest due to their versatile tunable properties and diverse applications, from energy storage to electromagnetic shielding. Researchers have been working to decipher the complex chemistry of MXenes at the nanoscale.

The team of Dr. Tristan Petit has now made significant progress in MXene characterization, as described in their recent publication. They utilized SXM to investigate the chemical bonding of  $Ti_3C_2T_x$  MXenes, with  $T_x$  denoting the terminations ( $T_x=O, OH, F, Cl$ ), with high spatial and spectral resolution. The novelty of this work is to simultaneously combine two detection modes, transmission and electron yield, enabling different probing depths.

SXM provided detailed insights into the chemical composition and structure of MXenes. According to Faidra Amargianou, first author of the study, "Our findings shed light on the [chemical bonding](#) within MXene structure, and with surrounding species, offering new perspective for their utilization across various applications, especially in electrochemical energy storage."



A drawing can present complex issues in an original way. But what if you don't have the time or experience to draw such illustrations yourself? Faidra Amargianou simply asks ChatGPT to create cartoons that convey the main messages of her work. Read the interview here: <https://science.hzbblog.de/cartoons-at-your-fingertips/> Credit: Faidra Amargianou/HZB/ChatGPT

For the first time, SXM was employed to image MXenes, revealing details of the local bonding between titanium and terminations within the MXene structure. The researchers also examined the influence of different synthesis routes on MXene chemistry, shedding light on the impact of terminations on the electronic properties of MXene.

Furthermore, the application of SXM in analyzing MXene-based

materials in [lithium-ion batteries](#) yielded valuable insights into changes in MXene chemistry after battery cycling. Amargianou explains, "The bulk of MXene electrode remains stable during electrochemical cycling with signs of possible  $\text{Li}^+$  intercalation. Electrolyte does not lead to degradation of the MXene and lays on top of the MXene electrode."

In summary, this study provides valuable insights into the local chemistry of MXenes and underscores the potential of SXM in the characterization of other layered materials. Petit concludes, "This work highlights the significance of advanced chemical imaging techniques like SXM in unraveling the interactions of layered materials in complex systems. We are currently working on enabling in situ electrochemical SXM measurements directly in liquid environment. "

**More information:** Faidra Amargianou et al, Nanoscale Surface and Bulk Electronic Properties of  $\text{Ti}_3\text{C}_2\text{T}_x$  MXene Unraveled by Multimodal X-Ray Spectromicroscopy, *Small Methods* (2024). [DOI: 10.1002/smtd.202400190](#)

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