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Four Dimensional Isotope Tracking with the N4DP Instrument at MLZ

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Neutron Depth Profiling (NDP) is a non-destructive, element-specific, high-resolution nuclear analytical technique commonly used to study concentration profiles of lithium, boron, nitrogen, helium, and several other light elements in various host materials. The N4DP instrument is located at the Prompt Gamma Activation Analysis (PGAA) beamline of the Heinz Maier-Leibnitz Zentrum (MLZ), which provides a cold neutron flux of up to $5 \times 10^{10}\,\mathrm{s}^{-1}\mathrm{cm}^{-2}$. The NDP technique uses the capture reaction of a specific nuclide with a subsequent decay into ions of well-defined energies. From the energy loss of these ions, concentration depth profiles can be determined with a precision of tens of nanometers.

Operating systems with light elements, such as lithium, require intensive monitoring studies to explain morphological interface effects. For example, in the operation of thin-film batteries, it is of great interest to follow the movement of the Li cloud during (dis-)charging with high precision. In addition, inhomogeneities in such electrochemical processes also require good spatial resolution to obtain concentration information at different locations within the battery. However, there is a lack of detectors with high detection efficiency and temporal resolution. We have developed a detector system based on double-sided silicon strip detectors (DSSSD) with extremely thin and homogeneous entrance windows to provide laterally resolved NDP measurement types for the N4DP instrument. A highly segmented DSSSD with 32$\times$266 stripes, including integrated, self-triggering electronics for vacuum operation, has been successfully tested and evaluated at the Research Reactor in Delft (RID), Netherlands. Using a dual-detector setup in a camera-obscura geometry, we achieved the image and reconstruction of Li-containing targets over a wide range of parameters. These range from a spatial resolution down to $\sim$100\,μm$\times$200\,μm, and a lower integration time limit in the order of seconds to collect sufficient statistics to monitor local variations of the Li concentration. This project is supported by the BMBF, contract No. 05K16WO1, 05K19WO8.

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