In-situ neutron PDF measurements of material in transformation: MXene and ferrite case studies

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In-situ scattering experiments are a powerful tool, yielding detailed atomic structural information correlated to external stimuli. While 3rd generation synchrotron X-ray sources have enabled many novel *in-situ* capabilities, the relatively low fluence of neutron sources and the differing materials interaction mechanisms present unique hurtles to analogous neutron scattering experiments. The NOMAD team at the Spallation Neutron Source has recently developed a gas flow cell operable up to 600 ºC and are currently developing a TiZr hydrothermal pressure cell for the observation of nucleation, growth, and phase evolution under various hydrothermal conditions. These capabilities will be showcased by *in-situ* neutron diffraction and atomic pair distribution function (PDF) measurements of hydrothermal ripening of the ferrite $Bi_2Fe_4O_9$ which exhibits size-dependent ferromagnetism at the nanoscale, and of *in-situ* nitridation in a two-dimensional MXene Mo_2C. The hydrothermal experiment will push the detection limit achievable on NOMAD, with an estimated 0.1-1% of the incident neutron flux resulting in coherent scattering from the nucleating phase. Particle size evolution will be tracked by neutron diffraction, while evidence of a ferromagnetic state will be inferred from the atomic PDF. Meanwhile, the gas flow-cell experiment will provide the first *in-situ* observation of MXene nitridation, which is one of the only synthesis routes towards two-dimensional nitride nanosheets. This work advances both *in-situ* NPDF methodology and the materials knowledge of these multifunctional materials under transformation.