Contribution ID: **38** Type: **Poster**

X-Ray Diffraction as a Tool for Structure Analysis of Functional Materials including Fusion Materials

Tuesday 29 July 2025 19:00 (1h 30m)

X-ray diffraction (XRD) analysis is an important method for characterizing materials in fusion reactors, particularly for understanding their microstructure and properties under the extreme conditions of fusion. This method can be applied to assess the effects of radiation damage, high temperatures, and other factors on materials such as steel and composites. These materials are used in the first reactor wall, the reactor roof, and other components. It is important for XRD experiments that the samples do not have high radioactivation to enable sample handling. Literature on tungsten showed the significance of understanding the radiation damage of fusion materials causing defects, cracking and microstructural changes inside the materials inside the fusion reactor.[1,2]

In the Advanced Materials group XRD measurements are used to investigate formed phases during synthesis via conventional melting, chemical reaction or additive manufacturing. The phase and element composition are important to know e.g., during the steel production, different elements like Mn, Cr and Ni are mixed in the steel to enhance mechanical properties and corrosion resistances, due to the formation of different intermetallic phases and alloys. In addition, investigations on the crystal size plays a crucial role in precipitation hardening materials, too large particles can agglomerate or cause fracture points along their crystal borders. Further information can be obtained from XRD measurement at elevated temperatures with our high temperature sample stage, it is possible to take XRD patterns below, at and above phase transitions or reactions. XRD can reveal changes in grain size, dislocation density, and other microstructural features caused by irradiation and other factors. Residual stress studies are of great importance to investigate materials that tend to cracking. Besides measuring at elevated temperatures, also measurements can be acquired during loading and unloading of alloys with hydrogen an interesting field in fusion research, which can lead to changes in the phase composition or if the hydrogen gets intercalated to changes in the lattice parameters, the diffusion process of the loading and unloading can be tracked with our hydrogen detection device. Lastly, XRD measurements are used for pre-characterization and optimization of large samples (~cm3) for neutron scattering experiments.

[1] Wielunska B. D., Dissertation, Characterization of Radiation Damage in Tungsten, Technical University Munich, Munich, 2020.

[2] Papadakis D., Manios E., Mergia K. Metals 2025, 15, 2, 172.

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Session Classification: Poster Session and Beer