Project Title: X-ray Interaction with Liquids: Dosage Calculation, Beam Damage, and Practical Implications

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Project description:

This student project will advance the understanding of X-ray interactions with liquids, bridging theoretical, computational, and practical domains. Today, X-ray imaging is intensively used in the Packaging Industry during development of novel more sustainable packaging materials and adhesives. During these experimental measurements the X-ray sbeam interact with the liquid media. Understanding how X-rays interact with different types of liquids i.e. water, wet adhesives, printing inks, Hydrogen Peroxide or other chemical solutions, is critical for accurate dosage calculation, exposure time estimation, number of X-ray "projections", minimizing beam-induced damage, and optimizing experimental setup at for instance MAX IV, which is a Large Scale Research Infrastructure (LSRI) i.e. a synchrotron equipment (X-ray base techniques) in Lund. This student project will investigate the mechanisms of X-ray interactions with liquids, focusing on energy deposition, crosslinking, pyrolysis, radiation dosage, and potential structural or chemical changes induced by the beam from the theoretical and numerical point of view from literature and web-sources. Through theoretical modeling, simulations, and experimental comparison/validation, the study aims to provide insights into these interactions and their implications for synchrotron-based research.

RQ

• How do X-ray photons deposit energy in liquids, how will that affect the temperature locally and how does this vary with photon energy, liquid composition, and exposure time?

• What are the mechanisms and thresholds for beam-induced damage in liquids (e.g., radiolysis, thermal effects)?

• How can X-ray dosage be calculated and optimized for practical applications (XCT, SWAXS, XPS) involving liquids?

Expected results

• Dosage Calculation: A validated model for predicting absorbed dose in liquids as a function of X-ray energy and liquid properties.

• Beam Damage: Identification of energy thresholds and exposure times leading to significant chemical or thermal changes.

• Practical Guidelines: Recommendations for minimizing damage at MAX IV, i.e. ForMAX/CoSAXS beamlines (e.g., beam filtering, pulse duration adjustments).

Literature:

(1) *Tables of X-Ray Mass Attenuation Coefficients (NIST XCOM)*, Hubbell, J. H., & Seltzer, S. M., **2004**

(2) *"GEANT4—a simulation toolkit." Nuclear Instruments and Methods in Physics Research A.*, Agostinelli, S., et al., **2003**

(3) *Radiology Master Class Basics of X-ray Physics*; https://www.radiologymasterclass.co.uk/tutorials/physics/x-ray_physics_production

(4) *Elements of Modern X-ray Physics - Second Edition*, Jens Als-Nielsen & Des McMorrow, Wiley **2011**, https://www.xray.cz/kryst/xray.pdf

(5) *Synchrotron Imaging of Synthetic and Lignocellulose-based Packaging Materials,* Linnea Björn, Department of Physics, Materials Physics, Chalmers, Doctoral thesis, **2025**, Synchrotron Imaging of Synthetic and Lignocellulose-based Packaging Materials