Contribution ID: **44** Type: **Oral**

Reconstructing the x-ray reflectivity from liquid surfaces using grazing incidence X-ray off-specular scattering at a fixed incident angle

Wednesday, 17 July 2024 16:20 (20 minutes)

The capillary wave model of a liquid surface predicts both the X ray specular reflection and the diffuse scattering around it. A quantitative method is presented to obtain the X-ray reflectivity (XRR) from a liquid surface through the diffuse scattering data around the specular reflection. With this approach the entire Qz-dependent reflectivity profile can be obtained at a single, fixed incident angle, using the grazing incidence X-ray off-specular scattering (GIXOS) geometry at a fixed horizontal offset angle with respect to the plane of incidence. This permits the profile to be obtained much faster than with conventional reflectometry where the incident angle must be scanned point-by-point to obtain a Qz-dependent profile. The XRR derived from the GIXOS-measured diffuse scattering, referred to in this work as pseudo reflectivity, provides a larger Qz-range compared with the reflectivity measured by conventional reflectometry. Transforming the GIXOS-measured diffuse scattering profile to pseudo XRR opens up the GIXOS method to widely available specular XRR analysis software tools. We compare the GIXOS-derived pseudo XRR with the conventional XRR measured by specular reflectometry from two simple vapor-liquid interfaces at different surface tension, and from a CTAB monolayer on the water surface. We find excellent agreement – beyond 11 orders of magnitude in signal - between the two methods, supporting our approach of using GIXOS-measured diffuse scattering to derive the effective specular XR. Pseudo XRR obtained at different horizontal offset angles with respect to the plane of incidence yield indistinguishable results and supports the robustness of the GIXOS-XRR approach.

The pseudo XRR method has also been extended to monolayer surfaces that have a non-zero bending rigidity. Bending rigidity increases the surface stiffness, and the scattering now falls faster in the transverse direction compared to the case of no bending rigidity. A consequence of this is to decrease the upper Q cut-off for which the capillary wave model applies, and this decreases the capillary wave roughness. Several examples from systems with non-zero bending rigidity will be presented

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Instrumentation and methods

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Session Classification: Sunil Sinha Session