Spatially resolved atom scattering from surfaces

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Scattering beams of atoms from the outermost electrons at surfaces has been used as a delicate and highly sensitive surface tool for many decades, to study surface average properties without spatial resolution [1]. In recent years, we have developed atom beam microprobes, which can apply these methods with well-controlled spatial resolution. The subsequent method of neutral atom microscopy can be applied to reveal surface topography [2,3] and we have established several novel imaging mechanisms. Here, we present recent results that focus on utilising established atom-surface scattering methods in a microscopic context, which open up a wide range of new applications in surface and nano-science.

Firstly, we show how well-defined helium-surface scattering leads to the capability to measure the structure of high aspect ratio samples, and that the depth of surface features can be obtained precisely [4]. We then discuss a method we have recently reported [7] that applies the principles of photometric-stereo to atom scattering. Using images collected at several sample-detector angles the surface profile can be reconstructed in 3D, in a process we term 'heliometric-stereo'. Practically, measurements can be made through tilt and rotation of the sample, or more efficiently by sampling from several detection positions simultaneously.

Helium diffraction from single crystals is well established, and we have previously shown that imaging of single crystal samples is consistent with diffraction [5]. Here, we now go on to report the first true point-diffraction results within a helium microscope, combining angular and spatial resolution and demonstrating a unique capability to map the 2D grain structure of a surface. We compare the experimental results to angular distributions obtained by solving a set of close- coupled equations representing the quantum helium scattering from the sample. Simulated images were generated using the ray-tracing framework we have developed [6], which has been enhanced to include the scattering probability from the surface elements and sample manipulations required. The results demonstrate that helium scattering methods can now be applied to samples that have otherwise been inaccessible to the technique i.e. those with small domains. Thus, new experimental insights on technological and applied samples are possible, as well as fundemental insights into intrinsically polycrystalline materials.

Finally, we report on the second generation research platform which we have just completed. The instrument offers the capability to install multiple detectors, experimentally realise heliometric stereo with high efficiency, and perform a wide range of diffraction studies. All the key components have been optimised, including the beam-source, optical elements and ultra-high sensitivity solenoid detectors. We discuss the significant advances the new platform offers, some of which have been realised already and others which represent capabilities that we believe will underwrite the future of the field.

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