A PRACTICAL CONSIDERATION OF SCANNING HELIUM MICROSCOPY

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For Jasmin.

Always, and forever.
DECLARATION

I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision.

The thesis contains published scholarly work of which I am a co-author. For each such work a written statement, endorsed by my co-authors, attesting to my contribution to the joint work has been included.

The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University’s Digital Repository, subject to the provisions of the Copyright Act 1968 and any approved embargo.

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________________________________________
Paul Dastoor
ACKNOWLEDGEMENTS

“Being a writer is a very peculiar sort of a job: it’s always you versus a blank sheet of paper (or a blank screen), and quite often the blank piece of paper wins.”

– Neil Gaiman

Writing these acknowledgements is a rather surreal experience, as it signals an end to the unique mix of triumph and tragedy that is a PhD. I would like to take a moment to thank the long list of people who have helped me in this undertaking – without you, none of it would have been possible.

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PUBLICATION LIST

The author and collaborators published the following papers during the term of the present thesis.

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ABSTRACT

The established field of Helium Atom Scattering (HAS) has long made use of neutral helium to offer unique opportunities with regards to surface characterisation. A thermal helium atom is an ideal probe particle: strictly surface sensitive, totally inert, a wavelength of the order of typical crystallographic dimensions, and well matched in both energy and momentum to dynamic surface processes. Technological limitations have restricted HAS to broad illumination of a sample surface. The development of a spatially resolved version of the technique - a Scanning Helium Microscope or SHeM - forms the basis for the work presented in this thesis. Such an instrument would prove of great benefit to the wide range of samples (including delicate adsorbate structures, organic molecules and biological materials) which suffer damage under the energetic probes of traditional microscopies.

Chapter 1 first reviews the nature of the helium atom-surface interaction (and the possible contrast mechanisms that arise as a result), before looking at the intensity constraints that have prevented the manufacture of a SHeM previously. Chapters 2 and 3 concern the development of a prototype instrument – the Mark I SHeM. A detailed discussion of the design decisions is included, followed by experimental studies conducted with the new instrument. With the successes found with the prototype, progress then began on creating an instrument from the ground up. Chapter 4 covers the design of the Mark II SHeM, as well as the performance improvements as compared to its predecessor. The experimental investigations into not only samples but the technique itself are explored in Chapter 5. These include studies of image formation, secondary beam effects, contrast mechanisms, and fundamental instrument optics. Finally, Chapter 6 comprises a review of the state of the emerging field with a particular focus on the technical requirements to more fully harness each of the available contrast mechanisms.
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- AFM – Atomic Force Microscopy
- DWF – Debye-Waller Factor
- EI – Electron Ionisation
- e-p – electron-phonon
- ESF – Edge Spread Function
- FI – Field Ionisation
- FWHM – Full Width Half Maximum
- FIM – Field Ion Microscope
- HAS – Helium Atom Scattering
- LSF – Line Spread Function
- NAM – Neutral Atom Microscope
- NEMI – Neutral Microscopy
- PSF – Point Spread Function
- RGA – Residual Gas Analyser
- RMS – Root Mean Square
- SEM – Scanning Electron Microscopy
- SHeM – Scanning Helium Microscope
- STM – Scanning-Tunnelling Microscope
- STXM – Scanning Transmission X-ray Microscopy
- TEM – Transmission Electron Microscopy
- WD – Working Distance