DEVELOPMENT OF DIGITAL INSTRUMENTATION FOR BOND RUPTURE DETECTION

A thesis presented in partial fulfilment
of the requirements for the degree of

Doctor of Philosophy

in

Engineering

at Massey University, Palmerston North,
New Zealand

Matthew John van der Werff

2009

ABSTRACT

In the medical world the precise identification of a disease can take longer than it is safe to wait to start treatment so there is a need for faster and more precise biosensors. Bond Rupture is a new sensor technique that maybe able to improve disease detection. It does this by inducing bonds to rupture from the surface, and also measuring the point at which this rupture occurs this enables the forces to be measured on the surface. Specifically, this project has focused on the application of Bond Rupture to detecting antigens when bound to a surface using their specific antibodies, and the idea that the rupture force of these antigens can also be measured. The sensor that this project is based around is the Quartz Crystal Microbalance (QCM), which oscillates horizontally when a voltage is applied, and can also be used to measure mass change on its surface via change in resonant frequency.

The aim of this project was to investigate possible Bond Rupture detection methods and techniques and has involved the development of a high speed digital electronics system, for the purposes of inducing and detecting Bond Rupture. This has involved the development of a FPGA based high speed transceiver board which is controlled by a Digital Signal Processor (DSP), as well as the development of various graphical user interfaces for end user interaction. Bond rupture testing was carried out by rupturing beads from the surface of a QCM in an experiment taking as little as 20 seconds.

The Bond Rupture effect has been observed via the high accuracy measurement of the frequency change while inducing Bond Rupture on the sensor, proving that the Bond Rupture effect indeed exists. The research performed is believed to be a world first in terms of the method used and accuracy acquired.

ACKNOWLEDGEMENTS

Like many others before me, the thesis writing has taken much longer than originally expected. I am grateful for the patience of those around me, waiting for me to finish.

First I would like to thank my three supervisors. To Yong Yuan who initiated this project, I have appreciated working with many more ideas than I could ever hope to implement and for giving me a great appreciation of Chinese cuisine. To Peter Xu for inspiring me to do my PhD, his excellent management in ensuring that the project kept ticking along. To John Bronlund though turning up as an official supervisor in the second year, his advice, ideas, and dropping in for chats has been invaluable. I have appreciated the fun times we have as a group have had discussing ideas for the project, and not to mention the subjects from food and wine, to politics, to skiing. I would like to thank Harry Chen for laboratory experiments carried out and preparation and putting up with the initial bugs in the developed system. I would like to thank Evan Hirst (the other PhD working on this project) who has been in this project almost as long as me, for being there to bounce ideas off and pointing out some of the more obvious problems when I have become carried away with an idea.

I am grateful for the mentoring given to me by Robin Dykstra who has generously given of his time to explain the ins and outs of signal processing, among other topics. I also appreciate the hardware which Robin has donated to this project saving a significant amount of time, which may have been devoted to reinventing the wheel instead of focusing on the project on hand. I am also grateful to the boys of the NMR lab Rob Ward and Terry Southern, both of whom have given me many ideas and provided me somewhere to bounce ideas around. I should also thank them for the many hours of debates into issues as wide as, a fierce debate of plunger versus espresso coffee, to the origin of life and the universe. I would like to especially thank Terry for his input into the initial design specifications of the FPGA board and other help with circuit design and DSP programming problems.

I would like to thank Warwick Taylor for the many hours spent proof reading my thesis.

I would like to thank my lovely wife Larina who has lovingly supported me though this long time of financial deficit, and Caleb my little boy (now seven months old) who has managed to distract me from work many times though the final months of writing. I would like to thank my parents Kirsty and Dave for their support from afar (thanks Skype), and my little sister Jasmin who said if no mention was made of her that I would be in big trouble. I would like to thank my mother in-law Lyn for all the help provided over the years, and my brother in-law Max for a great source of questions and ideas. Also thank the rest of my extended family, other brothers and sisters and their in-law counter parts, for their input and support. I would also like to thank other friends around me that have supported me during this time. I will end with thanking my father in-law Keith Betteridge for not only being there to bounce ideas off, but for that constant dreaded question “So have you finished your thesis yet?” to which I can now finally answer yes!

RELATED PUBLICATIONS

van der Werff, M. J., Y. J. Yuan, W.L. Xu (2005). Quartz Crystal Microbalance for Medical Diagnostics. First International Conference on Sensing Technology. S. C. M. G.Sen Gupta, C. H. Messom. Palmerston North, New Zealand. ***1:*** *500-504.*

van der Werff, M. J., Y. J. Yuan, E.R. Hirst, J. Bronlund, W.L. Xu (2007). "Quartz crystal microbalance induced bond rupture sensing for medical diagnostics." Ieee Sensors Journal 7(5-6): 762-769.

Yuan, Y. J., M. J. van der Werff, H. Chen, E.R. Hirst, W.L. Xu (2007). "Bond rupture of biomolecular interactions by resonant Quartz crystal." Analytical Chemistry ***79****(23): 9039-9044.*

van der Werff, M. J., Y. J. Yuan, W.L. Xu (2009) "QCM Bond Rupture using a FPGA based transceiver". " IEEE Sensors Journal, to be submitted.

CONTENTS