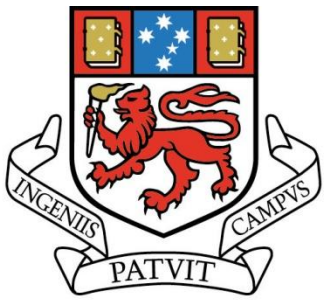
Porous polymer monolith supported Suzuki-Miyaura catalysis in microreactors



UNIVERSITY OF TASMANIA

Jeremy Alan Deverell

B.Sc Hons (University of Tasmania)

Submitted in fulfilment of the requirements
for the degree of

Doctor of Philosophy

School of Chemistry
University of Tasmania
Hobart, Tasmania
Australia

September 2011

Declaration of originality

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Jeremy Alan Deverell

September, 2011

Statement of co-authorship

Several people within the microreactor group contributed towards research reported in publications, and the contribution of each author is estimated to be approximately as documented below.

Paper 1: "Microfluidic devices for flow-through supported palladium catalysis on porous organic monolith".

Jeremy A. Deverell (75%, experimental and planning), Allan J. Canty (5%, planning and writing), Anissa Gömann (5%, experimental and planning), Rosanne M. Guijt (5%, planning and writing), Thomas Rodemann (5%, planning and writing), and Jason A. Smith (5%, planning and writing).

Paper 2: "Palladium-mediated organic synthesis using porous polymer monolith formed in situ as a continuous catalyst support structure for application in microfluidic devices".

Jeremy A. Deverell (65%, experimental and planning), Allan J. Canty (5%, planning and writing), Anissa Gömann (5%, experimental and planning), Rosanne M. Guijt (5%, planning and writing), Thomas Rodemann (5%, planning and writing), Jason A. Smith (5%, planning and writing), Katrina F. Munting (5%, experimental and planning), and Roderick C. Jones (5%, experimental and planning).

Paper 3: "Supported palladium catalysis using a heteroleptic 2-methylthiomethylpyridine-N,S-donor motif for Mizoroki-Heck and Suzuki-Miyaura coupling, including continuous organic monolith in capillary microscale flow-through mode".

Jeremy A. Deverell (35%, experimental and planning), Roderick C. Jones (35%, experimental, planning and writing), Allan J. Canty (5%, planning and writing), Michael G. Gardiner (5%, planning and writing), Rosanne M. Guijt (5%, planning

and writing), Thomas Rodemann (5%, planning and writing), Jason A. Smith (5%, planning and writing), and Vicki A. Tolhurst (5%, planning and writing).

Paper 4: "UV initiated formation of polymer monoliths in glass and polymer microreactors".

Jeremy A. Deverell (80%), Thomas Rodemann (5%, planning and writing), Jason A. Smith (5%, planning and writing), Allan J. Canty (5%, planning and writing), and Rosanne M. Guijt (5%, planning and writing).

Paper 5: "Macroporous monolith supports for continuous flow capillary microreactors".

Jeremy A. Deverell (40%, experimental and planning), Katrina F. Bolton (30%, experimental and planning), Allan J. Canty (5%, planning and writing), Rosanne M. Guijt (5%, planning and writing), Emily F. Hilder (5%, planning and writing), Thomas Rodemann (5%, planning and writing), and Jason A. Smith (5%, planning and writing).

Signed: _____ _____

Prof. Allan Canty	Dr Greg Dicinoski
Supervisor	Head of School
School of Chemistry	School of Chemistry
University of Tasmania	University of Tasmania

September 2011

Acknowledgements

First and foremost I would like to express my deepest gratitude to my supervisors Dr Thomas Rodemann, Dr Rosanne Guijt, and Prof. Allan Canty. This document would not exist if not for their guidance, encouragement, and incredible fortitude in persevering with me for all these years.

Thomas has been more than a supervisor, he has also been a mentor in both academia and in life. He is a dear friend, without whom I know I probably would not be here now. It was he that originally encouraged me to pursue a doctorate, for which I will always be grateful.

Rosanne is truly an amazing woman, for whom I have nothing but the deepest respect for as an academic and as a person. Her strength and objectivity were invaluable and allowed the project to continually move forward.

Allan's international fame as a master of palladium chemistry is very well deserved. I often found his wealth of knowledge and experience astonishing and almost always learned something new from him during each conversation.

Other than my supervisors, I would like to thank Dr Jason Smith for his invaluable insight and mastery of organic chemistry, Dr Emily Hilder for all her support both as a polymer monolith expert and as graduate research coordinator, and Dr Michael Breadmore for sharing his years of experience in all things microfluidic.

I especially need to thank the staff of the School of Chemistry, the Document Delivery service and the Graduate Research Office.

Special thanks to my grandfather, who sadly passed away during my studies, and my good friend Pam Mansfield for their love and support.

I must thank Dr Doug McLean for rocking, for his encouragement, and for his friendship.

Thank you to the talented staff of the Central Science Laboratory whom made this work possible, specifically Peter Dove, Mike Brandon, Dr Karsten Gömann, Dr Ashley Townsend, Dr James Horne, and John Davis.

And finally I would like to thank everyone who contributed to work: Katrina Munting, Dale Brandon, Paul Harvey, Peter Molesworth, Oscar Potter, Dr Andrew Grosse, Graham Meredith, Simon Stephens, Dr Anissa Gömann, Dr Joselito Quirino, Dr Mohamed Dawod, Dr Anna Nordborg, Dr Joe Hutchinson, and Adam James.

Table of contents

Abstract

Miniaturisation of reactions to the sub-millilitre scale, through the use of microreactor technology, has the potential to reduce costs by drastically reducing reaction times, improving yields and selectivities, as well as decreasing the environmental impact by reducing reagent and solvent use. Further improvements can be achieved by utilising heterogeneous and supported catalysts within microreactors in order to increase reaction efficiency, reduce energy requirements, and simplify product purification. This should also enable the integration of microreactors with other existing microfluidic technologies allowing synthesis, purification, analysis, and bio-testing to be performed on a single device in an automated fashion.

In this work, novel microreactors were fabricated utilising porous polymer monoliths (PPM's) prepared *in situ* within microfluidic devices as a support for the immobilisation of palladium complexes. Poly(glycidyl methacrylate-*co*-ethylene glycol dimethylacrylate) and poly(chloromethylstyrene-*co*-divinylbenzene) monoliths were prepared by either thermal or UV initiated radical polymerisation in several formats, including capillary, microchip, and column using both glass and polymer substrates. This required the development of new methods for anchoring PPM within polymer substrates with poor transmission in the deep UV region, which is necessary for photografting, thus enabling the use of polymer substrates with greater thermal resistance. The development of polymeric microreactors was pursued as mass production of microfluidic devices with multiple components is considerably easier and more economical compared to other substrates. Additionally, conditions were developed to allow the formation of PPM in columns with an internal diameter (ID) greater than 1 mm without the need for external compression to avoid shrinkage. The preparation of PPM using light emitting diode light sources was

investigated with the aim of reducing the cost associated with development of photoinitiated PPM's, enabling greater access to this technique. The PPM's were utilised to immobilise ligands that will bind palladium, 5-hydroxy-1,10-phenanthroline, 5-amino-1,10-phenanthroline, and an *N*-methylimidazolium salt. In order to demonstrate the feasibility of this technology, the Suzuki-Miyaura coupling of iodobenzene and *p*-tolylboronic acid was performed under continuous flow in the reactors, which produced quantitative yields with less than 0.01% of the immobilised palladium leached over a 24 h reaction period. This is the first reported used on a polymer microchip for supported Suzuki-Miyaura catalysis and also the first demonstration of non-room temperature supported palladium catalysis within a polymer microreactor. Novel technology was developed to allow easy interfacing with a broad range of microchips and for producing PPM in batch via UV initiation using low intensity light sources.

Publications and presentations

Publications (copies provided in the appendix)

"Microfluidic devices for flow-through supported palladium catalysis on porous organic monolith".

Allan J. Canty, Jeremy A. Deverell, Anissa Gömann, Rosanne M. Guijt, Thomas Rodemann and Jason A. Smith: *Australian Journal of Chemistry*, **2008**, 61(8), 630-366.

"Palladium-mediated organic synthesis using porous polymer monolith formed in situ as a continuous catalyst support structure for application in microfluidic devices".

Anissa Gömann, Jeremy A. Deverell, Katrina F. Munting, Roderick C. Jones, Thomas Rodemann, Allan J. Canty, Jason A. Smith, and Rosanne M. Guijt: *Tetrahedron*, **2009**, 65(7), 1450-1454.

"Supported palladium catalysis using a heteroleptic 2-methylthiomethylpyridine-N,S-donor motif for Mizoroki-Heck and Suzuki-Miyaura coupling, including continuous organic monolith in capillary microscale flow-through mode".

Roderick C. Jones, Allan J. Canty, Jeremy A. Deverell, Michael G. Gardiner, Rosanne M. Guijt, Thomas Rodemann, Jason A. Smith, and Vicki A. Tolhurst: *Tetrahedron*, **2009**, 65(36), 7474-7481.

"UV initiated formation of polymer monoliths in glass and polymer microreactors".

Jeremy A. Deverell, Thomas Rodemann, Jason A. Smith, Allan J. Canty, and Rosanne M. Guijt: *Sensors and Actuators B: Chemical*, **2010**, in press.

"Macroporous monolith supports for continuous flow capillary microreactors".

Katrina F. Bolton, Allan J. Canty, Jeremy A. Deverell, Rosanne M. Guijt, Emily F. Hilder, Thomas Rodemann, and Jason A. Smith: *Tetrahedron*, **2006**, 47(52), 9321-9324.

Presentations

ACROSS Symposium on Advances in Separation Science

Hobart, Tasmania, December 2008.

Poster entitled "Photo-initiated radical polymerisation of porous polymer monoliths in microchips with low-intensity near UV light sources".