Nuclear magnetic resonance force microscopy at millikelvin temperatures

Haan, A.M.J. den

Publications

1. A. Vinante, A. Kirste, A. den Haan, O. Usenko, G. Wijts, E. Jeffrey, P. Sonin, D. Bouwmeester, and T. H. Oosterkamp. High sensitivity SQUID-detection and feedback-cooling of an ultrasoft microcantilever. *Applied Physics Letters*, 101(12):123101, 2012

2. A. M. J. Den Haan, G. H. C. J. Wijts, F. Galli, O. Usenko, G. J. C. Van Baarle, D. J. Van Der Zalm, and T. H. Oosterkamp. Atomic resolution scanning tunneling microscopy in a cryogen free dilution refrigerator at 15 mK. *Rev. Sci. Instrum.*, 85(3):035112, 2014

3. H. C. Overweg, A. M. J. den Haan, H. J. Eerkens, P. F. A. Alkemade, A. L. La Rooij, R. J. C. Spreeuw, L. Bossoni, and T. H. Oosterkamp. Probing the magnetic moment of FePt micromagnets prepared by focused ion beam milling. *Applied Physics Letters*, 107(7), 2015

4. A. M. J. den Haan*, J. J. T. Wagenaar*, J. M. de Voogd, G. Koning, and T. H. Oosterkamp. Spin-mediated dissipation and frequency shifts of a cantilever at milliKelvin temperatures. *Phys. Rev. B*, 92:235441, 2015

5. J. J. T. Wagenaar*, A. M. J. den Haan*, J. M. de Voogd, K. M. Bastiaans, T. de Jong, D. J. Thoen, A. Endo, T. M. Klapwijk and T.H. Oosterkamp. Nuclear magnetic resonance force microscopy at milliKelvin temperatures. *in preparation*

* These authors contributed equally

Curriculum Vitae

Arthur Mattheus Johannes den Haan was born on June 18$^{\text{th}}$ 1985, in Brouwershaven, The Netherlands.
He completed his first year in electrical engineering at Hogeschool Zeeland, after finishing the school of higher general secondary education (havo) at Pontes Pieter Zeeman in 2003.
In 2004 he started to study physics at Leiden University and obtained his Bachelor of Science degree in 2008, for which he studied the dynamics of silver sulfide and liposomes using a high speed atomic force microscope.
He went on to do a master in experimental physics at Leiden University, for which he performed two master projects in condensed matter physics. First he studied acoustic wave propagation in soft granular matter under supervision of prof. dr. M. van Hecke. In his second project, he studied optimal control feedback in Magnetic Resonance Force Microscopy and characterized a new MRFM setup by using a Scanning Tunneling Microscope in the group of prof. dr. ir. T.H. Oosterkamp. He obtained his Master of Science degree in 2011.
In 2012 he started his PhD at Leiden University on a project funded by the Foundation for Fundamental Research on Matter (FOM), where he continued to work in the group of prof. dr. ir. T.H. Oosterkamp to explore and develop further the Magnetic Resonance Force Microscope for the use in condensed-matter physics systems.

Acknowledgments

I would like to thank my supervisor prof. dr. ir. T. H. Oosterkamp. He supported me in many areas and was very involved, also in difficult times.

Most of the experimental work and analysis shown in this thesis was performed together with Jelmer Wagenaar. Without the good cooperation with him, it would not have been possible to achieve the results presented in this thesis. We contributed equally to the majority of the experiments presented in this thesis. It was hard to get to the point in which the experiment (and especially the cryostat) worked. Without his input, this journey would have been like trying to wire-bond niobium.

Many people from the fine-mechanics department, in particular Gert Koning, Fred Schenkel and Dian van der Zalm have made indispensable contributions to the development of the experiments.

Furthermore I would like to thank the following people:
Bert Crama for helping with the radio-frequency circuitry.
Co Koning, Arno van Amersfoort and Raymond Koehler for their assistance in electronic issues.
Dr. Geert Wijts, Dr. Andrea Vinante and Dr. Sasha Usenko for handing over the experiment and explaining experiments and operations.
Marcel Hesselberth for his expertise and assistance on e-beam lithography and electron microscopy.
Dr. Amrita Singh for assisting the microfabrication of the copper sample with e-beam lithography.
Professor Teun Klapwijk and David Thoen for providing and etching NbTiN, for their expertise in superconductivity and for the involvement in lowering RF-dissipation.
Koen Bastiaans for characterizing the dissipation mechanisms in NbTiN.
Daan Boltje for assisting in the sputtering of copper and gold.
Dr. Mykhailo Azarkh, Dr. Jennifer Mathies and Dr. Peter Gast for magnetizing the magnetic particle on the cantilever.
Dr. Federica Galli and Dr. Gert-Jan van Baarle for helping with the Scanning Tunneling Microscopy.
Dr. Wim Bosch for the help with cryogenic techniques and for assistance in thermometry.
Hiske Overweg, Dr. Lucia Bossoni and Hedwig Eerkens, for their contribution to create and characterize a smaller magnetic particle.
Dr. Robert Spreeuw and Dr. Arthur La Rooij for providing the FePt sample.
Professor Jan Aarts and Professor Joost Frenken for their scientific input.

Tobias de Jong, Marc de Voogd and Dr. Lucia Bossoni for their help with simulations.
Ellie van Rijsewijk for her support and for the reminders of what is necessary.
Dr. Milan Allan for the useful comments on the thesis.

Finally I would like to thank many other people, some of them colleagues, who helped during my PhD: Bob van Waarde, Martin de Wit, Tom van der Reep, Kier Heeck, Oliver Ostojic, Dr. Sven de Man, Gesa Welker, Frank Buters, Dirk van Baarle, Dr. Marcel Rost, Rik Mom, Matthijs van Spronsen, Professor Jan van Ruitenbeek, Sasha Vrbica, Professor John Marohn, Ruud Kuyvenhoven, Andriy Taranovsky, Jeroen Meringa, Samuel Pressac, Dr. Louk Rademaker, Dr. Sander Roobol, Pavel Antonov, Nigel Fennet, Ernst Jan Vegter, Dr. Maarten van Es, Dr. Amir Saedi, Dr. Olaf Benningshof, Dr. Milan Allan, Professor Hans Hilgekamp and Dr. Dapeng Ding
I thank my family for their love and support and I thank Jolien Barto for spell checking and for her love.