

Ian W. Hunter

HATSOPOULOS PROFESSOR OF MECHANICAL ENGINEERING

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Professor Ian Hunter is the Hatsopoulos Professor of Mechanical Engineering and runs the BioInstrumentation Lab (<http://bioinstrumentation.mit.edu>) at the Massachusetts Institute of Technology. Ian was born in New Zealand and had an early interest in science, engineering and instrumentation which continues to the present. He started his first company when he was 9, by the age of 10 he had published his first paper (a design of a miniaturized single transistor radio) and by age 14 had built a fully functional gas liquid chromatograph (hydrogen flame ionization type) for chemical analysis. After graduating from the University of Auckland with BSc, MSc and PhD degrees he completed a Post-Doctoral Fellowship in the Department of Biomedical Engineering at McGill University, Canada. He then joined the faculty of McGill University and advanced to tenured Associate Professor in the Department of Biomedical Engineering. In 1994 Ian moved his lab to the Department of Mechanical Engineering at MIT.

His main areas of research are instrumentation, micro-robotics, medical devices and biomimetic materials. Over the years he and his students have developed many instruments and devices including: confocal laser microscopes, scanning tunneling electron microscopes, miniature mass spectrometers, new forms of Raman spectroscopy, needle free drug delivery technologies, nano- and micro-robots, micro-surgical robots, robotic endoscopes, high performance Lorentz force motors, and micro-array technologies for massively parallel chemical and biological assays. As a result of his research, Ian has over 500 publications. He also invents instruments and devices based on this research. This has led to over 150 issued and pending patents. Finally Ian's inventions have been used by numerous companies and in addition he has founded or co-founded over 25 companies.

Ian loves teaching and has been the recipient of several teaching awards at MIT including the Keenan Award for Innovation in Undergraduate Education, the Amar Bose Award for Excellence in Teaching and the Den Hartog Distinguished Educator Award.

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Education

University of Auckland, New Zealand	BSc	1974
University of Auckland, 1st class honors	MSc	1975
University of Auckland	DCP	1976
University of Auckland	PhD	1980

Selected Appointments

McGill University, Postdoctoral Fellow	1980-1981
Canadian Muscular Dystrophy Assoc., Postdoctoral Fellow	1980-1983
McGill University, Research Fellow	1984-1985
McGill University, Associate Member	1985-1994
McGill University, Assistant Professor	1985-1989
Canadian Inst. Advanced Research, Scholar	1985-1990
McGill Research Centre for Intelligent Machines, Member	1986-1994
Inst. for Robotics & Intelligent Systems, Project Director	1989-1994
McGill University, Associate Professor	1990-1994
MIT Associate Professor	1994-1996
MIT Co-director, Information Systems and Technology Laboratory	1995-present
MIT Full Professor	1996-present
MIT Professor of Bioengineering	1996-2004
MIT Hatsopoulos Professor	1996-present

Selected Awards:

Canadian Muscular Dystrophy Association Fellowship	1981
Medical Research Council of Canada Scholarship	1984
Canadian Institute for Advanced Research Scholarship	1987
General Motors Fellowship	1990
Outstanding Young Canadian Biomedical Engineer of the Year Award	1990
Canadian Institute for Advanced Research Fellowship	1991
d'Arbeloff Scholar	1994
General Motors R&D Academic Research Fellow	1995
Hatsopoulos Professor (personal chair)	1996
Fellow of the American Institute for Medical and Biological Engineering	1999
Honorary Professor, Bio-Engineering Institute, University of Auckland, New Zealand	2003
Keenan Award for Innovation in Undergraduate Education	2004

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Amar Bose Award for Excellence in Teaching	2004
Den Hartog Distinguished Educator Award	2007
National Academy of Inventors	2017

Ian Hunter Patents

Most Recent Patents:

Hunter, I.W., Taberner, A.J., Hemond, B.D., Wendell, D.M., Hogan, N.C., and Ball, N.B., "Controlled Needle-free Transport," US Patent 8,992,466, March 31, 2015.

Hunter, I.W., and Paster, E.T., "Flexible Conducting Polymer Energy Storage Device," US Patent 9,048,029, June 2, 2015.

Inman, S.W., and Hunter, I.W., "Irregular Excitation of Optical Sensors," US Patent 9,075,011, July 7, 2015.

Hunter, I.W., Taberner, A.J., and Hogan, N.C., "Bi-directional Motion of a Lorentz-force Actuated Needle-free Injector (NFI), US Patent 9,125,990, September 8, 2015.

Hunter, I.W., and Lafontaine, S.R., "Distributed Architecture for Uni-directional and Bi-directional Power Transfer in an Electrical Storage System," US Patent 9,129,743, September 8, 2015.

Hunter, I.W., Lafontaine, S.R., and Fofonoff, T.A., "Minimization of Torque Ripple," US Patent 9,231,462, January 5, 2016.

Hunter, I.W., Chen, Y., Jones, L.A., and Hogan, N.C., "Identification Techniques and Device for Testing the Efficacy of Beauty Care Products and Cosmetics," US Patent 9,265,461, February 23, 2016.

Kristoff, G., Lafontaine, S.R., and Hunter, I.W., "Dynamic Pressure Control in a Battery Assembly," US Patent 9,306,252, April 5, 2016.

Hunter, I.W., Hemond, B.D., and Hemond, H.F., "Methods, Apparatus, and System for Mass Spectrometry," US Patent 9,312,117, April 12, 2016.

Hunter, I.W., Taberner, A.J., Hemond, B.D., Wendell, D.M., Hogan, N.C., and Ball, N.B., "Controlled Needle-Free Transport," US Patent 9,308,326, April 12, 2016.

Hunter, I.W., "Plaque Removal and Differentiation of Tooth and Gum," US Patent 9,333,060, May 10, 2016.

Hunter, I.W., and Lafontaine, R., "Apparatus and Method for Rapidly Charging Batteries," US Patent 9,397,516, July 19, 2016.

Hunter, I.W., and Modak, A., "Automated Method for Simultaneous Bubble Detection and Expulsion", US Patent 9,486,589, November 8, 2016.

Professor Ian W. Hunter Abbreviated CV

Hunter, I.W., and Chen, Y., “Nonlinear System Identification Techniques and Devices for Discovering Dynamic and Static Tissue Properties,” US Patent 9,517,030, December 13, 2016.

Hunter, I.W., and Paster, E.T., “Continuous Measurement Chromatography and Method of Continuous Stochastic Perturbation Chromatography,” US Patent 9,588,087, March 7, 2017.

Hunter, I.W., and Chen, Y., “Design and Mathematical Methods for a Fast Miniature Hyperspectral Imaging Transform Spectrometer,” US Patent 9,681,798, June 20, 2017.

Hunter, I.W., Montemayor, L., Paster, E.T., Pillai, P., and Ruddy, B.P., “Conformable Antenna Using Conducting Polymers,” US Patent 9,728,843, August 8, 2017.

Demas, P.N., Hunter, I.W., Nawrot, M.T., Hemond, B., “Multi-Directional Low-Displacement Force Sensor,” US Patent 9,724,473, August 8, 2017.

Hunter, I.W., Hemond, B.D., and Hemond, H.F., “Methods, Apparatus, and System for Mass Spectrometry,” US Patent 9,735,000, August 15, 2017.

Hunter, I.W., Taberner, A.J., and Hogan, N.C., “Bi-Directional Motion of a Lorentz-Force Actuated Needle-Free Injector,” US Patent 9,789,256, October 17, 2017.

Mirvakili, S.M., and Hunter, I.W. “High-Performance Supercapacitors Based on Metal Nanowire Yarns,” US Patent 9,865,404, January 9, 2018.

Hunter, I.W., Hogan, N.C., and Brown, A., “Debridement Apparatus Using Linear Lorentz-force Motors,” US Patent 9,987,037, June 5, 2018.

Mirvakili, S.M., and Hunter, I.W., "High-Performance Supercapacitors Based on Metal Nanowire Yarns", US Patent 10,008,339, June 26, 2018.

Hunter, I.W., Montemayor, L., Paster, E.T., and Pillai, P., “Interconnection Between Conducting Polymer Materials,” US Patent 10,134,501, Nov 20, 2018.

Kojic, N., Hunter-Jones, B., and Hunter, I.W., “Nozzle for use in an Ultra-High Velocity Injection Device,” US Patent 10,159,793, Dec 25, 2018.

Hunter, I.W., Modak, A.P., and Hogan, N.C., “Adaptor for Removal of Fluid from Vial Using a Needle-free Syringe,” US Patent 10,195,113, Feb 5, 2019.

Hunter, I.W., and Mazumdar Chen, Y., “Systems, Apparatus, and Methods for Spectral Imaging,” US Patent 10,444,007, October 15, 2019.

Hunter, I.W., Taberner, A.J., and Hogan, N.C., “Bi-Directional Motion of a Lorentz-Force Actuated Needle-Free Injector (NFI),” US Patent 10,485, 928, November 26, 2019.

Most Recent Publications:

Taberner A.J., Hogan, N.C., Hunter, I.W., “Real-time-feedback-controlled Needle free Jet Injection Using Linear Lorentz-force Motors,” *Journal of Medical Engineering Physics*, 34:1228-1235, 2012.

Hemond, B., Hunter, I.W., Hughey, B.J., and Jones, L.A., “MICA: An Innovative Approach to Remote Data Acquisition,” *IEEE Instrumentation and Measurement Magazine*, 15 (5),22-27, October 2012.

Chen, Y., and Hunter, I.W., “Stochastic System Identification of Skin Properties: Linear and Wiener Static Nonlinear Method,” *Annals of Biomedical Engineering*, 40(10): 2277-2291, 2012 [<http://dx.doi.org/10.1007/s10439-012-0580-x>].

Sandford, E., Chen, Y., Hunter, I.W., Hillebrand, G., and Jones, L.,” Capturing Skin Properties from Dynamic Mechanical Analyses,” *Journal of Skin Research and Technology*, 19: e339–e348, 2013, [<http://dx.doi.org/10.1111/j.1600-0846.2012.00649.x>].

Chen, Y., and Hunter, I.W., “Nonlinear Stochastic System Identification of Skin Using Volterra Kernels,” *Annals of Biomedical Engineering*, published on-line December 22, 2012, 41(4), 847-862, April 2013.

Williams, R., Hogan, N.C., Nielsen, P.M., Taberner, A.J., Hunter, I.W., “A Computational Model of a Controllable Needle-free Jet Injector, *Proceedings of IEEE Engineering in Medicine and Biology Society 2012*, San Diego, CA, August 28-September 1, 2012; 10.1109/EMBC.2012.6346362: 2052-2055.

Liu, J., Hogan, N.C., Hunter, I.W.,” Intradermal Needle-free Powdered Drug Injection by a Helium-powered Device,” *Proceedings of IEEE Engineering in Medicine and Biology Society 2012*; San Diego, CA, August 28-September 1, 2012. 10.1109/EMBC.2012.6346366: 2068-2071.

White, J., Chang, J., Hogan, N.C., Hunter, I.W.,” Development of a Lorentz-force Actuated Intravitreal Jet Injector,” *Proceedings of IEEE Engineering in Medicine and Biology Society 2012*, San Diego, CA, August 28-September 1, 2012; 10.1109/EMBC.2012.6346098: 984-987.

Hogan, N.C., Talei-Franzesi, G., Abudayyeh, O., Taberner, A.J., Hunter, I.W., “Low cost Flexible Polymer Arrays for Long-term Neuronal Culture,” *Proceedings of IEEE Engineering in Medicine and Biology Society 2012*, San Diego, CA, August 28-September 1, 2012; 10.1109/EMBC.2012.6346053: 803-806.

Professor Ian W. Hunter Abbreviated CV

Ruddy, B.P., Hunter, I.W., “A Compact Direct-drive Linear Synchronous Motor with Muscle-like Performance,” Proceedings of the 2013 IEEE International Conference on Robotics and Automation, Karlsruhe, Germany, May 6-10, 2013, pp. 1498-1503, <http://dx.doi.org/10.1109/ICRA.2013.6630769>.

Chen, Y., Oliveira, J.M., and Hunter, I.W., “Two-Axis Bend Sensor Design, Kinematics and Control for a Continuum Robotic Endoscope,” Proceedings of 2013 IEEE International Conference on Robotics and Automation, Karlsruhe, Germany, May 6-10, 2013, pp. 696-702.

Spanbauer, A., Wahab, A., Hemond, B., Hunter, I., and Jones, L., “Measurement, Instrumentation, Control and Analysis (MICA): A Modular System of Wireless Sensors. Proceedings of 2013 IEEE International Conference on Body Sensors Networks, Cambridge, MA, May, 2013, pp. 17-21.

Chang, J.H., Hogan, N.C., Hunter, I.W., Pillai, Priam, “Needle-free Interstitial Fluid Acquisition Using a Lorentz-force Actuated Jet Injector,” Proceedings of Engineering in Medicine and Biology Conference (EMBC’13), Osaka, Japan, July 3-7, 2013, pp. 3491-3494.

Chang, J.H., Hogan, N.C., Hunter, I.W., "High Speed X-ray Imaging of Needle-free Jet Injections," Proceedings of 2014 IEEE International Symposium on Biomedical Imaging, Beijing, China, April 29 - May 2, 2014.

Chen, Y., Liang, J., Hunter, I.W., “Modular Continuum Robotic Endoscope Design and Path Planning,” Proceedings of 2014 IEEE International Conference on Robotics and Automation, Hong Kong, China, May 31-June 5, 2014, pp. 5393-5400.

Ruddy, B., Hunter, I.W., and Taberner, A.J., “Optimal Voice Coil Actuators for Needle-free Injection,” Proceedings of the 36th Annual International IEEE Engineering in Medicine and Biology Society Conference, Chicago, IL, August 27-31, 2014.

Chang, J.H., Hogan, N.C., and Hunter, I.W., “A Needle-free Technique for Interstitial Fluid Sample Acquisition Using a Lorentz-force Actuated Jet Injector,” *Journal of Controlled Release*, 211:37-43, 2015, (<http://dx.doi.org/10.1016/j.jconrel.2015.05.264>).

Hogan, N.C., Taberner, A.J., Jones, L.A. and Hunter, I.W., “Needle-free Delivery of Macromolecules Through the Skin Using Controllable Jet Injectors,” *Expert Opinion Drug Delivery*, 12(10):1637-1648, 2015, (<http://www.tandfonline.com/doi/full/10.1517/17425247.2015.1049531>).

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Mirvakili, S.M., Mirvakili, M.N., Englezos, P. Madden, J.D., and Hunter, I.W., "High Performance Supercapacitors from Niobium Nanowire Yarns," *Applied Materials and Interfaces*, 7(25):13882-13888, 2015.

Williams, R.M.J., Ruddy, B.P., Hogan, N.C., Hunter, I.W., Nielsen, P.M.F., and Taberner, A.J., "Analysis of Moving-coil Actuator Jet Injectors for Viscous Fluids," *IEEE Transactions on Biomedical Engineering* 63(6):1099-1106, 2015, (DOI: 10.1109/TBME.2015.2482967).

Modak, A.P., Hogan, N.C., and Hunter, I.W., "Adaptive Controller for a Needle-free Jet Injector System," 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Milano, Italy, August 25-29, 2015, 7345-7349, (DOI: 10.1109/EMBC.2015.7320088).

Hogan, N.C., Cloutier, A., and Hunter, I.W., "Jet Injection of a Monoclonal Antibody: A Preliminary Study," "37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Milano, Italy, August 25-29, 2015, 7336-7340, (DOI: 10.1109/EMBC.2015.7320086).

Park, G., Modak, A., Hogan, N.C., and Hunter, I.W., "The Effect of Jet Shape on Jet Injection," "37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Milano, Italy, August 25-29, 2015, 7350-7353, (DOI: 10.1109/EMBC.2015.7320089).

Mirvakili, S.M., and Hunter, I.W., "Bending Artificial Muscle from Nylon Filaments," *Proceedings of SPIE Smart Structures, Electroactive Polymer Actuators and Devices (EAPAD) XVIII*, Las Vegas, NV, March 20-24, 9798:97981L:1-7, 2016, (<http://dx.doi.org/10.1117/12.2225271>).

Raynal, A., Hogan, N.C., and Hunter, I.W., "Design of a Debridement Device Using Impinging Jets," *Proceedings of ASME Design of Medical Devices Conference (DMD2016)*, Minneapolis, MN, April, 11-14, 2016. *ASME Journal of Medical Devices*, 10, 030938:1-2.

Chen, Y., and Hunter I.W., "Design of a Miniature Hyperspectral Imaging Fourier Transform Spectrometer For Endoscopy," *Proceedings of the Optical Society's Imaging and Applied Optics (Imaging) Congress*, Heidelberg, Germany, July 25-28, 2016, 1-3.

Parker, M.D., Jones, L.A., Hunter, I.W., Taberner, A.J., Nash, M.P., Nielsen, P.M., "Multidirectional In Vivo Characterization of Skin using Wiener Nonlinear Stochastic System Identification Techniques," *Journal of Biomechanical Engineering*, 139:011004:1-11, 2017.

Mirvakili, S., and Hunter, I.W., "Multidirectional Artificial Muscles from Nylon," *Advanced Materials*, 29: 1604734(1-7), 2017, (DOI:10.1002/adma.201604734).

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Hogan, N.C., Anahtar, M., Taberner, A.J., and Hunter I.W., “Delivery of Immunoreactive Antigen Using A Controllable Needle-Free Jet Injector,” *Journal of Controlled Release*, 258:73-80, 2017, (<https://doi.org/10.1016/j.jconrel.2017.05.003>).

Mirvakili, S.M., and Hunter, I.W., “Fast Torsional Artificial Muscles from NiTi Twisted Yarns,” *ACS Applied Materials & Interfaces*, 2017, 9(19):16321–16326, 2017, (DOI: 10.1021/acsami.7b02335).

Mirvakili, S.M., and Hunter, I.W., “Vertically Aligned Niobium Nanowire Arrays for Fast Charging Supercapacitors,” *Advanced Materials*, 29:1700671:1-6, 2017, (DOI: 10.1002/adma.201700671).

Mirvakili, S., and Hunter, I.W., “A Torsional Artificial Muscle from Twisted Nitinol Microwire,” *Proceedings of SPIE 10163, Electroactive Polymer Actuators and Devices (EAPAD)*, Portland, OR, 2017 (DOI: 10.1117/12.2261712).

Zhang, A., Hogan, N.C., and Hunter, I.W., “Needle-free small-volume Liquid Injection System Powered by a Rotary Actuator,” *39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS)*, Seogwipo, Korea, July 11-15, 2017, 292-295.

Liu, J.H., Hogan, N.C., and Hunter, I.W., “Ampoule and Nozzle Development for Needle-Free Injections,” *Proceedings of the 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS)* Seogwipo, Korea, July 11-15, 2017, 304-308.

Mckeage, J.W., Brennan, K., Park, G., Hogan, N.C., Hunter, I.W., Ruddy, B., Nielsen, P., and Taberner, A.J., “High Speed X-ray Analysis of Liquid Delivery during Jet Injection,” *Proceedings of 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS)*, Seogwipo, Korea, July 11-15, 2017, 296-299.

Johnston, C., Nielsen, P.F., Hunter, I.W., Taberner, A.J., “Vapor Pressure Thermometry at Room Temperature,” *Proceedings of the IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*, Turin, 2017, pp. 1-5.

Mirvakili, S. M., and Hunter, I.W., “Artificial Muscles: Mechanisms, Applications, and Challenges,” *Advanced Materials*, 33:1704407:1-28, 2018, (DOI:10.1002/adma.201704407).

Jeon, I., Park, G. H., Wang, P., Li, J., Hunter, I. W., and Swager, T. M., “Dynamic Fluid-Like Graphene with Ultralow Frictional Molecular Bearing,” *Advanced Materials*, 31(43):1903195:1-7, 2019.