

Lance Cameron Kam

Associate Professor of Biomedical Engineering and
Associate Professor of Medical Sciences (in Medicine, pending)

FIELD OF SPECIALIZATION

Micro-/Nano-scale Engineering of Cell Function and Immune Engineering

Cells possess the remarkable ability to respond to a complex extracellular environment. My research and teaching programs focus on how cells recognize the spatial organization and mechanics of the extracellular environment, with a particular focus on how multiple signals are integrated to drive cell response. Our current projects are on cells of the adaptive immune system, which offer both a firm foundation in cellular physiology and immediate therapeutic potentials. These projects are organized into the following complementary areas of research:

1. Identify the mechanisms by which T cells can recognize the microscale distribution of multiple signals in the immune synapse.
2. Identify the mechanisms of force generation and mechanosensing by T cells.
3. Translate these basic insights of T cell physiology into tools for immunotherapy.
4. Advance the field of molecular and cellular mechanobiology.
5. Development of new tools for micro-/nano-patterning biomolecular systems, combining these cues to capture the rich complexity of the natural cell-cell and cell-environment interfaces.

ACADEMIC TRAINING

December, 1999	Rensselaer Polytechnic Institute <i>Ph.D., Biomedical Engineering</i> <i>Dissertation title: "Control over Neural Cell Function by Micropatterning"</i> <i>Sponsor: Rena Bizios, Ph.D.</i>
May, 1994	University of Hawaii at Manoa, Honolulu, HI <i>M.S. Mechanical Engineering</i>
May, 1991	Washington University in St. Louis, St. Louis, MO <i>B.S. Mechanical Engineering & B.S. Physics</i>

EMPLOYMENT RECORD

2016	(pending, secondary appointment) Associate Professor of Medical Sciences (in Medicine), Columbia University, New York, NY (9/16-)
2012-	Associate Professor of Biomedical Engineering, Columbia University, New York, NY (6/12-
2003	Assistant Professor of Biomedical Engineering, Columbia University, New York, NY (8/03-6/12)
1999	Postdoctoral Fellow, Chemistry, Stanford University, (6/99-6/03) <i>Mentor: Steven G. Boxer, Ph.D.</i>
1994	Graduate Research Assistant, Wadsworth Center, Albany, NY (8/94-5/99) <i>Mentors: Rena Bizios, Ph.D.; William G. Shain, Ph.D.</i>
1991	Graduate Research Assistant, University of Hawaii at Manoa, Honolulu, HI (8/91-5/94) <i>Mentor: Michael J. Antal, Jr., Ph.D.</i>

ACADEMIC AND PROFESSIONAL HONORS

- Rising Star selection.* BMES-SPRBM Conf. on Cellular and Molecular Bioengineering (2011).
- Visiting Professor.* College of Chemistry, Chemical Engineering, and Materials Science, Soochow University, Suzhou, China (2010).
- Guest Editor.* Special issue of *Cellular and Molecular Bioengineering* on “Cell mechanics and Signaling: From Micro to Nano”, (2010).
- Innovative Project Seed Funding.* Columbia University – Research Initiatives for Science and Engineering (2008 – 2010). “Bioengineering Approaches to Study Neural Circuit Assembly”.
- Invited Discussion Leader / Coordinator.* Gordon Research Conference on Biointerface Science (2008).
- Innovative Project Seed Funding.* Columbia University and the Gatsby Charitable Foundations – The Gatsby Initiative in Brain Circuitry (2005 – 2007). “Neuron Networks on Active Arrays”.
- Innovative Project Pilot Award.* Stanford University – Bio-X Interdisciplinary Initiatives (2002 – 2003). Engineering Supported Lipid Bilayers for Study of Cell Signaling
- Individual Postdoctoral Fellowship.* National Institutes of Health, National Institute of General Medical Sciences (2001). Supported Lipid Bilayers for Investigation of Cell-Cell Communication.
- Postdoctoral Fellowship.* Stanford University – National Institutes of Health Genome Training Program (2000). Hybrid DNA Systems in Studies of Supported Lipid Bilayer Dynamics

TEACHING AND RESEARCH TRAINING

Currently Instructor on the following courses

- BMEN E4001, Quantitative Physiology I
- BMEN E4550, Micro-/Nano-scale Structures in Cellular Engineering
- BMEN E4150, Cell as a Machine

PUBLICATIONS

Peer-Reviewed Full Length Original Research Publications (46)

1. Dang*, A.P., De Leo*, S., Bogdanowicz, D.R., Yuan*, D.J., Fernandes, S.M., Brown, J.R., Lu, H.H., and Kam, L.C., “Enhanced Activation and Expansion of T Cells Using Mechanically Soft Elastomer Fibers”, *Advanced Biosystems*, **2**:1700167 (2018).
2. Morrell, A.E., Brown, G.N., Robinson, S.T., Sattler, R.L., Baik, A.D., Zhen, G., Cao, X., Bonewald, L.F., Jin*, Weiyang, Kam, L.C., and Guo, X.E. “Mechanically induced Ca²⁺ oscillations in osteocytes release extracellular vesicles and enhance bone formation”, *Bone Research*, **6**:6 (2018).
3. Mayya, V., Judokusumo*, E., Abu Shah, E., Peel, C.G., Neiswanger, W., Depoli, D., Blair, D.A., Wiggins, C.H., Kam, L.C., and Dustin, M.L., “Durable Interactions of T Cells with T Cell Receptor Stimuli in the Absence of a Stable Immunological Synapse”, *Cell Reports*, **22**:340-349 (2018).
4. Lambert*, L.H., Goebrecht*, G.K.E., De Leo*, S.E., O’Connor, R.S., Nunez-Cruz, S., Li, T.-D., Yuan*, J., Milone, M.C., and Kam, L.C., “Improving T Cell Expansion with a Soft Touch”, *Nano Letters*, **17**: 821-6 (2017).
5. Hu, J., Gondarenko, A.A., Dang*, A.P., Bashour*, K.T., O’Connor, R.S., Lee, S., Liapis, A., Ghassemi, S., Milone, M.C., Sheetz, M.P., Dustin, M.L., Kam, L.C., and Hone, J.C., “High-throughput mechanobiology screening platform using micro- and nanotopography”, *Nano Letters*, **16**: 2198-204 (2016).

6. Basu, R., Whitlick, B.M., Husson, J., Le Floc'h, A.L., Jin*, W., Oyler-Yanic, A., Dotiwala, F., Giannone, G., Hivroz, C., Biais, N., Lieberman, J., Kam, L.C., and Huse., M., "Cytotoxic T cells use mechanical force to potentiate target cell killing", *Cell*, **165**:100-10 (2016).
7. Lee*, J.H., Dustin, M.L., and Kam, L.C., "A microfluidic platform reveals differential response of regulatory T cells to micropatterned costimulation arrays", *Integrative Biology*, **7**:1442-53 (2015).
8. Tabdanov*, E., Gondarenko, S., Kumari, S., Liapis, A., Dustin, M.L., Sheetz, M.P., Kam, L.C., Iskratch, T., "Micropatterning of TCR and LFA-1 ligands reveals complementary effects on cytoskeleton mechanics in T cells", *Integrative Biology*, **7**:1272-84 (2015).
9. Kumari, S., Depoil, D., Martinelli, R., Judokusumo, E.*, Carmona, G., Gertler, F.B., Kam, L.C., Carman, C.V., Burkhardt, J.K., Irvine, D.J., and Dustin, M.L., "Actin foci facilitate activation of the phospholipase C- γ in primary T lymphocytes via the WASP pathway", *eLife*, **4**:e04953 (2015).
10. Choudhuri, K., Llodra, J. Roth, E.W., Tsai, J.*, Gordo, S., Wucherpennig, K.W., Kam, L.C., Stokes, D.L., and Dustin, M.L., "Polarized release of T-cell-receptor-enriched microvesicles at the immunological synapse", *Nature*, **507**: 118-23 (2014).
11. Bashour, K.T.*, Tsai, J.*, Shen, K.*, Lee, J.H.*, Sun, E.*, Milone, M.C., Dustin, M.L., and Kam L.C., "Crosstalk between CD3 and CD28 is spatially modulated by protein lateral mobility.", *Molecular and Cellular Biology*, **34**:955-64 (2013).
12. Bashour, K.T.*, Gondarenko, A.*, Chen, H.*, Shen, K.*, Liu, X., Huse, M., Hone, J.C., and Kam, L.C., "CD28 and CD3 have complementary roles in T-cell traction forces", *Proceedings of the National Academy of Sciences, USA*, **111**: 2241-6 (2014).
13. Wang, Y., Xu, Z., Kam, L.C., and Shi, P.*, "Site-specific differentiation of neural stem cell regulated by micropatterned multicomponent interfaces", *Advanced Healthcare Materials*, **3**:214-20 (2014).
14. O'Connor R.S., Hao, X., Shen, K.*, Bashour, K.*, Akimova, T., Hancock, W.W., Kam, L.C., Milone, M.C., "Substrate rigidity regulates human T cell activation and proliferation.", *Journal of Immunology*, **189**:1330-9 (2012).
15. Judokusumo*, E., Tabdanov*, E., Kumari, S., Dustin, M.L., and Kam, L.C., "Mechanosensing in T Lymphocyte Activation", *Biophysical Journal – Letters* **102**:L5-7 (2012).
16. Nedelec, S., Peljto, M., Shi*. P., Amoroso, M.W., Kam, L.C., and Wichterle, H., "Concentration Dependent Requirement for Local Protein Synthesis in Motor Neuron Subtype Specific Response to Axon Guidance Cues", *Journal of Neuroscience*, **32**:1496-506 (2012).
17. Lei, N., Ramakrishnan, S., Shi*, P., Orcutt, J.S., Yuste, R., Kam, L.C., and Shepard, K.L. "High-resolution extracellular stimulation of dispersed hippocampal culture with high-density CMOS multielectrode array based on non-Faradaic electrodes." *Journal of Neural Engineering*, **8**:044003 (2011).
18. Shi*, P., Nedelec, S., Wichterle, H., and Kam, L.C., "Combined Microfluidics / Protein Patterning Platform for Pharmacological Interrogation of Axon Pathfinding." *Lab Chip*, **10**:1005-10 (2010).
19. Tsai, J., & Kam, L.C.. "Lateral Mobility of E-cadherin Enhances Cell Response", *Cellular and Molecular Bioengineering*. **3**: 84-90 (2010).
20. Shi*, P., Shen*, K., Ghassemi, S., Hone, J., and Kam, L.C., "Dynamic Force Generation by Neural Stem Cells", *Cellular and Molecular Bioengineering*, **2**: 464-74 (2009).
21. Shen*, K., Tsai*, J., Shi*, P., and Kam, L.C., "Self-aligned Supported Lipid Bilayers for Patterning the Cell-Substrate Interface", *Journal of the American Chemical Society - Communications*, **131**:13204-5 (2009).
22. Tsai*, J., and Kam, L.C., "Rigidity-dependent Crosstalk Between Integrin and Cadherin Signaling." *Biophysical Journal-Biophysical Letters*, **96**: L39-41 (2009).
23. Shen*, K., Thomas, V.K., Dustin, M.L., and Kam, L.C., "Micropatterning of Costimulatory Ligands Enhances CD4+ T Cell Function." *Proceedings of the National Academy of Sciences*,

- USA, **105**:7791-6 (2008). *Recognitions: PNAS From the Cover, "Most Read Articles" of PNAS, June 2008.*
24. Tsai*, J., Sun*, E., Gao⁺, Y., Hone, J.C., and Kam, L.C., "Non-Brownian Diffusion of Membrane Molecules in Nanopatterned Supported Lipid Bilayers." *Nano Letters*, **8**:425-30 (2008). *Recognitions: Cited in Faculty of 1000 Biology.*
 25. Shi*, P., Shen*, K., and Kam, L.C., "Local Presentation of L1 and N-cadherin in Multicomponent, Microscale Patterns Differentially Direct Neuron Function in Vitro." *Developmental Neurobiology*, **67**:1765-76 (2007).
 26. Perez⁺, T.D., Nelson, W.J., Boxer, S.G., and Kam, L., "E-cadherin Tethered to Supported Lipid Bilayers as a Model for Cell Adhesion," *Langmuir*, **21**: 11963-8 (2005). *Recognitions: Cited in Faculty of 1000 Biology.*
 27. Cherniavskaya⁺, O., Chen⁺, C.J., Heller, E., Sun*, E., Provenzano*, J., Kam, L., Hone, J., Sheetz, M.P., and Wind, S.J., "Fabrication and surface chemistry of nanoscale bioarrays designed for the study of cytoskeletal protein binding interactions and their effect on cell motility," *Journal of Vacuum Science and Technology B* **23**: 2972-8 (2005).
 28. Kam, L. and Boxer, S.G., "Spatially Selective Manipulation of Supported Lipid Bilayers by Laminar Flow: Steps Towards Biomembrane Microfluidics," *Langmuir*, **19**: 1624-1631 (2003).
 29. Kam, L., Shain, W., Turner, J.N., and Bizios, R., "Selective Adhesion of Astrocytes to Surfaces Modified with Immobilized Peptides," *Biomaterials* **23**:511-515 (2002).
 30. Ajo-Franklin, C.M., Kam, L., and Boxer, S.G., "High Refractive Index Substrates for Fluorescence Microscopy of Biological Interfaces with High z-Resolution," *Proceedings of the National Academy of Sciences, USA*, **98**: 13643-13648 (2001).
 31. Kam, L. and Boxer, S.G., "Cell Adhesion to Protein-micropatterned Supported Lipid Bilayer Membranes," *Journal of Biomedical Materials Research* **55**: 487-495 (2001).
 32. Kam, L., Shain, W., Turner, J.N., and Bizios, R., "Axonal Outgrowth of Hippocampal Neurons on Micro-Scale Networks of Polylysine-Conjugated Laminin," *Biomaterials* **22**: (2001) 1049-1054 (2001).
 33. Lu, L., Nyalakonda, K., Kam, L., Bizios, R., Gopferich, A., Mikos, A.G., "Retinal Pigment Epithelial Cell Adhesion on Novel Micropatterned Surfaces Fabricated from Synthetic Biodegradable Polymers," *Biomaterials*, **22**: 291-7 (2001).
 34. Kam, L., and Boxer, S.G., "Formation of Supported Lipid Bilayer Composition Arrays by Controlled Mixing and Surface Capture," *Journal of the American Chemical Society* **122**: 12901-12902 (2000).
 35. Turner, A.M.P., Dowell, N., Turner, S.W.P., Kam, L., Isaacson, M., Turner, J.N., Craighead, H.G., and Shain, W., "Attachment of Astroglial Cells to Microfabricated Pillar Arrays of Different Geometries," *Journal of Biomedical Materials Research* **51**:430-441 (2000).
 36. Kung, L.A., Kam, L., Hovis, J.S., and Boxer, S.G., "Patterning Hybrid Surfaces of Proteins and Supported Lipid Bilayers," *Langmuir* **16**:6773-6776 (2000).
 37. James, C.D., Davis, R.C., Meyer, M., Perez, A., Turner, S., Withers, G., Kam, L., Banker, G., Craighead, H.G., Isaacson, M., Turner, J.N., Shain, W., "Aligned Microcontact Printing of Micrometer Scale Polylysine Structures for Controlled Growth of Cultured Neurons on Planar Microelectrode Arrays," *IEEE Transactions in Biomedical Engineering* **47**:17-21 (2000).

38. Kam, L., Shain, W., Turner, J.N., and Bizios, R., "Correlation of Astroglial Cell Function on Micro-patterned Surfaces with Specific Geometric Parameters," *Biomaterials* **20**:2343-2350 (1999).
39. Lu, L., Kam, L., Hasenbein, M., Nyalakonda, K., Bizios, R., Gpferich, A., Young, J.F., and Mikos, A.G., "Retinal Pigment Epithelial Cell Function on Substrates with Chemically Micropatterned Surfaces," *Biomaterials*, **20**:2351-2361 (1999).
40. James, C.D., Davis, R.C., Kam, L., Craighead, H.G., Isaacson, M., Turner, J.N., Shain, W., "Patterned Protein Layers on Solid Substrates by Thin Stamp Microcontact Printing," *Langmuir* **14**: 741-744 (1998).
41. Turner, S., Kam, L., Isaacson, M., Craighead, H.G., Shain, W.G., and Turner, J.N., "Cell Attachment on Silicon Nanostructures," *Journal of Vacuum Science and Technology B* **15**: 2848-54 (1997).
42. Craighead, H.G., Turner, S.W., Davis, R.C., James, C., Perez, A.M., St. John, P.M., Isaacson, M.S., Kam, L., Shain, W., Turner, J.N., and Banker, G., "Chemical and Topographical Surface Modification for Control of Central Nervous System Cell Adhesion," *Journal of Biomedical Microdevices* **1**: 49-64 (1998).
43. St. John, P., Kam, L., Turner, S.W., Craighead, H.G., Isaacson, M., Turner, J.N., Shain, W., Preferential Glial Cell Attachment to Microcontact-printed Surfaces. *Journal of Neuroscience Methods* **75**: 171-177 (1997).
44. Allen, S.G., Kam, L., Zemann, A.J., Antal, M.J., "Fractionation of Sugar Cane with Hot, Compressed, Liquid Water," *Industrial and Engineering Chemistry Research* **35**: 2709-2715 (1996).
45. Hebenicht, C., Kam, L.C., Wilschut, M.J., Antal, M.J. "Homogenous Catalysis of ETBE Formation from *tert*-Butanol in Hot, Compressed Liquid Ethanol," *Industrial and Engineering Chemistry Research* **34**: 3784 (1995).
46. Carlsson, M., Hebenicht, C., Kam, L., Antal, M.J. "Study of the Sequential Conversion of Citric to Itaconic to Methacrylic Acid in Near-Critical and Supercritical Water," *Industrial and Engineering Chemistry Research* **33**: 1989-1996 (1994).

Peer-Reviewed/Invited Review Articles and Commentaries (11)

1. Lee*, J.-H., and Kam, L.C., "Revealing the role of microscale architecture in immune synapse function through surface micropatterning," *Methods in Molecular Biology*, **1584**:291-306 (2017).
2. Jin*, W., Black, C.T., Kam, L.C., and Huse, M., "Probing synaptic biomechanics using micropillar arrays," *Methods in Cell Biology*, **1584**:333-346 (2017).
3. Dustin, M.L., and Kam, L.C., "Tapping out a mechanical code for T cell triggering," *Journal of Cell Biology*, **213**: 501-3 (2016).
4. Dutta*, D., and Kam, L.C., "Micropatterned, multicomponent supported lipid bilayers for cellular systems," *Methods in Cell Biology*, **120**: 53-67 (2014).
5. Kam, L.C., Shen*, K., and Dustin, M.L., "Micro- and Nanoscale Engineering of Cell Signaling," *Annual Review of Biomedical Engineering*, **15**: 305-26 (2013).
6. Milone, M.C., and Kam, L.C., "Investigative and clinical applications of synthetic immune synapses," *Wiley Interdisciplinary Reviews Nanomedicine and Nanobiotechnology*, **5**: 75-85 (2013).
7. Shen*, K., Milone, M.C., Dustin, M.L., and Kam, L.C., "Nanoengineering of Immune Cell Function", *MRS Proceedings* (2010).

8. Kam, L.C., and Roy, P. “Special Issue: Cell Mechanics and Signaling: From Micro to Nano” *Cellular and Molecular Bioengineering*, **3**: 1-2 (2010).
9. Kam, L.C., “Capturing the nanoscale complexity of cellular membranes in supported lipid bilayers” *Journal of Structural Biology*, **168**: 3-10 (2009).
10. Shen*, K., Qi*, J., and Kam, L.C., “Microcontact Printing of Proteins for Cell Biology” *Journal of Visualized Experiments*, **22** (2008).
11. Hone, J., and Kam, L., “Nanobiotechnology: Looking Inside Cell Walls.” *Nature Nanotech*, **2**: 140-141 (2007).

PATENTS (12)

1. Law, B.K.J., Low, H.Y., Suryana, M., Wee, K.F., Sheetz, M.P., Yim, K.F.E., Ng, Z.J., Teo, K.K., and Kam, L.C., “Process for making an array”, US Patent Application US20180017551A1 (2018).
2. Kam, L.C., Lu, H.L., De Leo, S.E., Bashour, K.T., Bogdanowicz, D., Chuang, P., “Methods, Compositions, and Systems for Activation and Expansion of Cells”, Pending, US Patent application 15/302,475(2017).
3. Kam, L.C., Dustin, M.L., and Yeager, K.E., “A cell loading well for microscopy of rare cells”, Provisional (2012).
4. Hickey, G., and Kam, L.C., “Enhanced expansion of T cells by pharmacological inhibition of cell contractility”, Provisional (2012).
5. Hickey, G., and Kam, L.C., “Bead-based format for rigidity-dependent control over ex vivo expansion of cells”, Provisional (2012).
6. Milone, M.C., Kam, L.C., Shen, K., Hao, X., and O’Conner, R., “Activation and Expansion of T Cell Subsets Using Biocompatible Solid Substrates with Tunable Rigidity”, Pending, US Patent Application 14/342599 (2011).
7. Kam, L., “Image-side Optical Sectioning in Microscopy”, Provisional (2011).
8. Milone, M.C, Shen, K., and Kam, L.C., “Ex vivo activation and expansion of human T cell subsets using biocompatible solid substrates with tunable rigidity”, Provisional (2011).
9. Kam, L., Shen, K., Dustin, M.L., Thomas, V.K., “Micropatterned T cell stimulation”, US Patent application 20080317724 (2008).
10. Ishii, C., Boxer, S.G., and Kam, L., “Spatially encoded and mobile arrays of tethered lipids”, Pending, US Patent application 20040121377 (2004).
11. Boxer, S.G., and Kam, L., “Method for generating pure populations of mobile membrane-associated biomolecules on supported lipid bilayers”, US Patent application 20040018601 (2004).
12. Boxer, S.G., and Kam, L., “Biosensor arrays and methods”, US Patent No. 6,503,452 (2000).

CURRENT RESEARCH GRANT ACTIVITY

Principal Investigator: National Institutes of Health (NIAID, R01AI110593)

PI: L Kam, Co-I: H Lu

“Advanced Rigidity-based Material for Enhanced Immunotherapy”

New technologies for controlling the expansion of T cells have great potential for advancing adoptive immunotherapy. This project develops a fiber-based polymer system to stimulate T cells, leveraging the enhanced activation and expansion observed on materials of lower rigidity.

Principal Investigator: National Institutes of Health (NIAID, U24AI118669)

PI: L Kam, Co-I S Sia

“Sample Sparing Chambers for Imaging of T cell Response and Function”

This project seeks to develop and deploy microscopy chambers that provide high-efficiency imaging of rare T cell populations.

Principal Investigator: National Institutes of Health (NIAID, R21AI119953)

“Controllable Rigidity Surfaces for T Cell Mechanobiology”

This project seeks to develop a surface to T cell mechanobiology that presents a rigidity that can be controlled using a magnetic field.

Principal Investigator: National Science Foundation (1562905)

Co-PI's: M Huse and L Kam

“Mechanopotential of Cytotoxic T Cell Function”

This project seeks to unveil the role of mechanical forces in CD8+ T cell killing of APC. Specific goals include characterization of forces exerted by these cells and their underlying molecular mechanisms.

Principal Investigator: National Science Foundation (1743420)

“Predictive Optimization of T Cell Expansion”

This project seeks to identify proteomic and genetic biomarkers that will predictively identify which of a variety of platforms for initiating T cell expansion will work best for an individual undergoing treatment for CLL.