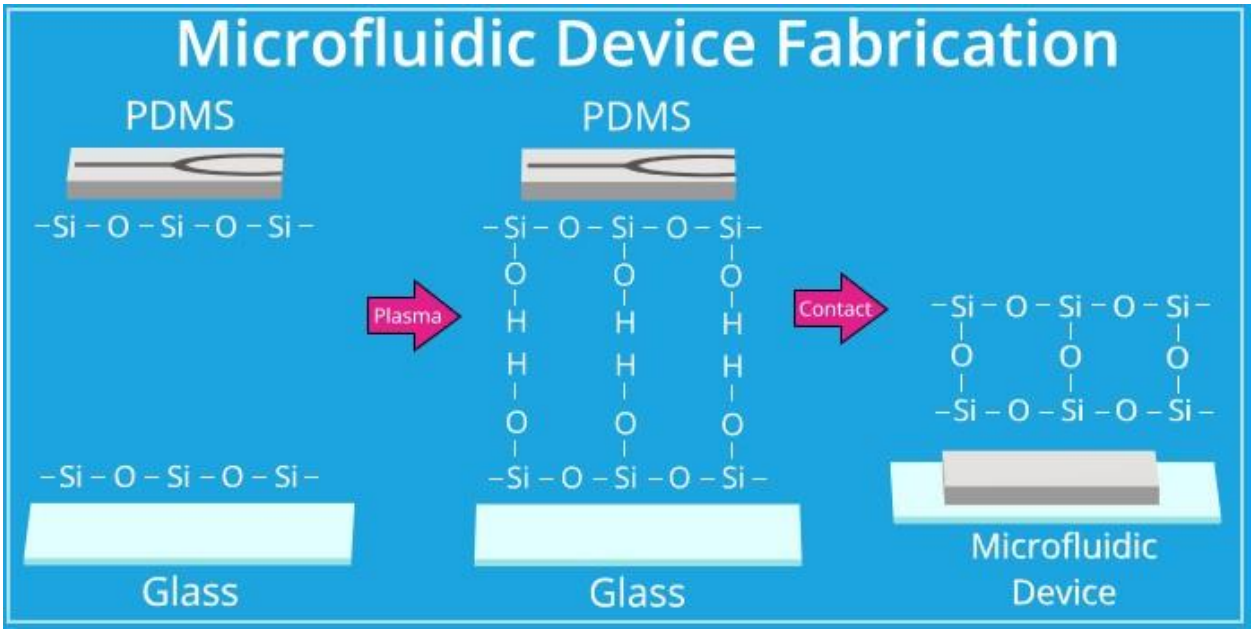
A Brief Guide to Microfluidic Device Applications
In the Life Sciences



Microfluidic technology is a rapidly growing tool in the life sciences that allows researchers to exert an unprecedented level of control over cells, biomolecules, and their microenvironments. Working within channels smaller than ten micrometers (microchannels), researchers can manipulate individual components of their biological system of interest with high resolution. There are many other key advantages to working with small size and volume, including portability, low cost, rapid prototyping, easier automation, and the ability to work with limited sample sizes and reagents. As a result, microfluidic device research has spread prodigiously over the last 20 years, leading to a multitude of microfluidic device applications.

Harrick Plasma cleaners are used extensively for the fabrication of microfluidic devices and to provide beneficial surface functionalities in microchannels. Plasma is a partially ionized gas consisting of electrons, ions and neutral atoms or molecules used frequently to remove organic contamination and modify material surface properties. In fabricating microfluidic devices made from polydimethylsiloxane (PDMS) and glass, an air or oxygen plasma introduces oxygen-containing functional groups, ultimately creating a device surface with silanol groups (SiOH). When placed in contact, the silanol groups react to form siloxane bridges (Si-O-Si) that provide a water-tight seal. Rigid thermoplastic devices can also be bonded in this way with the addition of an intermediate coating such as (3-Aminopropyl) triethoxysilane (APTES). In addition to bonding, plasma treatment increases hydrophilicity and improves aqueous fluid flow in microchannels.

In this note, you will find brief overviews of microfluidic device applications and references to further help in microfluidic device research. For even more resources, please feel free to visit our Technical Library where you can find over 2,000 Technical Articles related to microfluidic device fabrication and development.

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Applications

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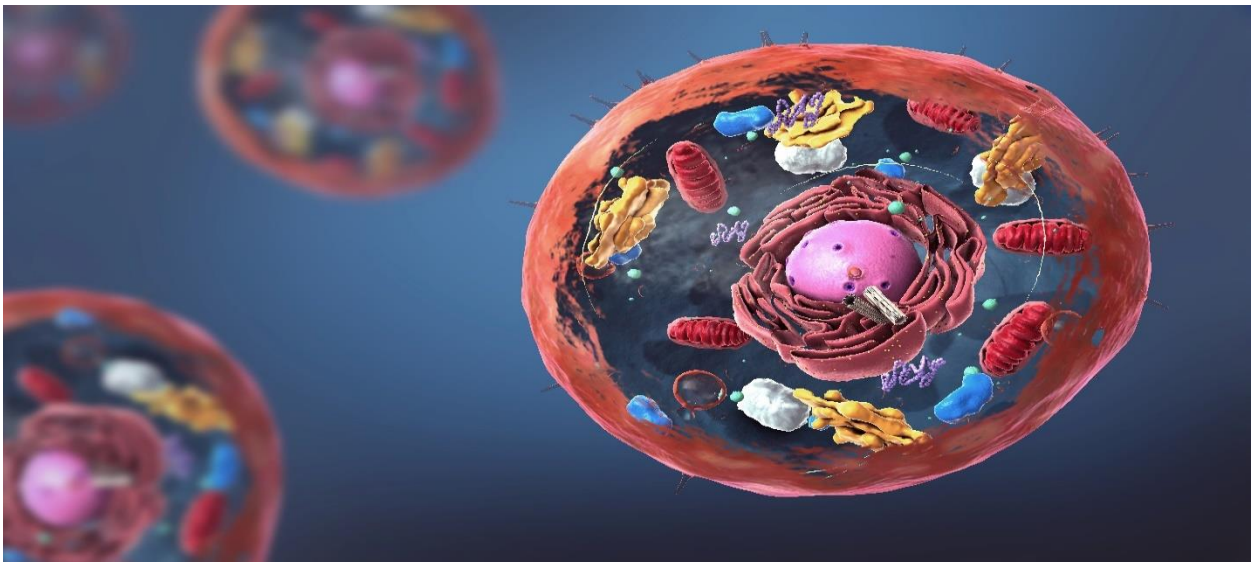

Cell Biology

Microfluidic devices provide researchers with a method of probing cell biology through the manipulation of their microscale environments. Cells rely on their connections with the extracellular matrix and neighboring cells to regulate vital functions. As a result, the chemical and mechanical properties of a material's surface significantly influence viability, proliferation, and differentiation. Key attributes that can be controlled in the fabrication of microfluidic devices include fluid dynamics, shear forces, mechanical strength and elasticity, surface charge and functional groups. Exploiting these properties in three-dimensional microchannels enables researchers to better mimic a specific cell type's native environment, thereby eliciting the cell's native morphology and function.

Plasma cleaning introduces polar, biologically beneficial functional groups (Carboxyl, Carbonyl, Hydroxyl and Amine) to microchannel surfaces that are essential to several cell biology applications. These polar functional groups increase hydrophilicity and improve aqueous fluid flow through the microfluidic devices. Surface wettability reduces the formation of bubbles that have been shown to block channels and negatively impact cell viability. In addition, the native biological environment is hydrophilic, making this property essential for biomimicry. Often, plasma treated surfaces show improved cell adhesion and nonspecific adsorption of cell media constituents. Finally, plasma treatment enables the introduction of polar surface coatings and extracellular matrix constituents. Using plasma, researchers can design cell environments through the introduction of these coatings.

Here, you will find summaries of microfluidic devices used for cell biology studies, with a focus on the study of individual cell's structures and function, usually regarding one cell type or lineage. For more information on microfluidic devices in which complex tissues or organ structures are constructed, please see the Organ on a Chip section.

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Cell Culture

Cell culture technology is rapidly advancing towards more robust 3D platforms that better mimic human physiology. The use of standard 2D cell culture platforms, such as cell culture flasks and petri dishes, result in flat, abnormal cell morphologies. While these are suitable for common cancer cell lines, human cell lines and induced pluripotent stem cells (IPSCs) may require native morphologies to function as intended. 3D microfluidic devices are often preferred because of their ability to recapitulate the extracellular matrix (ECM) and other structures. This has been shown to be particularly important in the study of stem cells where researchers have been able to drive progenitor cells down specific cell lineages by controlling chemical and mechanical properties of the cell culture platform. With this improved biomimicry, higher uniformity can be achieved in cell populations.

In the following articles, microfluidic devices are employed for the purpose of culturing cells. In some cases, plasma treatment is shown to improve cell adhesion. Additionally, plasma has been used to facilitate adsorption of ECM constituents or polymers such as Poly-L-lysine (PLL) that can further improve biomimicry.

Cell Culture Articles from Harrick Plasma Users

- Han S, Kim J, Li R, Ma A, Kwan V, Luong K, and Sohn LL. "Hydrophobic Patterning-Based 3D Microfluidic Cell Culture Assay". Adv. Healthcare Mater. 2018 7: 1800122 10.1002/adhm.201800122
- Giupponi E, Visone R, Occhetta P, Colombo F, Rasponi M, and Candiani G. "Development of a microfluidic platform for high-throughput screening of non-viral gene delivery vectors". Biotechnol. Bioeng. 2018 115: 775-784 10.1002/bit.26506
- Occhetta P, Visone R, and Rasponi M. "High-Throughput Microfluidic Platform for 3D Cultures of Mesenchymal Stem Cells". Methods Mol. Biol. 2017 1612: 303-323 10.1007/978-1-4939-7021-6_23

Molecular Biology

Following cell culturing, researchers can proceed with the study of molecular dynamics underpinning cell functions and interactions. The focus of this research varies widely, containing such topics as the study of cell signaling, genetics, transport, organoids and much more. To elucidate meaningful information regarding cell structures and internal mechanisms, cells must function as they would in their native environments. Again, biomimicry and the control of biomolecules with higher resolution plays an important role in driving native cell behavior. Furthermore, many microfluidic designs offer optical transparency for analysis with fluorescent microscopy, a key technology in the study of molecular biology. As a result, researchers can observe and record events in real time with living cells in the microchannels.

In the following articles, cells are analyzed using specially designed microfluidic devices that probe various cell properties.

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Molecular Biology Articles from Harrick Plasma Users

- Wang ZZ, Wood MD, Mackinnon SE, and Sakiyama-Elbert SE. "A microfluidic platform to study the effects of GDNF on neuronal axon entrapment". J. Neurosci. Methods 2018 308: 183-191 10.1016/j.jneumeth.2018.08.002
- Pham QL, Rodrigues LN, Maximov MA, Chandran VD, Bi C, Chege D, Dijamco T, Stein E, Tong NAN, Basuray S, and Voronov RS. "Cell Sequence and Mitosis Affect Fibroblast Directional Decision-Making During Chemotaxis in Microfluidic Mazes". Cell. Mol. Bioeng. 2018 11: 483-494 10.1007/s12195-018-0551-x
- Hipolito J, Peretz-Soroka H, Torres AM, Booy E, Yang K, Gupta M, Meier M, McKenna S, Koch M, Santos S, Stetefeld J, and Lin F. "Microfluidic Devices for Studying the Effect of Netrin-1 on Neutrophil and Breast Cancer Cell Migration". Adv. Biosystems 2018 2: 1700178 10.1002/adbi.201700178

Biomechanics

With microfluidic devices, researchers are able to introduce dynamic physical forces that can be used to investigate cell biology in large populations. Microfluidic devices inherently subject cells to more native physical forces through the introduction of fluid flow. By placing cells in shear stress, researchers have even been able to study the deformability of large populations of single cells in near real time. Furthermore, the polymers that typically comprise microfluidic devices themselves can be stretched and strained to elicit biological responses in adhered cells.

In the following articles, microfluidic devices are designed specifically for biomechanical studies of cell biology.

Biomechanics Articles from Harrick Plasma Users

- Li W, Mao S, Khan M, Zhang Q, Huang Q, Feng S. “Responses of cellular adhesion strength and stiffness to fluid shear stress during tumor cell rolling motion”. ACS Publications, 2019. 10.1021/acssensors.9b00678
- Deng Y, Davis SP, Yang F, Paulsen KS, Kumar M, Sinnott DeVaux R, Wang X, Conklin DS, Oberai A, Herschkowitz JI, and Chung AJ. "Inertial Microfluidic Cell Stretcher (iMCS): Fully Automated, High-Throughput, and Near Real-Time Cell Mechanotyping". Small 2017 13: 1700705 10.1002/smll.201700705

Cell Sorting

Microfluidic devices are commonly used to sort cells based on key characteristics, such as size, affinity, or chemical attributes, with high sensitivity and throughput. Several mechanisms for separation have been reported, including inertial focusing, droplet formation or manipulation via optical tweezers, magnetic forces, or acoustic waves. Microfluidic devices can also be designed to contain mechanical or electrochemical switches that direct cells into different microchannels. Cell sorting in microfluidic devices typically can be performed faster than other techniques as separation occurs continuously. Sorting cells is particularly important for studies requiring single cell resolution, such as for Single Cell Sequencing.

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In the following articles, cells are sorted into distinct groups depending on specifically targeted characteristics.

Cell Sorting Articles from Harrick Plasma Users

- Abdulla A, Liu W, Gholamipour-Shirazi A, Sun J, and Ding X. "High-Throughput Isolation of Circulating Tumor Cells Using Cascaded Inertial Focusing Microfluidic Channel". Anal. Chem. 2018 90: 4397-4405 10.1021/acs.analchem.7b04210
- Hisey CL, Dorayappan KDP, Cohn DE, Selvendiran K, and Hansford DJ. "Microfluidic affinity separation chip for selective capture and release of label-free ovarian cancer exosomes". Lab. Chip 2018 18: 3144-3153 10.1039/c8lc00834e
- Song Z, Li M, Li B, Yan Y, and Song Y. "Automatic detecting and counting magnetic beads-labeled target cells from a suspension in a microfluidic chip". Electrophoresis 2018 10.1002/elps.201800345
- Shields CW 4th, Reyes CD, López GP. “Microfluidic cell sorting: a review of the advances in the separation of cells from debulking to rare cell isolation.” Lab Chip. 2015;15(5):1230-1249. 10.1039/c4lc01246a

Single Cell Sequencing

Single cell RNA sequencing (ScRNA-seq) is a powerful, rapidly evolving tool used to identify individual cells and evaluate their unique characteristics and function. The development of this technology spurred the creation of the Human Cell Atlas, an international scientific movement and successor to the human genome project. While every cell in the human body shares a genetic blueprint, each individual cell expresses a different set of genes dependent on their environment and lineage. ScRNA-seq enables researchers to differentiate cells with greater resolution to better understand the highly ordered tissues that comprise the human body.

Plasma treatment is integral to several single cell sequencing methodologies including Drop-Seq and Seq-Well. In the Drop-Seq protocol, individual cells are encapsulated in nanoliter sized droplets with barcoded microbeads using a specially designed microfluidic device. As a result, single cell resolution is achieved in all subsequent steps.

Single Cell Sequencing Articles from Harrick Plasma Users

- Gierahn TM, Wadsworth II MH, Hughes TK, Bryson BD, Butler A, Satija R, Fortune S, Love JC, and Shalek AK. "Seq-Well: portable, low-cost RNA sequencing of single cells at high throughput". Nat. Methods 2017 14: 395 10.1038/nmeth.4179
- Kim SC, Clark IC, Shahi P, and Abate AR. "Single-Cell RT-PCR in Microfluidic Droplets with Integrated Chemical Lysis". Anal. Chem. 2018 90: 1273-1279 10.1021/acs.analchem.7b04050
- Sousa C, Golebiewska A, Poovathingal SK, Kaoma T, Pires-Afonso Y, Martina S, Coowar D, Azuaje F, Skupin A, Balling R, Biber K, Niclou SP, and Michelucci A. "Single-cell transcriptomics reveals distinct inflammation-induced microglia signatures". EMBO Rep. 2018 19: e46171 10.15252/embr.201846171
- Yuan J, Sims PA. An Automated Microwell Platform for Large-Scale Single Cell RNA-Seq. Sci Rep. 2016 6: 33883. 10.1038/srep33883

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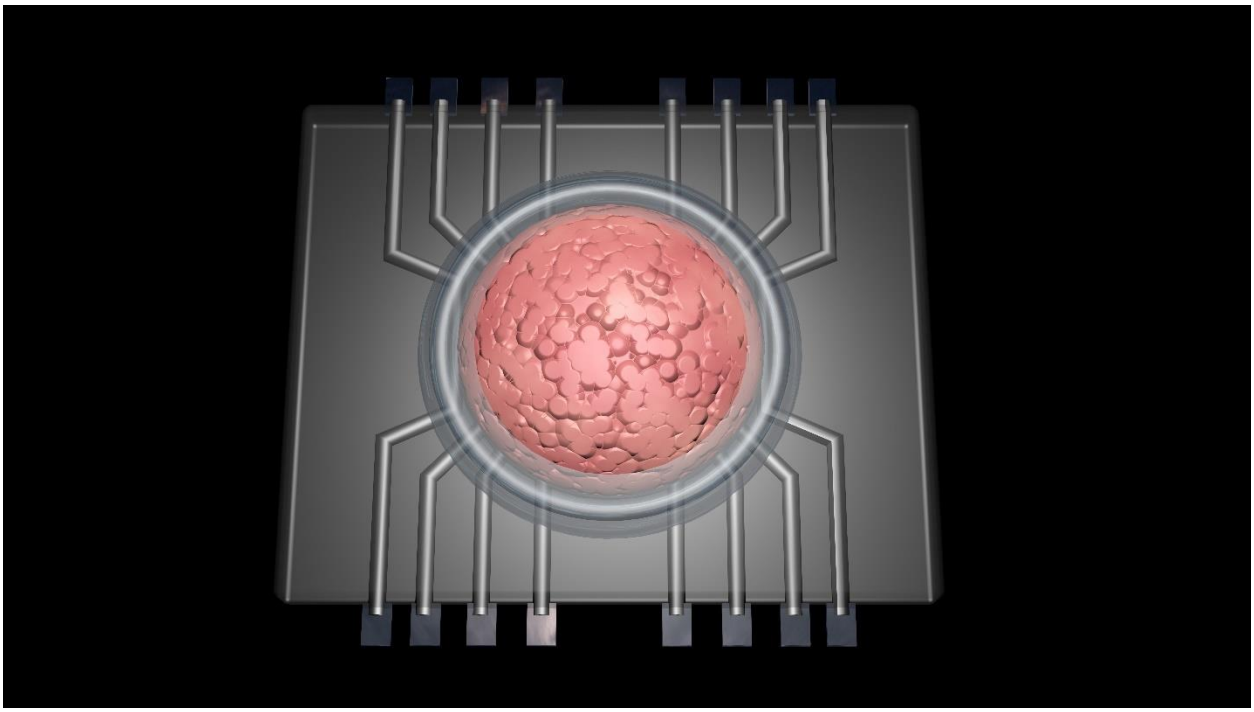

Organ on a Chip Models

Organ on a chip models constructed in microfluidic devices offer a unique set of rewards for researchers studying complex tissues and biological systems. With fluid flow through microchannels, organ on a chip models can provide essential nutrients and oxygen, spatiotemporal chemical gradients and dynamic mechanical forces that support and drive the development of targeted organ structures. As a result, researchers have been able to recapitulate specific tissues, including tissues of the lung, heart, muscle, liver, teeth and more. They have also been able to test and study the formation of tumors, wound recovery, and membrane transport. The ability to recapitulate specific biological structures (healthy or in a disease state) advances the modeling of drug delivery, disease progression or substance toxicity.

In the following application briefs, you will find organ on a chip microfluidic devices and their uses in various fields of research. This section is oriented towards biological systems with multiple cell types and complex structures. For more information on research investigating individual cells and cell culturing, please see the above Cell Biology section. More information on organ on a chip models is available in our Organ on a Chip application note on our website.

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Drug Delivery

Microfluidic devices offer advanced *in vitro* testing of drug delivery, eliminating many of the negative qualities present in conventional models. Despite significant physiological differences, animals are relied on heavily for drug testing before clinical trials can begin in humans. Access to animals limits the number of drugs that can be effectively tested, particularly when large animals are needed. Organ on a chip models can be manufactured and distributed in mass, providing greater access for drug development. Furthermore, organ on a chip models have been developed using induced pluripotent stem cells (IPSCs), opening the door to personalized drug delivery testing.

In the following articles, organ on a chip models are developed to test the efficacy of a novel drug or therapy *in vitro*.

Drug Delivery Articles from Harrick Plasma Users

- Kuhn P, Eyer K, and Dittrich PS. "A microfluidic device for the delivery of enzymes into cells by liposome fusion". Eng. Life Sci. 2018 18: 149-156 10.1002/elsc.201600150
- Osaki T, Uzel SGM, Kamm RD. “On-chip 3D neuromuscular model for drug screening and precision medicine in neuromuscular disease”. Nat Protoc. 2020;15(2):421-449. 10.1038/s41596-019-0248-1
- Leung MHM, and Shen AQ. "Microfluidic Assisted Nanoprecipitation of PLGA Nanoparticles for Curcumin Delivery to Leukemia Jurkat Cells". Langmuir 2018 34: 3961-3970 10.1021/acs.langmuir.7b04335
- Lee JS, Romero R, Han YM, Kim HC, Kim CJ, Hong J-S, and Huh D. "Placenta-on-a-chip: a novel platform to study the biology of the human placenta". J. Matern. Fetal Neonatal Med. 2016 29: 1046--1054 10.3109/14767058.2015.1038518

Pathology Models

Before successful treatments can be developed, researchers must fully understand what drives the progression of a disease within the body. Organ on a chip models help researchers in this endeavor by simulating disease in an environment that can be analyzed easily. These devices can be replicated in mass to observe the various paths that a disease might take *in vitro*. Furthermore, IPSC derived organ on a chip model my facilitate the study of disease progression in specific individuals.

In the following articles, organ on a chip models are developed to study the progression of human diseases *in vitro*.

Pathology Articles from Harrick Plasma Users

- Choi Y, Hyun E, Seo J, Blundell C, Kim HC, Lee E, Lee SH, Moon A, Moon WK, and Huh D. "A microengineered pathophysiological model of early-stage breast cancer". Lab Chip 2015 15: 3350--3357 10.1039/c5lc00514k
- Supriya N, Danh T, Ghassan M, and Mehdi N. "Microfluidic Tumor–Vascular Model to Study Breast Cancer Cell Invasion and Intravasation". Adv. Healthcare Mater. 2018 7: 1701257 10.1002/adhm.201701257

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- Venugopal Menon N, Tay HM, Pang KT, Dalan R, Wong SC, Wang X, Li KHH, and Hou HW. "A tunable microfluidic 3D stenosis model to study leukocyte-endothelial interactions in atherosclerosis". APL Bioeng. 2018 2: 16103 10.1063/1.4993762

Therapeutic Devices

By mimicking tissue function, organ on a chip devices present a unique opportunity to supplement the body in various therapeutic applications. Organ on a chip therapeutic devices can be implanted or remain external to the body, but are ultimately connected intimately with a specific organ function. One highly sought application of microfluidic devices is as a portable hemodialysis machine. Such a device would be more discrete and less cumbersome than current dialysis machines. To implant a microfluidic device, it must integrate with the skin to avoid rejection by the body. Finally, these devices can be populated with autologous cell populations to enhance compatibility with the patient.

In the following articles, organ on a chip models are developed to act as therapeutic devices.

Therapeutic Device Articles from Harrick Plasma Users

- Ausri IR, Feygin EM, Cheng CQ, Wang Y, Lin ZY, and Tang X. "A highly efficient and antifouling microfluidic platform for portable hemodialysis devices". MRS Commun. 2018 8: 474-479 10.1557/mrc.2018.43
- Schmidt DJ, Moskowitz JS, and Hammond PT. "Electrically Triggered Release of a Small Molecule Drug from a Polyelectrolyte Multilayer Coating". Chem. Mater. 2010 22: 6416--6425 10.1021/cm102578j

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Biosensors

Biosensor microfluidic devices are self-contained, integrated systems that selectively detect an analyte of biological interest (proteins, DNA, cells, exosomes, gases, drugs, toxins) using a bioreceptor element and a signal transduction element. These devices convert physiochemical signals generated by a biorecognition event into a measurable electrical signal. Biosensors are often classified by their biorecognition element (nucleic acid, aptamer, antigen/antibody, enzyme, or cell) or their transducer mechanism (Optical, electrochemical or mechanical/piezoelectric). In general, biosensors offer several key advantages over traditional detection equipment including portability, low cost, ease of use, rapid detection, high sensitivity, and high throughput.

In addition to microfluidic device fabrication, plasma treatment is used in the development of biosensors to clean sensor surfaces and to bind various biorecognition elements or essential coatings to the microfluidic channel surfaces. Many biosensors employ fluorescent microscopy to detect and quantify their targeted analyte. For these sensors, plasma cleaning can be used to remove organic contamination that may otherwise fluoresce and corrupt the acquired data. Additionally, several biorecognition elements can covalently bond to the highly reactive plasma treated surfaces. As a result, biomolecules can be immobilized on microchannel surfaces to act as the biorecognition element. Plasma treatment can also be used prior to applying surface coatings with similar affinities for biomolecules. Frequently, silanization following plasma treatment enables the immobilization of the biorecognition element.

In the following application briefs, you will find biosensors constructed using plasma treatment to detect various analytes.

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Nucleic Acids & Aptamers

Nucleic acids and aptamers offer several advantages when used as the biorecognition element in a microfluidic biosensor. Aptamers are single-stranded DNA or RNA oligonucleotides that bind target biomolecules with high affinity and sensitivity. In the past, aptamers have been shown to selectively target proteins, enzymes, viruses, antibiotics, or specific cells such as cancer. They are often stable at high temperatures and in harsh biological environments, making them preferable to antibodies that will denature more readily. In addition, once isolated, aptamers can be produced and maintained easily in bulk.

In the following articles, nucleic acids or aptamers are used as the biorecognition element in a biosensor. They have been shown to capture a multitude of target biomolecules with high affinity.

Nucleic Acids & Aptamer Articles from Harrick Plasma Users

- Nguyen N-V, Yang C-H, Liu C-J, Kuo C-H, Wu D-C, and Jen C-P. "An Aptamer-Based Capacitive Sensing Platform for Specific Detection of Lung Carcinoma Cells in the Microfluidic Chip". Biosensors 2018 8: 98 10.3390/bios8040098
- Soares, R. R.; Neumann, F.; Caneira, C. R.; Madaboosi, N.; Ciftci, S.; HernándezNeuta, I.; Pinto, I. F.; Santos, D. R.; Chu, V.; Russom, A.; Conde, J. P. & Nilsson, M. “Silica bead-based microfluidic device with integrated photodiodes for the rapid capture and detection of rolling circle amplification products in the femtomolar range”, Biosensors and Bioelectronics (2019) 128: 68 – 75. 10.1016/j.bios.2018.12.004
- Chen, C.-Y.; Wang, C.-M.; Chen, P.-S. & Liao, W.-S. “Self-standing aptamers by an artificial defect-rich matrix”. Nanoscale, The Royal Society of Chemistry (2018) 10: 3191-3197. 10.1039/C7NR07381J
- Liu W, Wei H, Lin Z, Mao S, and Lin J-M. "Rare cell chemiluminescence detection based on aptamer-specific capture in microfluidic channels". Biosens. Bioelectron. 2011 28: 438 -- 442 10.1016/j.bios.2011.07.067

Immunoassays

While Nucleic Acids and Aptamers are showing a great deal of promise, most conventional detection platforms rely on immunoassay technology. Immunoassays exploit the antigen-antibody relationship for the detection of viruses, cancers, and various other pathogens with appropriate biomarkers. However, conventional immunoassays, such as enzyme-linked immunosorbent assay (ELISA), require highly trained personal, expensive analytic equipment and long waiting periods for results. Microfluidic-based immunoassay can be designed to function at the point of care (PoC), using personnel with minimal training. As a result, these PoC devices offer greater access to testing in disadvantaged areas. Additionally, plasma treatment has been used to enhance immunoassay function. By tuning microchannel hydrophilicity, plasma cleaning improves antigen or antibody immobilization and increased device sensitivity by providing higher density of the biorecognition element.

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In the following articles, portable, low cost immunoassays are developed to detect various diseases at the point of care.

Immunoassay Articles from Harrick Plasma Users

- Wang Y, Wang J, Meng J, Ding G, Shi Z, Wang R, and Zhang X. "Detection of Non-small cell Lung Cancer Cells Based on Microfluidic Polarization Microscopic Image Analysis". Electrophoresis 2018 10.1002/elps.201800284
- Chen Y-J, Schoeler U, Huang C-H(B, and Vollmer F. "Combining Whispering-Gallery Mode Optical Biosensors with Microfluidics for Real-Time Detection of Protein Secretion from Living Cells in Complex Media". Small 2018 14: 1703705 10.1002/smll.201703705
- Lin Y-H, Wu C-C, Peng Y-S, Wu C-W, Chang Y-T, and Chang K-P. "Detection of anti-p53 autoantibodies in saliva using microfluidic chips for the rapid screening of oral cancer". RSC Adv. 2018 8: 15513-15521 10.1039/C7RA13734F

Catalytic Biosensors

Biosensors are often designed to measure the products of a chemical reaction rather than the targeted biomolecules itself. This type of biosensor is needed if the targeted molecule cannot be detected directly using the other biorecognition elements discussed or if the biomolecule is found in quantities too small to detect conventionally. In these cases, researchers employ enzymes or cells to produce the detectable product in measurable quantities. Enzymes can be covalently linked to microchannel surfaces following plasma treatment or plasma treatment can be used to improve cell adhesion.

In the following articles, plasma treatment is used to bind enzymes or cells to microchannel surfaces to produce catalytic biosensors.

Catalytic Biosensor Articles from Harrick Plasma Users

- Kotanen CN, Karunwi O, Alam F, Uyehara CF, and Guiseppi-Elie A. "Fabrication and in vitro performance of a dual responsive lactate and glucose biosensor". Electrochim. Acta 2018 267: 71-79 10.1016/j.electacta.2018.02.042
- Liu Z, Jin M, Cao J, Niu R, Li P, Zhou G, Yu Y, van den Berg A, and Shui L. "Electrochemical sensor integrated microfluidic device for sensitive and simultaneous quantification of dopamine and 5-hydroxytryptamine". Sens. Actuators, B 2018 273: 873-883 10.1016/j.snb.2018.06.123

Wearable Sensors

Portable, wearable biosensors are highly sought by the medical community to detect biomolecules in real time. The main advantage of a wearable biosensor is that patients can be observed in real time under specific conditions for improved diagnostic capabilities. These microfluidic devices are often connected intimately with the wearer such that transport occurs between the wearers body and the microfluidic device. They can be trapped to the body or connected directly, such as with microfluidic contact lenses in the eye.

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In the following articles, wearable biosensors have been constructed to interface with the body.

Wearable Sensor Articles from Harrick Plasma Users

- An H, Chen L, Liu X, Zhao B, Ma D, and Wu Z. "A method of manufacturing microfluidic contact lenses by using irreversible bonding and thermoforming". J. Micromech. Microeng. 2018 28: 105008 10.1088/1361-6439/aaceb7
- Kim SB, Lee K, Raj MS, Lee B, Reeder JT, Koo J, Hourlier-Fargette A, Bandodkar AJ, Won SM, Sekine Y, Choi J, Zhang Y, Yoon J, Kim BH, Yun Y, Lee S, Shin J, Kim J, Ghaffari R, and Rogers JA. "Soft, Skin-Interfaced Microfluidic Systems with Wireless, Battery-Free Electronics for Digital, Real-Time Tracking of Sweat Loss and Electrolyte Composition". Small 2018 14: 1802876 10.1002/smll.201802876

Environmental

Another variation of microfluidic device employed in the life sciences are biosensors that detect the presence of toxins, bacteria, or various biomolecules in the environment. Conventional environmental analysis is typically constrained by large laboratory bench sized equipment unsuitable for field testing. Microfluidic biosensors are much more mobile and can be automated to reduce the need of specially trained technicians. In addition to portability, label-free techniques are being developed to reduce testing time and cost. As a result, access to testing for bacteria, heavy metals, and a variety of other dangerous materials can be provided to many more people. Advancements in environmental sensor such as these have the potential to raise quality of life for impoverished and remote areas.

In the following articles, biosensors are designed for use in various environments to test for bacteria, toxins, or biomolecules.

Environmental Articles from Harrick Plasma Users

- Gracioso Martins AM, Glass NR, Harrison S, Rezk AR, Porter NA, Carpenter PD, Du Plessis J, Friend JR, and Yeo LY. "Toward complete miniaturisation of flow injection analysis systems: microfluidic enhancement of chemiluminescent detection". Anal. Chem. 2014 86: 10812-10819 10.1021/ac502878p
- Maguire I, Fitzgerald J, Heery B, Nwankire C, O'Kennedy R, Ducrée J, and Regan F. "Novel Microfluidic Analytical Sensing Platform for the Simultaneous Detection of Three Algal Toxins in Water". ACS Omega 2018 3: 6624-6634 10.1021/acsomega.8b00240
- Mathesz A, Valkai S, Újvárosy A, Aekbote B, Sipos O, Stercz B, Kocsis B, Szabó D, and Dér A. "Integrated optical biosensor for rapid detection of bacteria". Optofluid. Microfluid. Nanofluid. 2015 2: 15-21 10.1515/optof-2015-0002

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For more research articles citing Harrick Plasma equipment visit our Technical Library or our Microfluidic Devices and Microfluidic Devices Using Rigid Polymers pages

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