# Patents, Research Publications, Projects with Rainmaker Engineering Instrument, Microarray Focus

## Programmable Arrays

*WIPO Patent Application WO/2013/063126*
*PROGRAMMABLE ARRAYS, Published May 2, 2013*
***Engineering Arts** and ARIZONA BOARD OF REGENTS (Arizona State University).*

## High Density Diffusion-Free Nanowell Arrays (featured on cover)

*Bharath R. Takulapalli, …, Peter Kahn, Al Brunner, …, Joshua LaBaer, and Peter Wiktor Journal of Proteome Research 2012 11 (8), 4382-4391 DOI: 10.1021/pr300467q (2013)*

**Project Description** – Rainmaker2 (RM2) & Rainmaker3 (RM3) Instruments and dispense heads: Engineering Arts (Phoenix Arizona)/ Aurigin Technology (Singapore) led development, construction and support of custom engineering prototype instruments. 16 Channel picoliter on-the-fly targeted nanowell printing with **programmable** aspiration and deposition volume of 25 **picoliters** to 1 nanoliter. **The RM2 and RM3 instruments have been in routine use over 10 years** at ASU Biodesign. Most publications and patents in this section have utilized the RM2 and RM3 instruments for microarray . In 2021 we released the RM3 printing HD-NAPPA (14,000 wells per 1x3 inch slide) to production. In Feb, 2023 we released the UHD Silicon Nanowells slides to production, **doubling** our HD-NAPPA printing density. In 2025 we will further reduce costs by doubling **again**, releasing a version with greater than 40,000 nanowells per 1x3 inch slide (EPIC-NAPPA). See: RM2 Video (short) , RM3.ASU, UHD-NAPPA Print Video(2023), Protein Microarray Panel Discussion (serum screening for Biomarkers), SPOC.BIO (ASU spinout and RM3, Sensor Integrated Proteome on Chip), Biodot Rainmaker Website, Biodot Rainmaker Video, Schott Minifab Phoenix

Contacts: Peter Kahn: pkahn@engineeringarts.com / **Industrial** Microarray Printing with Rainmaker:

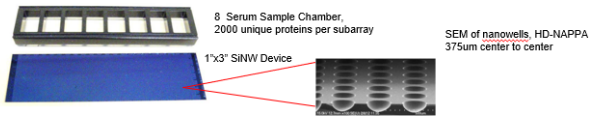
Research Specialist Arlene Ow visually inspects the tips on the Rainmaker3 before a piezo dispense print to produce a high density NAPPA. Photo by Andy DeLisle

BIODOT AN ATS COMPANY

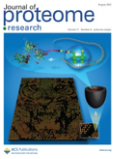
SCHOTT MINIFAB

**Microarray Manufacturing (formerly Applied Microarrays Inc):**
- Non-contact piezo spotting
- 136 slides or 128 plates per spotting build
- Custom fixtures for semiconductor devices
- Spot volumes from picoliter to microliter range
- 100% automated optical inspection
- Intelligent chip feature-finding software for semiconductor devices

SiNW (Silicon Nanowell) Devices for NAPPA
- 14,000 wells per 1x3" device (HD-NAPPA)
- 20,000 wells per 1x3" device (UHD-NAPPA), Released 2/2023
  - 2000 **unique** proteins per each subarray (8 subarrays per device)




ASU BIODESIGN INSTITUTE ARIZONA STATE UNIVERSITY




SPOC An INanoBio Company

NOTE – Happy to arrange a live demonstration of the RM3 at ASU Biodesign. The RM3 is operated within an ASU in a core facility (NAPPA Protein Array Core). Outside research groups and businesses have access to the RM3 for their application development. Contact pkahn@engineeringarts.com for more info.

Novel sensor-integrated proteome on chip (SPOC) platform with thousands of folded proteins on a 1.5 sq-cm biosensor chip to enable high-throughput real-time label-free screening for kinetic analysis
*Chidozie Victor Agu, Rebecca L Cook, William Martelly, Lydia R Gushgari, Mukilan Mohan, Bharath Takulapalli, doi: 10.1101/2024.01.23.575909, Preprint (2024)*

Optimization of High Density Nucleic Acid-Programmable Protein Array Master Mix Printing
*Taylor Miller, May 2024, ASU MS Applied Project (2024)*

Identification of antibody targets for tuberculosis serology using High-Density Nucleic Acid Programmable Protein Arrays,
*Lusheng Song, … Peter Wiktor, Peter Kahn, Al Brunner… D. Mitchell Magee (mitch.magee@asu.edu), Jacqueline M. Achkar, doi: 10.1074/mcp.M116.065953 (2017)*

Multiplexed Nucleic Acid Programmable Protein Arrays
*September 2017, Theranostics 7(16):4057-4070 Xiaobo Yu, Lusheng Song, et al.*

Antiviral Antibody Profiling by High-density Protein Arrays
*Bian, X., Wiktor, P., Kahn, P., Brunner, A., Khela, A., Karthikeyan, K., Barker, K., Yu, X., Magee, M., Wasserfall, C. H., Gibson, D., Rooney, M. E., Qiu, J. and LaBaer, J., Proteomics, 15: 2136–2145. doi: 10.1002/pmic.201400612 (2015)*

Microreactor Array Device
*Peter Wiktor, Al Brunner, Peter Kahn, Ji Qiu, Mitch Magee, Xiaofang Bian, Kailash Karthikeyan and Joshua LaBaer*, *Scientific Reports 5, Article number: 8736 doi:10.1038/srep08736 (2015)*

A Contra Capture Protein Array Platform for Studying Post-translationally Modified (PTM) Auto-antigenomes.
*Karthikeyan K, .., Kahn P, Wiktor P, Brunner A, …Takulapalli B, Buckner J, Nepom G, LaBaer J, Qiu J. Mol Cell Proteomics. 2016 Jul;15(7):2324-37. doi: 10.1074/mcp.M115.057661. (2016)*

ABH-glycan microarray characterizes ABO subtype antibodies: fine specificity of immune tolerance after ABO-incompatible transplantation
*Mylvaganam Jeyakanthan, .. Lori J.*
*West American Journal of Transplantation doi: 10.1111/ajt.13625 (2015).*

Nanoprobe NAPPA Arrays for the Nanoconductimetric Analysis of Ultra-Low-Volume Protein Samples Using Piezoelectric Liquid Dispensing Technology
*Eugenia Pechkova, Peter Wiktor, Nicola Bragazzi, Fernanda Festa, Claudio Nicolini NanoWorld Journal 04/2015; 1(1):26-31. DOI: 10.17756/nwj.2015-004*

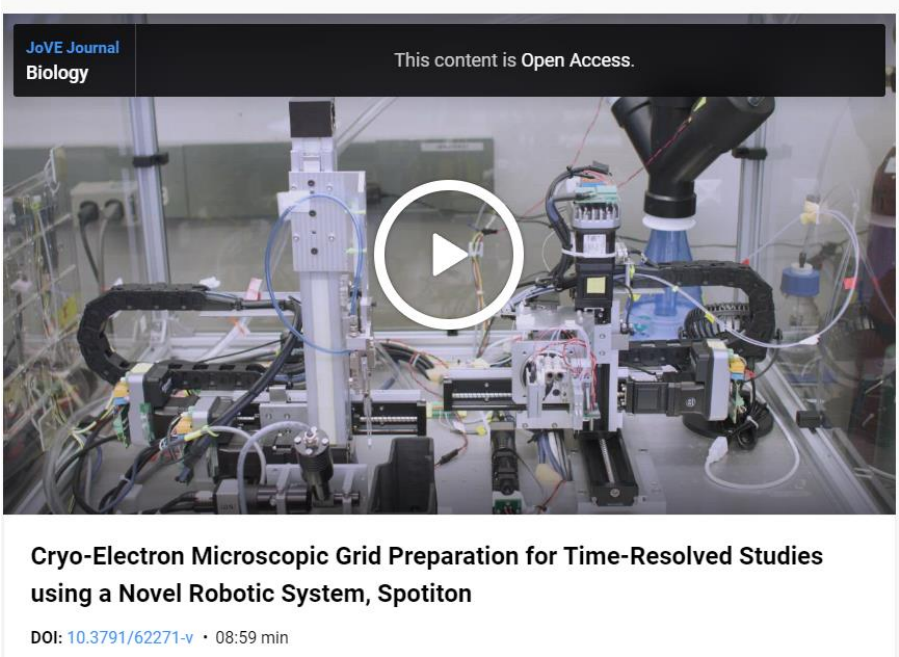
Measurement of Small Molecule Binding Kinetics on a Protein Microarray by Plasmonic-Based Electrochemical Impedance Imaging
*Wenbin Liang, S Wang, F Festa, P Wiktor,W Wang, M Magee, J LaBaer, Nongjian Tao Analytical Chemistry 08/2014; 86(19). DOI:10.1021/ac5024556*

In situ electroporation of surface-bound siRNAs in microwell arrays
*Tilak Jain, Adrian Papas, Amol Jadhav, Ryan McBride and Enrique Saez*
Lab Chip, 2012, 12, 939

# Patents, Research Publications, Projects with Engineering Arts Dispense Technology, CryoEM Focus

US Patent US9702795
Apparatus and method for producing specimens for electron microscopy
*Issued: 11 July, 2017*
*Carragher; Bridget, Potter; Clinton S., Jain; Tilak , Kahn; Peter, Wiktor; Peter*

Cryo-Electron Microscopic Grid Preparation for Time-Resolved Studies using a Novel Robotic System, Spotiton
J Vis Exp. 2021(168):e62271 (JoVE Journal), **DOI:** 10.3791/62271-v , Peer Review Video Journal !!
Budell, W. C., Allegri, L., Dandey, V., Potter, C. S., Carragher, B.




Project Description - Spotion Instrument: Engineering Arts (Phoenix Arizona) designed and built the Spotiton instrument; custom engineering prototype Cyro-EM instrument in 2014 for the NYSBC team (NYC). **The instrument has been in routine use for 9 years**. Lead mechanical engineer was Terry Rohde (Engineering Arts). Custom control software was written by Peter Kahn (Engineering Arts) but all recent improvements have been led by NYSBC's local software development engineer (Luis Allegri, NYC). The software development platform is C# .NET (Visual Studio, windows forms development). The NRAMM team (led by Chase Budell) has worked hard to continuously improve the instrument by adding capabilities throughout the years. Engineering Arts (Peter Kahn) was on site in 2019 to perform a major upgrade adding time resolved capability (ability to rapidly mix then freeze **two** samples on a grid) but other than that ….the NRAMM team has been self-sufficient with remote support from the Engineering Arts team provided from time to time. Most publications and patents in this section have utilized the Spotiton instrument. SPT has developed and offers a single channel commercial version of the instrument (Chameleon).

Contacts: Peter Kahn: pkahn@engineeringarts.com, William (Chase) Budell: wbudell@nysbc.org ,

Time-resolved cryoEM using Spotiton
10 Aug 2020, Nature Methods, Brief Communication
*Venkata P. Dandey, William C. Budell, Hui Wei, Daija Bobe, Kashyap Maruthi, Mykhailo Kopylov, Edward Eng, Peter A. Kahn, Jenny E. Hinshaw, Nidhi Kundu, Crina M. Nimigean, Chen Fan, Nattakan Sukomon, Seth Darst, Ruth Saecker, James Chen, Brandon Malone, Clinton S. Potter, Bridget Carragher*

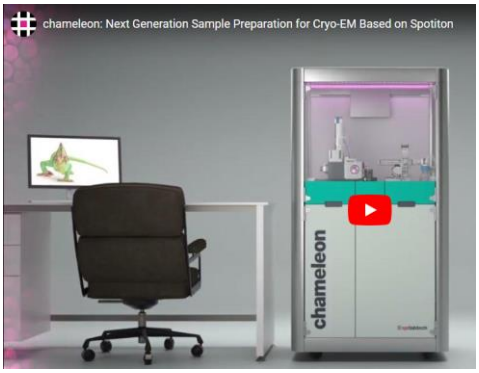
Spotiton: New features and applications
*Journal of Structural Biology, Volume 202, Issue 2, (2018)*
*Venkata P. Dandey, Hui Wei, Zhening Zhang, Yong Zi Tan, Priyamvada Acharya, Edward T. Eng, William J. Rice, Peter A. Kahn, Clinton S. Potter, Bridget Carragher*

A new method for vitrifying samples for cryoEM.
*Razinkov I, Dandey VP, Wei H, Zhang Z, Melnekoff D, Rice WJ, Wigge C, Potter CS, Carragher B Journal of Structural Biology, 195(2):190-198. (2016)*

Spotiton: A prototype for an integrated inkjet dispense and vitrification system for cryoTEM
*Tilak Jain, Patrick Sheehan, John Crum, Bridget Carragher, Clinton S. Potter Journal of Structural Biology, Volume 179, Issue 1, (2012)*

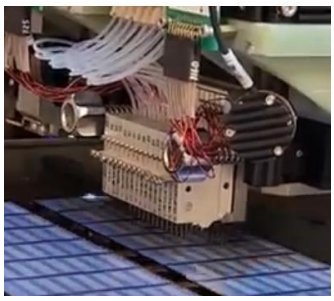
*A Microdroplet-Based Colorimetric Sensing Platform on a CMOS Imager Chip*
*Kyle R. Mallires, Di Wang, Peter Wiktor, and Nongjian Tao*
*Analytical Chemistry 2020 92 (13), 9362-9369 DOI: 10.1021/acs.analchem.0c0175*

SPT Chameleon Instrument Overview: https://www.sptlabtech.com/resources/chameleon-overview-video , Commercial instrument further developed and released by SPT Labtech based on the Spotiton instrument and US9702795 patent license.

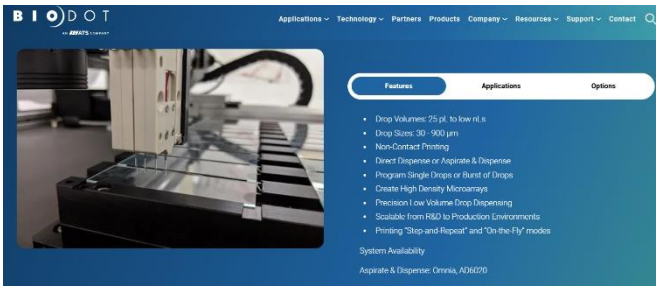


# Engineering Arts Dispense Heads:

Engineering Arts has manufactured precision picoliter dispense heads in the USA since 1993. The all glass fluid path is perfect for aspirate and dispense applications of precious biological samples. Engineering Arts proprietary non-contact piezoelectric low volume dispensing technology allows users to programmatically select a wide range of dispensed volumes as a single drop or high-frequency burst. Liquid volumes, from 25 picoliters to 2 nanoliters, can be dispensed On-the-Fly. Individual dispense heads are mounted on 4.5mm centers and triggered independently for true high-speed microarray printing. Engineering Arts dispense heads are at the heart of manufacturing equipment used to produce miniaturized devices for the following research and diagnostic applications: microarray, lab-on-chip, microfluidic and chemical sensing.



16 dispense heads on the RM3




Engineering Arts (OEM) Dispense Heads on Biodot Equipment

# Acknowledgments:


We gratefully acknowledge the **NATIONAL INSTITUTES OF HEALTH** for supporting Engineering Arts in the early days of our product development. Engineering Arts has been profitable for the last 5 years and has not received / pursued any further government grants.

Small Business Grants Complete:5R42RR031446, 5R42GM106704, 1R43HG006822, 1R43GM108126

We gratefully acknowledge the dedicated scientists at **Arizona State University Biodesign Institute** for all their hard work and collaboration on the development of the RM2, RM3 and Silicon Nanowell High Density Protein Microarray platforms.

We gratefully acknowledge **NYSBC/NRAMM** for all the hard work and collaboration during the development of the Spotiton Cryo-EM instrument. We gratefully acknowledge our collaboration with **SPT Labtech** for all the hard work to develop, release and support the commercial version of the Spotiton instrument: SPT Labtech Chameleon Instrument.

We gratefully acknowledge Aurigin Technology (Singapore based part owner of Engineering Arts and top notch engineering team) for their collaboration and support. Aurigin provided essential precision engineering knowledge and resources for the RM2 and RM3 equipment development projects.