

APPLICATION BRIEF

Wafer Processes for BioMEMS

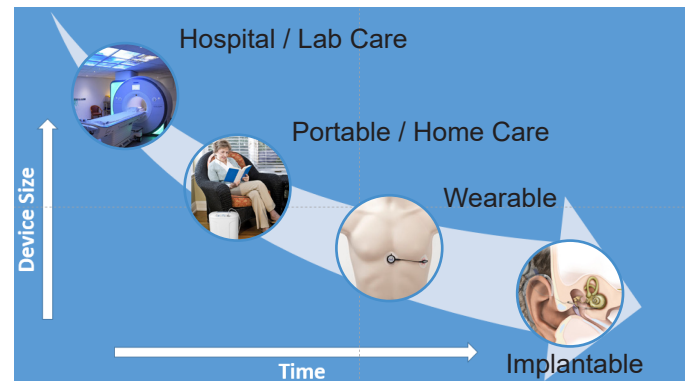
Introduction

BioMEMS is an exciting area of the MEMS market, with growing numbers of products now coming to market after many years of research. Key applications for BioMEMS may fall under medical/pharmaceutical, food safety or environmental/public safety monitoring. According to Yole Développement^[1], "With the addition of microfluidic chips (Si-based, polymer-based, glass-based), the BioMEMS market, represented by silicon MEMS devices used for life sciences and healthcare applications, is expected to more than double - from \$3B in 2017 to \$6.9B in 2023, with a CAGR of 14.9% from 2017 – 2023".

Microfluidic chips are the predominant MEMS structure utilized, but there are also biomedical applications for optical MEMS and MEMS sensors (e.g. measuring flow, gas, motion and pressure). There are now many BioMEMS products on the market, and more at various stages of development.

There are multiple drivers for the miniaturization of medical devices, such as:

- Reducing the sensor element to the scale of the target species increases sensitivity
- Reduced sample/reagent volumes – reduced pain/costs
- Reduced time to result, due to small volume
- Portability of system
- Point of care diagnostics
- Multi-agent capability
- Potential for in-vivo (implanted inside a living body)
- Most realistic, reduced cost in-vitro (analysis carried out outside the body, literally meaning "in a glass vessel") e.g, "organ-on-a-chip"



Material Selection

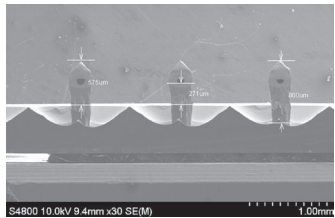
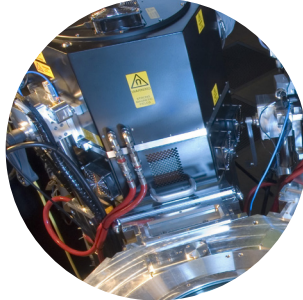
BioMEMS can be made of a number of different materials. Historically silicon was the most popular due to established micromachining technology and easy integration with control electronics. However, bulk silicon is not biocompatible^[2] and can cause a reaction with living tissue if implanted in-vivo, so other materials like inert metals, glass or polymers (e.g. PDMS, Parylene or PMMA) are also important in BioMEMS. Glass is transparent and has good strength and chemical inertness, but is more difficult/expensive to micromachine in mass production. Polymers are cheap and easy to mass-manufacture, and in certain cases are transparent and biocompatible. However they are generally weaker and may deform under certain conditions. Polymers usually have poor high temperature tolerance and are more difficult to integrate with electronic control. Piezo materials like PZT or AlScN have the very useful property of generating an electrical charge when stressed, or conversely deforming on application of an electric signal. These materials are used in BioMEMS applications such as micropumps, ultrasonic imaging, smart catheters, and energy harvesting devices. Consequently, material choice will vary depending on the specific application.

SPTS's Processes for BioMEMS Manufacturing

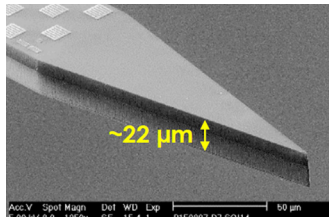
As a key supplier to the MEMS industry, SPTS has been supporting BioMEMS manufacturing for many years, with etch processes for silicon, glass and polymers, PVD of AlN, and MVD of specialized surface coatings. The following examples illustrate some of our most recent collaborations, developing a variety of BioMEMS.

Silicon BioMEMS

Silicon BioMEMS usually involve etching vertical holes or trenches typically >100µm deep into the silicon, using the well-established Deep Reactive Ion Etching (DRIE). As a pioneer of this technique since its invention in the mid-1990's, SPTS continues to offer market-leading Si DRIE technology with high etch rates, smooth sidewalls and excellent tilt control. One on-going project, with Swansea University, is focused on manufacturing hollow, tapered silicon microneedles for transdermal fluid sampling, drug delivery and vaccine delivery^[3]. SPTS Si DRIE is also being used at imec for micromachining silicon to create the "Neuropixels" neural probe^[4] which contains almost 1000 CMOS sensors on a thin silicon 1cm(L) x70µm(W) x20µm(H) probe for recording the electrical activity of neurons across the brain.



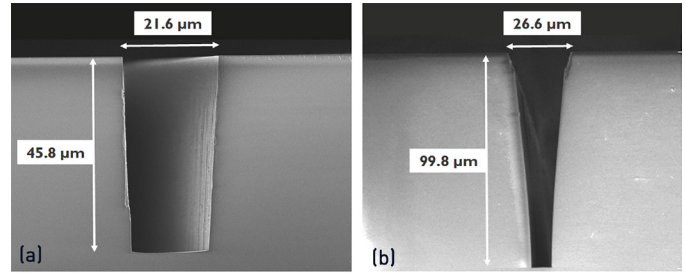
Silicon microneedles
(Courtesy of University of Swansea)



DRIE-etched silicon
"Neuropixels" neural probe
(Courtesy of imec)

Glass BioMEMS

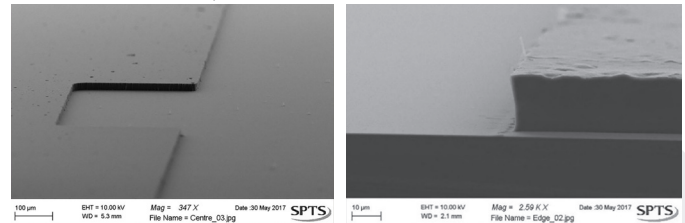
In a recent joint paper with imec^[5], we illustrated how our Synapse™ system could be used to etch smooth microchannels in quartz. When etching 20µm wide microfluidic channels using a photoresist mask, we achieved an aspect ratio of 2.1:1 (Etch Rate ~0.4µm/min) and with an aluminium mask the aspect ratio rose to >3.8:1, with an etch rate of ~0.5µm/min. Using SPTS's Molecular Vapor Deposition (MVD®) technology, the glass microchannels were coated with 3-[Methoxy(polyethyleneoxy)propyl] trimethoxysilane, resulting in a static advancing contact angle of 40.5° for water passing through the microchannel. In this work, the quartz microchannels were used to hold a serum containing human red-blood cells, for imaging/cell counting. The smoothness of the etched channel surface was critical to allow clear, high resolution imaging.



Deep quartz microchannel etch using (a) 14µm deep PR mask and (b) 5µm deep Al mask

Polymer BioMEMS

SPTS also contributed to the EU-funded InfoMed Project^[6], a large consortium of 39 partners ranging from universities, start-ups, equipment suppliers to manufacturing fabs, establishing an integrated pilot line for medical devices, developing scalable processes and demonstrating various products. One demonstrated product named "Cytostretch", developed by TU Delft and being transferred to production, involved combining induced pluripotent human stem cells with a stretchable multi-electrode array to mimic the physical in-vivo environment for more realistic and cost-effective testing of drugs. As part of this project, SPTS developed a dry ICP etch process for PDMS, with an etch rate of ~1.8µm/min and cross-wafer uniformity of 1.7%.



ICP etched PDMS

For more details about the SPTS process solutions used for BioMEMS manufacturing, go to www.orbotech.com/spts

References

- [1] "BioMEMS & Non-Invasive Sensors: Microsystems for Life Sciences & Healthcare 2018" Report by Yole Développement, August 2018
- [2] "Is Silicon Suitable for Making Implantable Biomedical Devices" Anfeng Wang et al. Presented at AIChE Annual Meeting 2005
- [3] "Advanced deep reactive-ion etching technology for hollow microneedles for transdermal blood sampling and drug delivery." Y. Liu, H. Ashraf, K. Roberts, N. Knight, P. Eng, & O. Guy. IET Nanobiotechnology 7(2), 59-62.(2013)
- [4] "Fully integrated silicon probes for high-density recording of neural activity", James J Jun et al. Nature, volume 551, p232-236 (November 2017)
- [5] "Microfluidics on 200mm Quartz Substrates using Semiconductor Fab Dry Etch Process as an Enabler for Imaging Applications in Life Sciences" Andim Stassen et al, presented at MNE 2017, Braga Portugal (Sept 2017)
- [6] <http://informed-project.eu/>

SPTS Technologies, an Orbotech company, designs, manufactures, sells, and supports etch, PVD, CVD and MVD® wafer processing solutions for the MEMS, advanced packaging, LED, high speed RF on GaAs, and power management device markets. For more information about SPTS Technologies, email enquiries@spts.com or visit www.orbotech.com/spts

Cautionary Statement Regarding Forward-Looking Statements

Except for historical information, the matters discussed in this press release are forward-looking statements within the meaning of the U.S. Private Securities Litigation Reform Act of 1995. These statements relate to, among other things, future prospects, developments and business strategies and involve certain risks and uncertainties. The words “anticipate,” “believe,” “could,” “will,” “plan,” “expect” and “would” and similar terms and phrases, including references to assumptions, have been used in this press release to identify forward-looking statements. These forward-looking statements are made based on management’s expectations and beliefs concerning future events affecting Orbotech and are subject to uncertainties and factors relating to Orbotech’s operations and business environment, the previously announced acquisition of Orbotech by KLA, the manner in which the parties plan to effect the transaction, including the share repurchase program, the ability to raise additional capital necessary to complete the repurchase program within the time frame expected, the expected benefits, synergies and costs of the transaction, management plans relating to the transaction, including with respect to the Company’s ownership interest in Frontline, the expected timing of the completion of the transaction, the parties’ ability to complete the transaction considering the various closing conditions, including conditions related to regulatory and Orbotech shareholder approvals, the plans, strategies and objectives of management for future operations, product development, product extensions, product integration, complementary product offerings and growth opportunities in certain business areas, the potential future financial impact of the transaction, and any assumptions underlying any of the foregoing.

Actual results may differ materially from those referred to in the forward-looking statements due to a number of important factors, including but not limited to the possibility that expected benefits of the transaction may not materialize as expected, that the transaction may not be timely completed, if at all, that KLA-Tencor may not be able to successfully integrate the solutions and employees of the two companies or ensure the continued performance or growth of Orbotech’s products or solutions, the risk that the Company may not achieve its revenue expectations within and for 2018 (including, without limitation, due to shifting move-in dates); cyclicalities in the industries in which the Company operates, the Company’s supply chain management and production capacity, order cancellation (often without penalty), timing and occurrence of product acceptance (the Company defines ‘bookings’ and ‘backlog’ as purchase arrangements with customers that are based on mutually agreed terms, which, in some cases for bookings and backlog, may still be subject to completion of written documentation and may be changed or cancelled by the customer, often without penalty), fluctuations in product mix within and among divisions, worldwide economic conditions generally, especially in the industries in which the Company operates, the timing and strength of product and service offerings by the Company and its competitors, changes in business or pricing strategies, changes in the prevailing political and regulatory framework in which the relevant parties operate, including as a result of the United Kingdom’s prospective withdrawal from the European Union (known as “Brexit”) and political uncertainty in the United States, or in economic or technological trends or conditions, including currency fluctuations, inflation and consumer confidence, on a global, regional or national basis, the level of consumer demand for sophisticated devices such as smart mobile devices, automotive electronics, flexible applications and devices, augmented reality/virtual reality and wearable devices, high-performance computing, liquid crystal display and organic light emitting diode screens and other sophisticated devices, the Company’s global operations and its ability to comply with varying legal, regulatory, exchange, tax and customs regimes, the timing and outcome of tax audits, including the best judgment tax assessment issued by the Israel Tax Authority with respect to the audit of tax years 2012-2014 in Israel and the related criminal investigation, the Company’s ability to achieve strategic initiatives, including related to its acquisition strategy, the Company’s debt and corporate financing activities; the timing, final outcome and impact of the criminal matter and ongoing investigation in Korea, including any impact on existing or future business opportunities in Korea and elsewhere, any civil actions related to the Korean matter brought by third parties, including the Company’s customers, which may result in monetary judgments or settlements, expenses associated with the Korean matter, and ongoing or increased hostilities in Israel and the surrounding areas.

The foregoing information should be read in connection with the Company’s Annual Report on Form 20-F for the year ended December 31, 2017, and subsequent SEC filings. The Company is subject to the foregoing and other risks detailed in those reports. The Company assumes no obligation to update the information in this press release to reflect new information, future events or otherwise, except as required by law.