SPTS
A KLA Company

APPLICATION
**BRIEF**

# MEMS Microphones

## Introduction

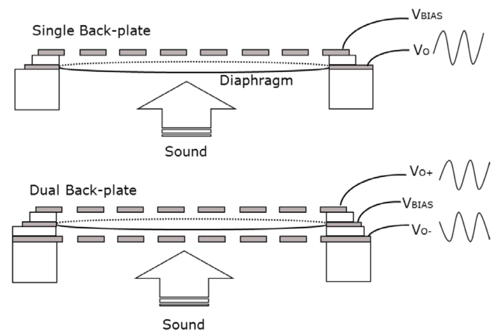
The market for MEMS microphones has been growing rapidly in recent years for a variety of applications, primarily mobile devices, but also other products such as hearing aids, Bluetooth headsets, "digital assistants" (like Amazon Echo / Google Home) and increasingly in cars. According to IHS Inc, more than four billion MEMS microphones will ship in 2016, and will reach almost six billion units annually by 2019[1]. Microphones in smartphones today do more than capture voice for transmission. They also work as audio sensors in a very low power mode to support voice activation and they provide high quality audio when the phone is used for video recording.

Compared to traditional Electret Condenser Microphones (ECM), MEMS microphones tend to offer a smaller footprint/thickness, a high signal to noise ratio (SNR), lower power consumption and are easier to integrate into a semiconductor package that unlike ECMs then lends itself to automated PCB assembly. Their reduced size allows arrays of multiple MEMS microphones to be used in small products like mobile phones or Bluetooth headsets to recognize sound directionality and most importantly to provide noise cancellation capability. Silicon MEMS microphones also offer greater immunity to radio-frequency interference (RFI) and electromagnetic interference (EMI), and they can withstand the high temperatures of a surface-mount technology (SMT) process.

## Types of MEMS Microphones

**MEMS Condenser (Capacitive) Microphones**

The first capacitive, or condenser, microphones were developed at Bell Labs in 1916. Traditional condenser microphones are air gap capacitors with a back-plate and a flexible diaphragm. Modern capacitive MEMS microphones operate on the same principle and are basically miniaturized condenser microphones manufactured in a silicon wafer process. Capacitive microphones use two or three plates, a diaphragm and one or two back-plates, that form an air gap capacitor that has a high bias charge. When the diaphragm moves in response to sound, the capacitance changes and the resulting voltage is amplified.

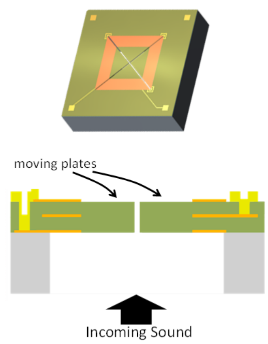



*Capacitive MEMS microphone principles:*
*A) Single back-plate and B) Dual back-plate.*
*[Source: Infineon]*

The dual back-plate design[2] produces a differential (compared to single-ended) output, which minimizes distortion due to its symmetrical construction. A differential element is also more readily managed through the audio processing chain, which potentially reduces power requirements for the accompanying ASIC. Infineon have also demonstrated a fully functional MEMS microphone within a fan-out "e-WLB" (embedded Wafer Level Ball Grid Array) package - an important step in miniaturisation and cost-effective integration with other chips in a single package[3], and in 2019 introduced "sealed dual membrane" technology[4] to create a low pressure / low viscosity environment around the backplate to improve Sound-to-Noise Ratio (SNR) to 75dB(A) - compared to 70dB(A) for a dual backplate microphone, without increasing device size. The sealed chamber also protects against dust or moisture ingress which could degrade the microphones performance over time.

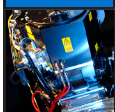
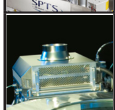
**Piezoelectric MEMS Microphones**

A piezoMEMS microphone uses the piezoelectric effect of specific materials, such as aluminium nitride (AlN), which generates an electrical signal when the diaphragm made of such material is deformed by a sound wave. Without an enclosed air gap, acoustic damping (a major source of noise in capacitive microphones) is eliminated, and recent developments using scandium-doped AlN promise a significant improvement in SNR over capacitive MEMS microphones. At the same time they are more robust and less susceptible to degradation over time because piezoMEMS microphones lack the small capacitive gap that is sensitive to dust or moisture. In addition, the leading piezoMEMS microphone manufacturer, Vesper, explains[4] "whereas capacitive systems have to be constantly on, listening for keywords such as 'Alexa' or 'Siri', piezoMEMS microphones do not have a charge pump, and so have a very fast startup time. They can therefore do duty cycles very rapidly when in 'always listening' mode, allowing up to 90% reduction in power usage." In 2016, Vesper announced a new "quiescent-sensing" microphone[5] which actually uses the power of the piezo element itself to turn on the microphone. This means there will be the potential to have a multitude of voice sensors in a device without any power penalty. This opens up a lot of new applications where currently infrequent use and a constant power drain make voice-control impractical in battery powered devices.



*PiezoMEMS microphone [Source: Vesper]*

## SPTS Processes for Microphone Manufacturing

| | | Capacitive MEMS Microphones | PiezoMEMS Microphones |
|---|---|---|---|
|  | **Omega® Silicon DRIE** | Cavity etch with high silicon etch rate (10-25µm/min) | - |
|  | **Omega® ICP/Synapse Etch** | Dielectric and metal etching | Dielectric, metal, AlN and high rate AlScN etching |
|  | **Primaxx® VHF Etch** | High throughput, stiction-free removal of sacrificial oxide between membrane and back-plate.<br>High selectivity to SiN and Al | Removal of sacrificial oxide if used to support piezoelectric film during deposition.<br>Compatible with AlN and AlScN films |
|  | **Xactix® $XeF_2$ Etch** | Release etch – stiction-free removal of sacrificial silicon, with long undercuts through small openings | Removal of sacrificial silicon if used to support piezoelectric film during deposition |
|  | **Sigma™ PVD** | - | Deposition of AlN / AlScN with superior texture (FWHM*<1.5°), stress control and film thickness uniformity |
|  | **Delta® PECVD** | Deposition of sacrificial oxide layers<br>Deposition of $SiO_x$ and SiN diaphragm films with excellent stress control | - |
|  | **MVD®** | Deposition of anti-stiction, hydrophobic and charge control coatings | Deposition of anti-stiction, hydrophobic and charge control coatings |

## Summary

With the evolution of smartphones and many new voice-activated products, the demand for smaller, energy-efficient microphones is expected to continue to grow rapidly over the next few years. SPTS's etch and deposition technologies offer makers of both capacitive and piezo-based MEMS microphones the process capabilities they require throughout the production process.

*FWHM = Full Width Half Maximum – This is a measure of the spread of x-ray diffraction (XRD) from a sample. A perfect crystal will produce a very sharp peak (i.e a very low FWHM), while defects like dislocations, mis-aligned grains and curvature due to non-uniform deposition, will result in a broader XRD curve and a higher FWHM

**References**

[1] http://press.ihs.com/press-release/apple-products-are-driving-market-growth-mems-microphones-ihs-says

[2] http://www.analog-eetimes.com/news/mems-microphone-design-better-audio

[3] "A MEMS Microphone in a FOWLP", H. Theuss et al, Proc. 2019 IEEE 69th Electronic Components and Technology Conference (ECTC) p855-860

[4] "A Revolutionary MEMS Technology for Ultra-High Performance Microphones " M. Füldner. Presented at MEMS Executive Congress 2019, 22-24 Oct, San Diego

[5] http://www.i-micronews.com/mems-sensors/7737-a-new-wave-of-mems-microphones-vesper-introduces-piezoelectric-mems-microphones.html?

[6] http://vespermems.com/press/vesper-demonstrates-first-commercial-quiescent-sensing-mems-device-consumer-products/quiescent-sensing-mems-device-consumer-products/



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