SPTS
An orbotech Company

APPLICATION
BRIEF

MEMS Microphones

Introduction

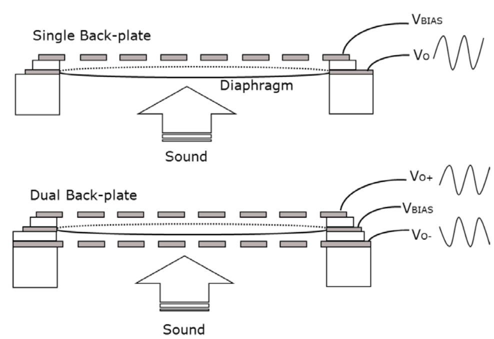
The market for MEMS microphones has been growing rapidly in recent years for a variety of applications, primarily mobile devices, but also other products such as hearing aids, Bluetooth headsets, "digital assistants" (like Amazon Echo / Google Home) and increasingly in cars. According to IHS Inc, more 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.

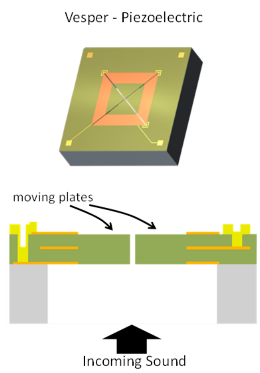


Capacitive MEMS microphone principles:
A) Single back-plate and B) Dual back-plate.
[Source: Infineon]

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. It also reduces RF interference, resulting in fewer signal processing steps.

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

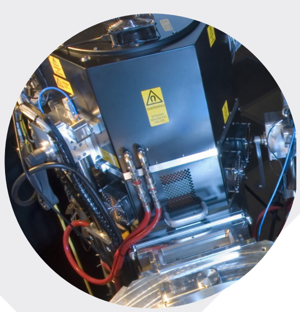


PiezoMEMS microphone [Source: Vesper]

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[3] "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[4] 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.

SPTS Processes for Microphone Manufacturing

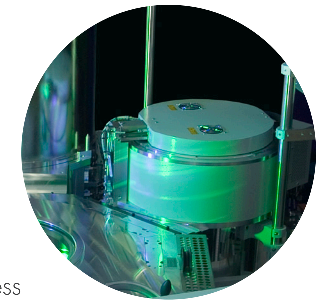
Capacitive MEMS microphones use many of the processes which SPTS has been providing to the MEMS industry for decades. SPTS's silicon DRIE process is used to create the large air cavity, where our Rapier™ plasma etch system offers a high silicon etch rate (typically between 10-25µm/min, depending on a customer's sidewall roughness and profile requirements) which delivers a high wafer throughput.



Rapier™ Si DRIE

SPTS's dry vapor HF or xenon difluoride etch processes can be used to etch sacrificial layers which define the smaller air gap between the membrane and back-plate(s), without the risk of stiction between the two remaining surfaces. Our PECVD solutions can be used for the deposition of sacrificial oxide layers, and also offer excellent stress control of the deposited films which form the diaphragm.

In the case of piezoMEMS, the properties of the AlN film are of paramount importance, so in addition to the standard etch and deposition processes common with capacitive microphones, deposition of a high quality piezoelectric film and associated metal electrodes is of the utmost importance. SPTS has been depositing AlN films using their Sigma® PVD system for almost 20 years. We are the market-leader in the PVD of AlN films for a host of applications which include BAW filters, silicon oscillators, energy harvesters and various sensors/actuators. For piezoMEMS, the piezoelectric efficiency is very dependent on the "texture" of the deposited AlN. Utilizing Sigma's "Soft Etch" Module and a patented pre-treatment of the oxide underlayer prior to AlN deposition, it is possible to improve the texture of the AlN (i.e. lower FWHM* to < 1.5°) and therefore improve the piezoelectric properties of the film. We also offer patent-protected Sigma® technology to ensure superior film thickness uniformity and stress control.



Sigma® Soft Etch Module

In addition to our PVD technology, SPTS also offers optimized etch processes for AlN in our ICP or Synapse™ plasma sources. For PZT, we recommend using the Synapse™ source which has a plasma density 10x greater than a conventional ICP source, and has been designed specifically for materials which are difficult to etch in using standard ICP processes.

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.

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

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

*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

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