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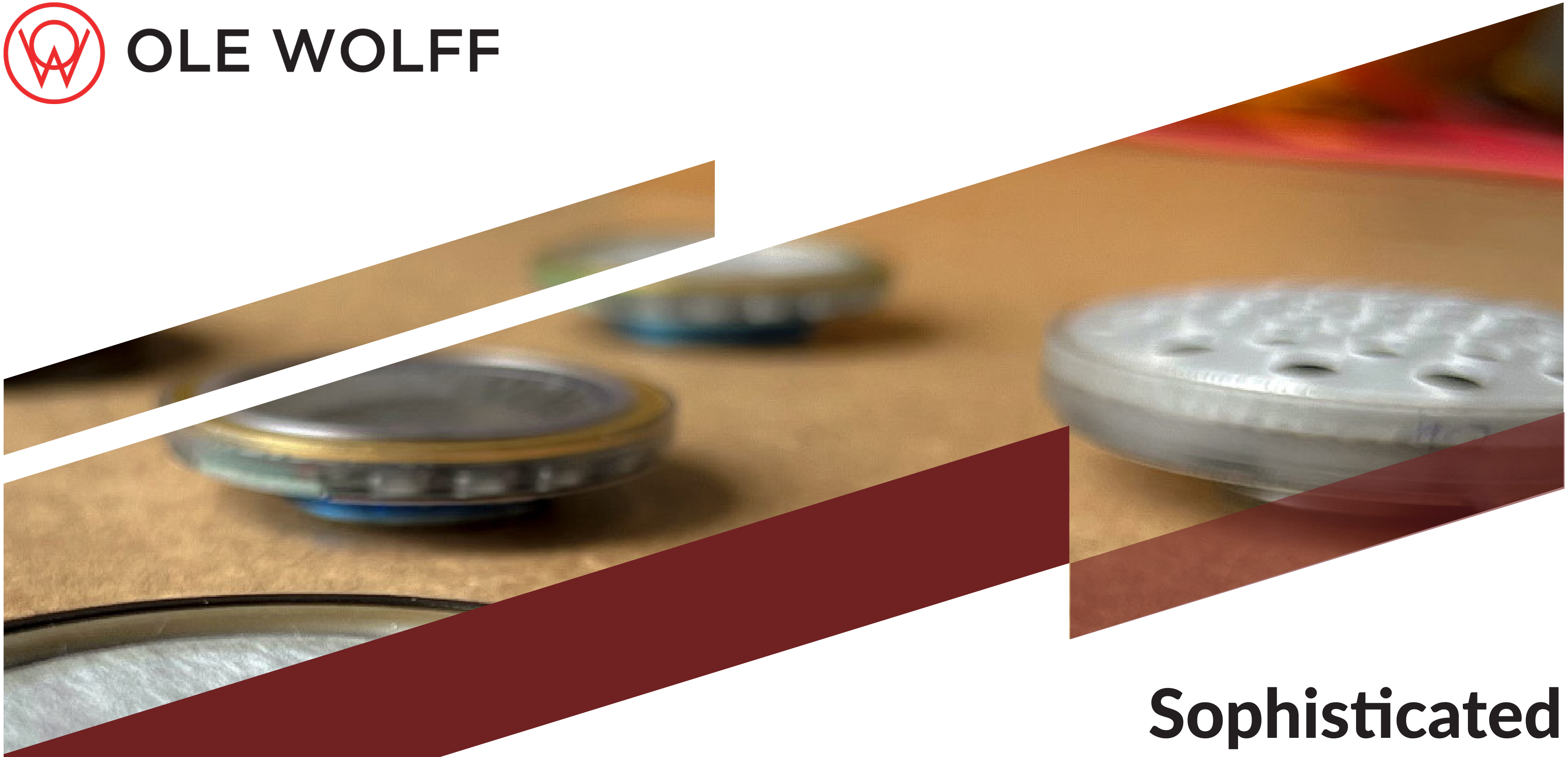

Sophisticated diaphragm designs for micro drivers/speakers

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Introduction

When miniaturizing already small driver and speaker designs, it is not simply a matter of scaling down all component dimensions. This approach often exceeds critical limits, especially when aiming for an extreme micro-speaker shape or integrating special functions within the miniature speaker's internal design.

The primary challenge lies in the moving parts—particularly the diaphragm, a delicate and crucial component responsible for converting mechanical movements into sound.

This White Paper explores this issue by analyzing three distinct micro drivers/speakers, focusing on their diaphragm designs. It explains how these advanced designs enhance acoustic efficiency and reduce distortion by improving linearity.

Additionally, the paper includes a dedicated section on diaphragm manufacturing, covering the different foil types used in micro drivers/speakers and the processes involved in shaping them.

Case 1: Circular Ø5mm driver for in-ear phones

The **OWR-05049T-38A** is a circular Ø5mm driver developed to fit into earphones positioned at the very entrance of the ear canal and thereby closest possible to the ear drum. A position of the driver nearest possible to the ear drum will assure the best high frequency performance, but there are physical obstacles to overcome for placing of a driver inside the ear canal.

This would take a driver with a diameter less than a diameter of 4mm and next there would be a comfort problem. It is not nice to have a foreign body inside the ear canal for a longer period.

A driver, even as small as Ø5mm in diameter by nature has a very small diaphragm. As the diaphragm transfers mechanical movements into sound pressure proportional to its area, the sensitivity is challenged.

A common way of attaching the diaphragm to the rest of the miniature driver is to bond it on the edge of the body /frame/basket of the driver. This way, the diaphragm has a horizontal flat plane at its outer circumference (see *Fig. 1*).

Fig. 1

Common method of attaching the diaphragm to the basket.

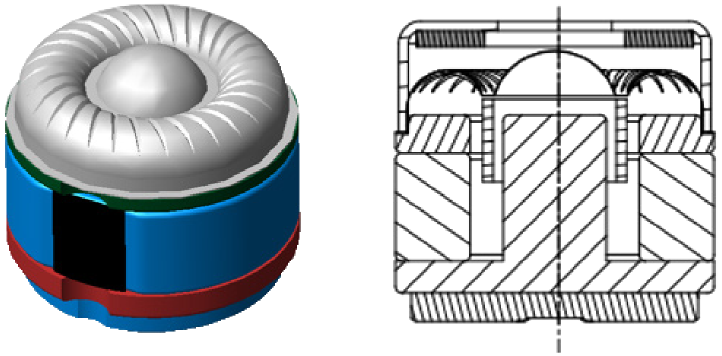
However, such a flat horizontal plane will decrease the effective area of the diaphragm and thereby reduce its sensitivity. This is of course most severe on very small drivers because the effective area follows the formula **Sd = pi x radius²** and reducing the outer diameter will decrease the area in the second order of the radius.
With larger drivers the percentage of space taken for the attachment area is obviously not as high as it is for small drivers.

It should be mentioned that there must also be reserved space at the outer periphery for a suspension allowing the diaphragm to move up and down freely and this even makes it extra challenging to reserve enough space for an effective diaphragm area.

So, all in all, not much space is left for a decent Sd, effective area of the diaphragm in these miniature drivers/speakers.

The **OWR-05049T-38A** driver is especially designed to elegantly handle this challenge.
In *Fig. 2*, the diaphragm is attached to the drivers body/frame/basket.

Fig. 2



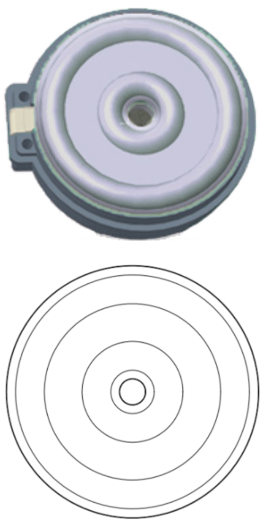
As shown, the diaphragm has a vertical edge and not a horizontal edge as normally used for the bonding.
This means that the suspension starts right at the drivers outer periphery and thereby optimal area is left for the Sd.

In comparison with other Ø5mm drivers using the common way of diaphragm attachment, **OWR 05049T-38A** add another 3-4dB to the sensitivity, which is significant, knowing the wireless earphones are powered by button cell batteries, which takes up space, and are limited in their amount of power. Thereby, all components in the earphone must be power efficient, and the **OWR 05049T-38A** contributes to this in an elegant way.

Case 2: Circular Ø12mm driver with embedded microphone in diaphragm

The **OWR-1204T** driver (Ø12mm) is specially designed to have an embedded miniature electret microphone positioned in the very center of the driver for ANC (Active Noise Control) purpose. Therefore, a center hole in the diaphragm is needed and causes the diaphragm design to have two suspensions, one at the outer circumference and another one around the center hole, where the diaphragm is fixed to the body of the driver.
This diaphragm design we call a "doughnut shaped" diaphragm.

Fig. 3



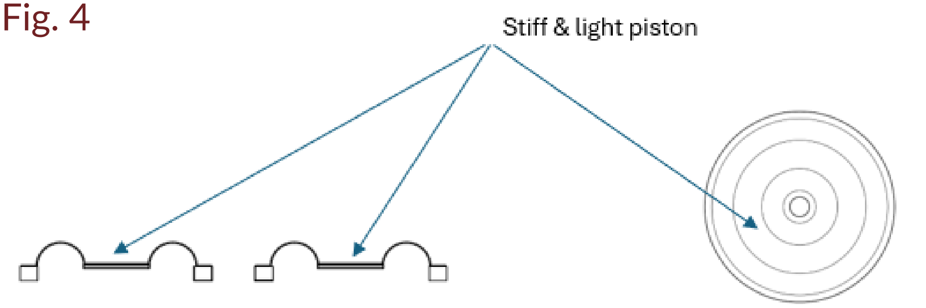
The huge challenge with the "doughnut" shaped diaphragm is the tuning of two separate suspensions, which ideally should have the same mechanical compliance. But because the circumference of the inner suspension is much smaller than the circumference of the outer suspension, this is not possible.

However, in the forming process and by differentiating the radii of the edges of the two suspensions, it is possible to a certain degree to optimize the compliances of the two suspensions to be closer to each other and a more linear vertical movement of the piston area can be obtained.

In the "doughnut" shaped diaphragm design a separate piston material must be bonded to the diaphragm, because the flat circular area between the two suspensions else will be far too soft to act as a piston. This piston part needs to be as stiff and light as possible for assuring an optimal HF response.

The ring-shaped piston is shown in *Fig. 4*. On the left, a cross-section is shown and on the right, the driver is shown from the top.

Fig. 4



The drawback is of course, that the effective piston area is slightly reduced compared to the "normal" diaphragm design resulting in a minor decrease in sensitivity.

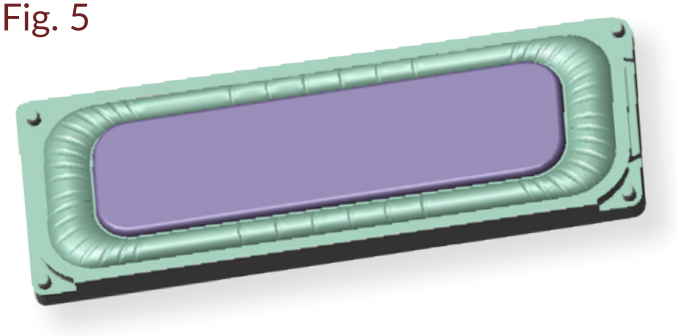
Case 3: Rectangular micro loudspeaker 9mm x 25mm

The **OWS-092530CW15A-8** micro loudspeaker has extreme dimensions of 9mm x 25mm needed for special applications like Smart Glasses and other similar devices with space constraints in one direction.
This formfactor challenges the diaphragm performance to the limit, because the corners will tend to act as local resonators having a low compliance compared to the suspension on the long sides, which has a rather high compliance needed for achieving a low F0.

Therefore, a special diaphragm design is required for allowing a high diaphragm stroke needed for reproducing high sound pressure levels at low frequencies with low distortion.

When looking at the diaphragm in *Fig. 5*, a special pattern of grooves can be observed distributed on the suspension, which is also wider at the corners and the width compared to the length compensating for an else lower compliance.
The shape of the grooves as well as the dept, the angles and distance between the grooves are carefully optimized for best linear high SPL performance using the finite element simulation tool COMSOL.

Fig. 5



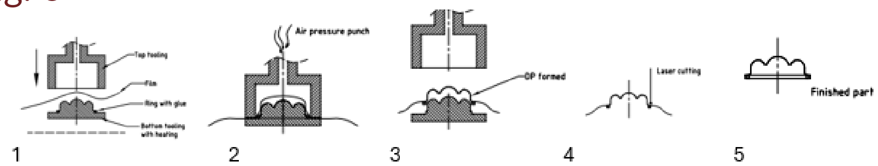
Processing a micro speaker diaphragm

Many different foils are used for manufacturing micro speaker/driver diaphragms depending on the characteristics of the desired performance. Common for all is they are polymer based and either extruded or mold in thicknesses down to as thin as 6um.
Very often these thin foils are laminated by three or more layers for achieving special properties like increasing internal mechanical friction loss etc. The center layer is typically PU based.

The foil types used are numerous:
PET, PEN, PEI, PU, PAR, PEEK among other more exotic composite polymers as well.

The processes for thermo-forming these foils into the final diaphragm shape are typically following the sequence shown in *Fig. 6*.

Fig. 6



Step 1: The foil is placed between a top tool and a bottom tool where the bottom tool has the shape of the diaphragm.
A carrier ring with glue is positioned onto the bottom tool.

Step 2: Hot air is blown into the two closed tools from the top.

Step 3: The two tools are opened, and the diaphragm is formed into shape.

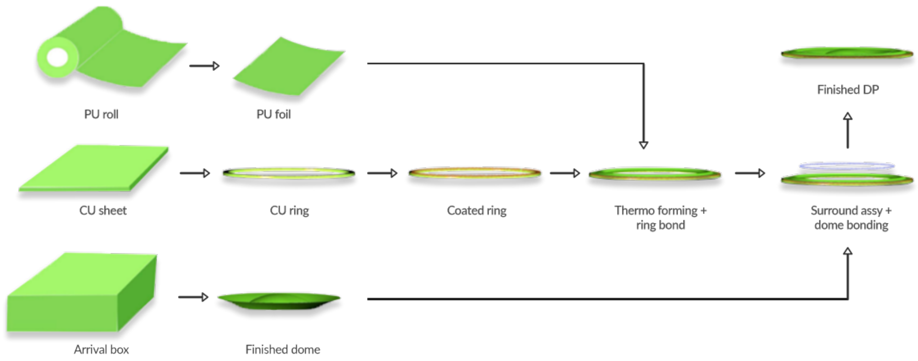
Step 4: The diaphragm now glued to the carrier ring is cut free by laser.

Step 5: The diaphragm is end-processed as a finished part.

Very often, a separate dome made from very stiff and light material is bonded onto the Sd (effective area) of the diaphragm, assuring an even better high frequency response extending the upper frequency where the Sd else tends to break up in partial areas being out of phase with each other and resulting in an uneven and falling response.

A typical process flow diagram for manufacturing the diaphragm incl. dome is shown in *Fig 7*.

Fig. 7



(Source: YUONYUNN MEMBRANE COMPANY.)

Conclusion

The diaphragm must be considered as the "heart" of the driver/ micro speaker design.
The diaphragm not only influences the sensitivity by the effective area Sd, but it also to a very high degree determines the frequency response as well as the overall linearity.

Even very small design changes in the diaphragm can have a huge effect on the piston behavior.
Therefore, finite element simulation tools like COMSOL, are invaluable in the achievement of the audio target performance set by the kickoff of a micro driver/speaker project.

In fact, an optimal diaphragm design can make the whole difference from a bad performing driver/speaker to an excellent one.

Ole Wolff takes advantage of the supreme of all available simulation tools for bringing diaphragm performance for micro drivers/speakers to the next level.

In case of questions or a wish for a dialog, the following e-mail address and mobile phone number can be used:

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