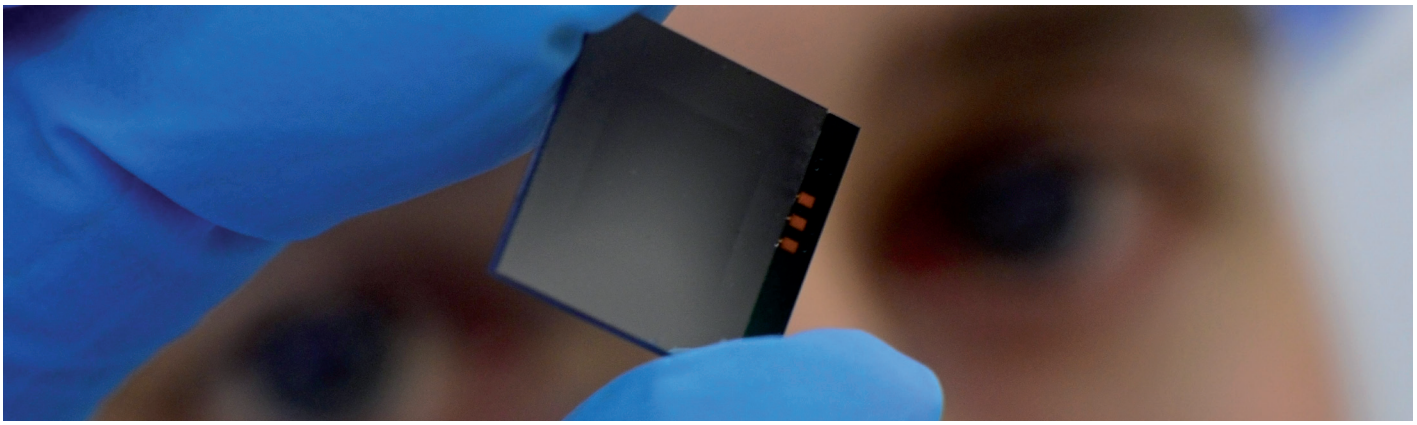
MEMS LOUDSPEAKER UTILIZING METALLIC GLASS MEMBRANE AND DEPOSITED MAGNET



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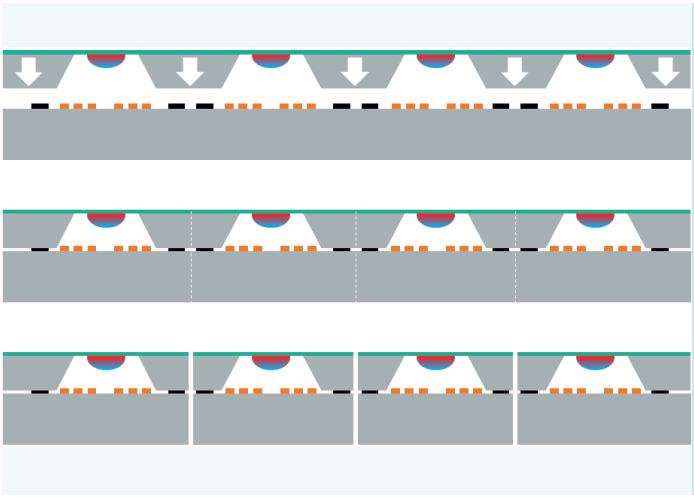
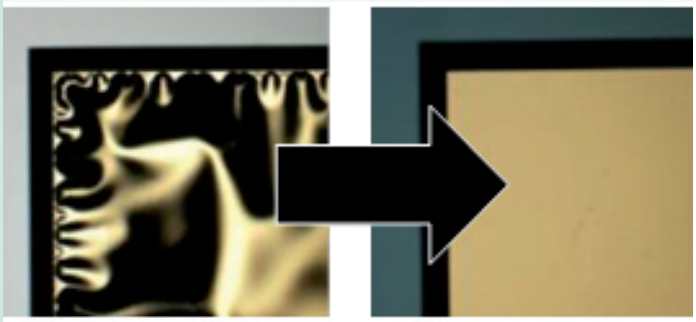
Nowadays, micro loudspeakers are part of all mobile electronic devices such as smart phones, tablets and laptops. This market is estimated to demand more than one billion microspeakers per year and is still growing. Fraunhofer ENAS is working on the development of a micro loudspeaker with MEMS technologies. Metallic glass is applied as material for the movable membrane of the loudspeaker. In combination with dispensed magnetic paste and a micro coil, an electrodynamic actuator has been fabricated. Metallic glass membranes and micro coils are fabricated on separate wafers and subsequently assembled by low-temperature wafer bonding (Figure 1). Finally the wafer stack is diced into chips. The specification of this MEMS speaker technology demonstrator is summarized in Table 1.

Table 1: Specification of MEMS speaker technology demonstrator

Feature	Specification
Size	12 x 12 x 0.8 mm^3
Substrate	Silicon
Sound pressure level	50 dB at 10 cm, 15 kHz, 9 V_{pp} *
Impedance	6 Ω
Membrane	
Size	Square, 6 x 6 mm^2
Material	Pd-based TFMG
Deposition technology	Sputtering
Permanent magnet	
Size	Circular, Ø 2 mm
Material	Paste with NdFeB particles
Deposition technology	Screen printing / dispensing
Remanence	0.35 T
Micro coil	
Inner diameter	0.5 mm
Number of turns	20, spiral
Conductor width / spacing	50 / 50 µm
Conductor thickness	10 ... 12 µm
Material	Copper
Deposition technology	Seed layer sputtering, electroplating

** Sound pressure can be increased by reducing the distance between micro coil and magnet. For the measured demonstrator the distance was about 200 µm and membrane deflection < 2 nm.*





Metallic glasses

Due to their amorphous micro structure, metallic glasses exhibit superior mechanical properties compared to crystalline materials:

- Large elastic limit
- High strength
- No material fatigue
- Corrosion and wear resistance
- Isotropic and homogeneous
- Stress release in SCLR (viscous flow)

Depending on the material composition, metallic glasses can be designed to show electrical conductivity and magnetism as well. Furthermore metallic glasses can be deposited by standard physical vapor deposition process (sputtering). However, the process parameters need to be well-controlled. Table 2 shows properties of Pd-based thin film metallic glass (TFMG) in comparison with polysilicon. Membranes of today's MEMS microphones are typically made of polysilicon. There is a wide range of potential applications for metallic glass in MEMS. For example wherever large (elastic) deformations of micro structures are needed, metallic glasses are promising candidates.

Table 2: Properties of Pd-based TFMG in comparison with polysilicon

	Pd-based TFMG	**Polysilicon**
Young's modulus (Resistance against elastic deformation)	58 GPa (tensile test) 70 GPa (bending test)	170 GPa
Elastic limit (Maximum strain without permanent deformation)	2.0 %	0.7 %
SCLR (Supercooled liquid region)	360…400 °C	-

Figures:
page 1: MEMS loudspeaker with metallic glass membrane and deposited magnet
page 2: Loudspeaker construction and assembly process in cross-sectional view (left);
Stress release in metallic glass membrane by annealing within SCLR (5 min at 370 °C) (right)

Photo acknowledgments: Fraunhofer ENAS