TECHNOLOGIES FOR MICROFABRICATION OF MEMS DEVICES

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A MEMS process has the goal of creating suspended microstructures, accessible through electrical signals. To this purpose, it is fundamental to create conductive and suspended parts, interconnections (electrodes) and small gaps useful for the capacitive sensing on which mostly inertial sensors are based. Finally, operation in vaccum enables damping and thus noise minimization.

The entire process is divided into 4 steps:
1. structural layer growth (Epitaxial growth)
2. structural layer etching (DRIE)
3. release of the polysilicon frames
4. packaging

1. The first steps, consisting in the STRUCTURAL LAYER GROWTH, is usually performed through a procedure known as EPITAXIAL GROWTH, where a thick layer of polysilicon is formed by mixing a proper quantity of precursor gasses in a chamber, properly heated and kept at a proper pressure.

The overall thickness of the obtained layer, usually ranging in the 20-50 μm range, is fundamental for inertial sensors, as their intrinsic noise (NEAD and NERD), indeed, decreases w/ increasing mass values and so w/ increasing thickness.

Another relevant aspect is the thickness uniformity bcz it affects the resonance frequency of out-of-plane (OOP) modes, generating different sensitivity from part to part in z-axis accelerometers, due to the variability of the resonance frequency, or different sensitivity from part to part of pitch/roll gyroscopes, due to the variability of mode-split values, for instance.

2. The second step in the microfabrication is the STRUCTURAL LAYER ETCHING which is used to define the shape of the suspended parts. It is fundamental to reach a high form-factor, so to have narrow and deep trenches. For this reason, isotropic etching is not a good option, but it's better to use an ANISOTROPIC ETCHING APPROACH which is obtained through a procedure known as DEEP REACTIVE ION ETCHING (DRIE), where a high form-factor (~30) can be obtained through the consecutive application of small isotropic etching w/ following protection of sidewalls (at the end of each steps) which determines a quasi-vertical etching at the end.

To goal is to etch as small gaps as possible, as this sets the transduction factor of capacitive driving and sensing. W/ lower gaps, we can obtain the same motion using lower driving signals, or larger signals for the same motion can be achived.
In turn, this is beneficial to reduce input-referred effects of electronic noise.

Once again, the gaps uniformity is fundamental. Differences in etching, from part to part may induce differences in resonance frequency (due to spring etching) or in transduction factor (due to gap etching).
Additionally, local differences on the same structure may induce quadrature errors in gyroscopes. From this standpoint, also the sidewalls orthogonality (so called SKEW ANGLE EFFECT) is fundamental to avoid OOP effects of drive forces in pitch/roll gyroscopes.

REM:
- isotropic → in the all directions w/ the same intensity
- anisotropic → especially in one desired direction

3. Once the structural layer shape is defined, it's the turn of POLYSILICON FRAMES RELEASE.
This is obtained by etching the sacrificial oxide underneath the structure through proper gases. This etching advances by a distance, underneath the structure, which is proportional to the etching time: the step thus defines also the minimum width of the parts that shall remain anchored, which is also the maximum width of the suspended parts.
Wherever a suspended frame should be larger than this width, holes in the frame should be positioned so to allow the correct release.

4. Finally, PACKAGING is used for a triple role of:

a. protecting the structure from external dust;
b. setting the proper operation pressure, so adapting the Q factor to the specification requirements;
c. forming an inert gas environment to avoid silicon oxidation during the device lifetime.

The step consists in BONDING a CAP wafer on the top of the MEMS wafer, where bonding is ensured by a proper material sealing the MEMS cavity.
In generale, there exist 2 bonding techniques, according to the type of material used to seal the MEMS cavity:

- GLASS-FRIT BONDING: uses a sort of glass powder, called glass-frit, which melts at reasonably low temperatures, compared to metal melting temperatures.

- EUTECTIC BONDING: uses an alloy of material that, under thermo-compression, melts to form the sealing

Once more, repeatability of the package pressure from part to part is fundamental to ensure performance repeatability of different structures: indeed, pressure influences the Q factor and in turn all the parameters that are a function of it (noise, ringdown time, bandwidth, motion amplitude...).