

One-Day Fast-Prototyping Process for Functionalized Membrane Array on Flexible Substrate

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Since the emergence of the MEMS industry, rapid prototyping became crucial to allow for efficiently testing new designs at low cost by small batches production and rapid fabrication technologies as conductive polymer [1], conductive inkjet [2] or sacrificial-layer-free fabrication processes [3]. In the same time, flexible electronics is becoming one of the main emerging topics in the electronics field. In this work, we are experiencing a new ultra-fast-prototyping dry process that enables to produce functionalized capacitive membrane arrays on Kapton®, from Dupont®, polyimide as flexible substrate in an only one-day process philosophy based on laser etching.

The process consists in releasing membranes by a calibrated laser etch in a Kapton, on the top of which a thin metal layer has been deposited, and next bonding the sheet on a metal-coated Pyralux® sheet, also from Dupont, that will act as bottom electrode and flexible substrate (fig. 1). In this work, the active 52µm Kapton sheet features 16 membranes of 1mm diameter and 25µm remaining polyimide thickness.

Characterization of the etch speed is done considering three parameters as presented in [4]: laser velocity, V, number of etch passes, N, and the proportion of the total laser power, P, merged together as an etch factor that is $N \cdot P / V$, the total laser power being 3.5W. Multiple tests have been done showing good linearity following the ratio between the number of passes and speed (fig. 2). Multiple runs have been performed showing low variation in terms of etch depth (<5% of total depth), demonstrating the repeatability and predictability of the process.

The roughness of the etched surface is another parameter of importance. Inhomogeneity in etch speed will directly lead to limitation in terms of minimum membrane thickness that can be reached with the laser etching. Measurements have been carried out with a topography measurement system showing roughness around 205nm (Ra) and 1.19µm (Rz) (Fig. 3). This will ensure repeatability in membranes mechanical and electrical properties.

Adhesive thermal bonding is used to bond Kapton to substrate. Since adhesion between Kapton and substrate metal is poor, PMMA has been spin-coated on both substrate and Kapton foils with a thickness of about 500 nm. PMMA-PMMA bonding occurs when glass transition temperature is reached [5], around 105°C, but the higher the temperature and the pressure applied, the higher the bonding strength. In this work, we are operating the bonding at 500kPa pressure to be sure to avoid destroying the samples and at 165°C. These parameters led to sufficient adhesion strength.

Two types of substrates have been considered: the first one featured a 1µm copper layer as top electrode deposited by evaporation and the second one used a conductive coating spray. The latter features a strong interest for its low cost and low time of deposition, but lead to a rough 20µm-thick metal layer.

Measurements are done through scanning vibrometer using electrostatic actuation. With 50V DC bias and 20V AC periodic chirp signal excitation, measurements showed good agreements with the simulations for the first sample, i.e. a resonance frequency of 150kHz (fig. 4) with amplitude of 0.15-0.3nm. On the other hand, the second sample did not show good results due to the high level of dissipation that the conductive coating seems to induce, making the sample an over-damped system. In that case, it was not possible to distinguish resonance frequency because of noise. At present, such coating spray does not seem suitable for this type of applications.

As result of this work, we demonstrated a new type of ultra-fast prototyping process for functionalized membranes on flexible substrate based on laser etching and adhesive bonding.

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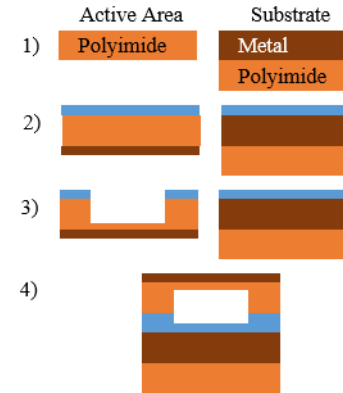


Figure 1. Process flow. 1) Initial state, 2) PMMA and Metal layer deposition, 3) Laser etching and 4) Heat bonding.

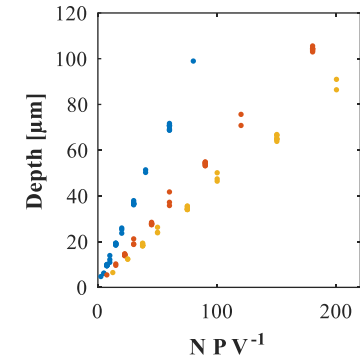


Figure 2. Calibration curve: depth versus the etch factor. The color of the dots is related to the laser power with $P = 10\%$ (blue), 30% (orange), or 50% (yellow) of the total power.

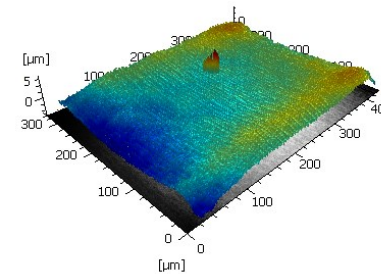


Figure 3. Topography measurement on the backside of a membrane after laser release.

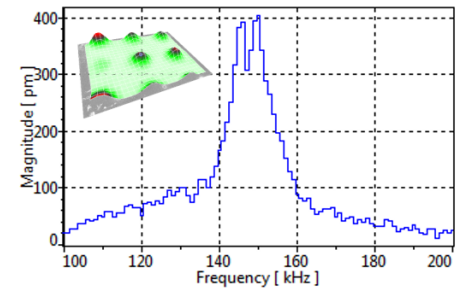


Figure 4. Amplitude of vibrations regarding to the frequency measured by scanning vibrometer on a membrane of the sample with evaporated copper top electrode for a 50V DC bias and 20 V AC excitation. The inset shows the amplitude of displacement of nine membranes of the sample at the resonance frequency.