Evaluation of Undercut and Applicability of a Batch HF Vapor Etching System in MEMS Release Etch Processes

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While there are numerous challenges in the manufacture of MEMS devices, one of the most critical is performing the release etch. Various process solutions have been developed, including wet processing, dry processing, the use of supercritical fluids and vapor phase processing. However, most of these schemes have focussed on single-wafer applications. While these have provided satisfactory results from a process performance perspective, the relatively long process times required in many release etches has rendered them unacceptable from a throughput and cost of ownership perspective. Consequently, there is a need for a controllable, predictable release etch capable of achieving throughput necessary for volume production.

This paper will explore the various parameters which control the etch characteristics of a batch HF vapor processor. We will then examine whether the blanket film etch rate may be used as a predictor of the lateral etch rate underneath device structures. We investigate whether the diffusion path becomes an inhibitor to the exchange of reactants and products at the oxide interface underneath the device structure, with the objective of being able to achieve an undercut of >40 microns in a uniform and predictable manner. Results demonstrating reliable functionality of three level polysilicon micro-engines, released in this optimized etch, are also included to reinforce viability of this process.

The primary factors controlling the etch rate are those which affect the vapor composition. Specifically, these would include the MFC controlled delivery of N2 to the HF and IPA vapor generators as well as the N2 dilution flow. The vapor generators contain liquid chemical – either IPA or 49% (weight) HF. The vapor and gas flows are mixed prior to delivery into the process chamber. Figure 1 shows the effect of the HF and IPA vapor flows on the amount of oxide removal.

The response in Figure 1 shows a fairly linear relationship between the amount of oxide removed and the N2 flow through the HF and IPA vapor generators. Coupled with the N2 dilution flow, a process may be configured to achieve the targeted etch rate in the range of 500 angstroms per minute. While a faster etch can be achieved, experiments have shown that etch rates in excess of 800 angstroms per minute may lead to the formation of a macroscopic condensate film which can lead to problems with stiction. Consequently, we have targeted an etch rate suitable to achieve an undercut of two to three microns per hour as a maximum.

In order to evaluate the undercut, test structures were prepared which consisted of a one micron polysilicon pattern with a five micron wide polysilicon opening over a two micron thick oxide film, as shown in Figure 2 (a).

Several tests were run in order to determine if the undercut is linear with respect to time. The etch rate stability was first confirmed, and then tests were run using time as a variable, as well as the starting undercut. In this manner we were able to determine if the diffusion of the etchant species was being inhibited as the oxide interface receded from the point of initiation. Figure 2 (b), (c), and (d) shows the progression of the etch at 4, 12 and 24 hours. The etch progression is relatively linear with respect to time, indicating that the diffusion of reactants through the gap created by the removal of the 2 micron oxide film is not inhibiting the vapor delivery or the removal of reactants even when the undercut has exceeded 30 microns. Figure 3 shows that the etch leaves no residue and is uniform on both sides of the slot.

The stable, predictable progression of the undercut makes the vapor process ideal for release etch of MEMS features requiring an undercut from one or two microns to in excess of 50 microns. The viability of the release etch is confirmed by the functionality of released three level polysilicon micro-engines with comparable lifetimes to micro-engines released in a standard release process.

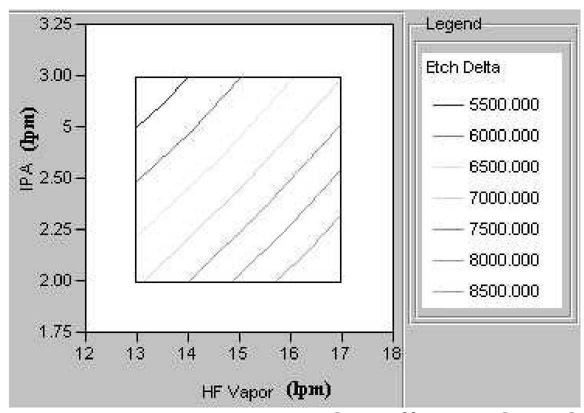

Figure 1: HF vs. IPA Vapor Flow Effect on Thermal Oxide Removal (angstroms)

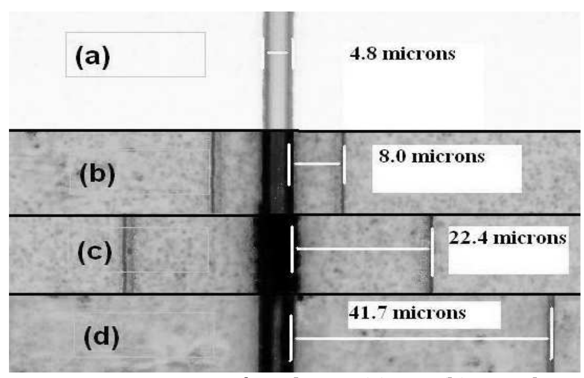

Figure 2: IR Image of Undercut (a) t=0 (b) t = 4 hr (c) t= 12 hr (d) t = 24 hr

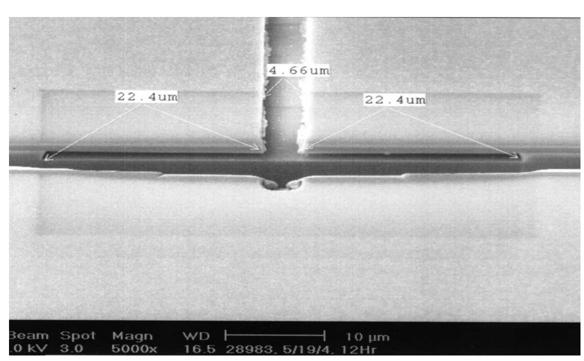

Figure 3: FIB cross-section of 12 hour etch undercut

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