An improved vapor-phase deposition technique for anti-stiction monolayers

Robert Ashurst[1], Carlo Carraro, Roya Maboudian
College of Chemistry, University of California at Berkeley, Berkeley, CA 94720

Boris Kobrin[2], Victor Fuentes, Richard Yi, Romek Nowak, J.D. Chinn
Applied Microstructures, Inc., 4425 Fortran Drive, San Jose, CA 95134

This paper reports on the results of a new technique and apparatus for the vapor deposition of anti-stiction monolayers for MEMS and nano-devices. A vapor deposition technique has obvious advantages compared to traditional liquid phase processes, namely in the elimination of release stiction and the drastic reduction of chemical waste. The use of a vapor-phase monolayer has been previously demonstrated [1,2]. However, these implementations lacked the robustness and practicality for manufacturing MEMS devices. For a MEMS foundry or pilot-manufacturing environment, the vapor-phase application of anti-stiction monolayers have been limited by the absence of commercially available hardware for controlling the deposition process and to ensure repeatability.

In this paper, we report the quality, stiction analysis and process reproducibility of a monolayer deposited using a cost effective vacuum processing system that integrates a surface preparation and monolayer deposition reaction in a single tool (Fig.1). A substrate (or holder with individual devices) is loaded into a process chamber, which is automatically cycled through a plasma surface preparation followed by the monolayer deposition process. The deposition process was controlled by using a technique that accurately meters the precursors and catalysts [3] prior to their injection into the process chamber. Residual deposition of the monolayer coating from the process chamber is subsequently removed using a plasma process.

The use of dichlorodimethylsilane (DDMS) [4] as an anti-stiction monolayer was characterized and reported in this paper. The coatings were evaluated in several ways, including atomic force microscopy (AFM), contact angle analysis (CAA), work of adhesion by cantilever beam array (CBA) technique and coefficient of static friction using a sidewall testing device. Additionally, X-ray photoelectron spectroscopy (XPS) was used to verify the quality of the monolayer film.

Results of contact angle measurements on 150 mm Si wafers (Table-1) indicate good hydrophobicity of the coating, and effectiveness of the plasma surface preparation prior to the monolayer coating. The AFM image (Fig. 2, left) of a DDMS monolayer on Si(100) shows a smooth and particle-free surface. Fig. 3 shows the XPS spectrum of the vapor deposited coating which is virtually identical to the DDMS monolayer for an ideal film. The system [3] was very flexible, and other alkylhalosilanes precursors (e.g. FDTS, FOTS, OTS) may also be used in the system.

References:
[1] T. Mayer, et al., J. Vac. Sci. Technol. B 18(5), 2000, p.p. 2433-2440
[2] W. R. Ashurst, et al., Sensors and Actuators A 104, 2003, p.p. 213-221
[3] patent pending – Applied MicroStructures, Inc.
[4] patent pending – UC Berkeley

Keywords: MEMS, tribology, self-assembled monolayer, anti-stiction coating, vapor phase deposition

---

[1] ashurbr@stiction.cchem.berkeley.edu
[2] boris_kobrin@appliedmst.com

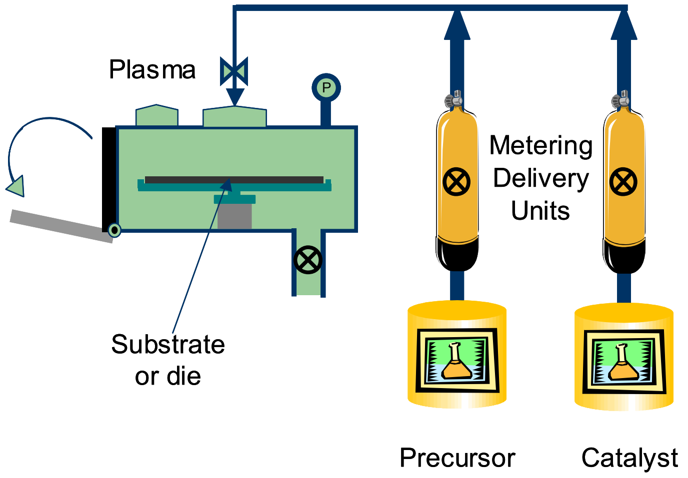

Table-1

Sample	CAA (Contact Angle Analysis) (degs)
Bare Si	23
Post-surface Treatment	<1
Deposited Monolayer (DDMS)	
Center	102.5
Bottom	102.7
Left	102.8
Top	103.0
Right	102.9
Plasma Preparation	<1

Fig. 1: Schematic of the vapor deposition system.

Table 1: Contact angle data (6" Si wafer).

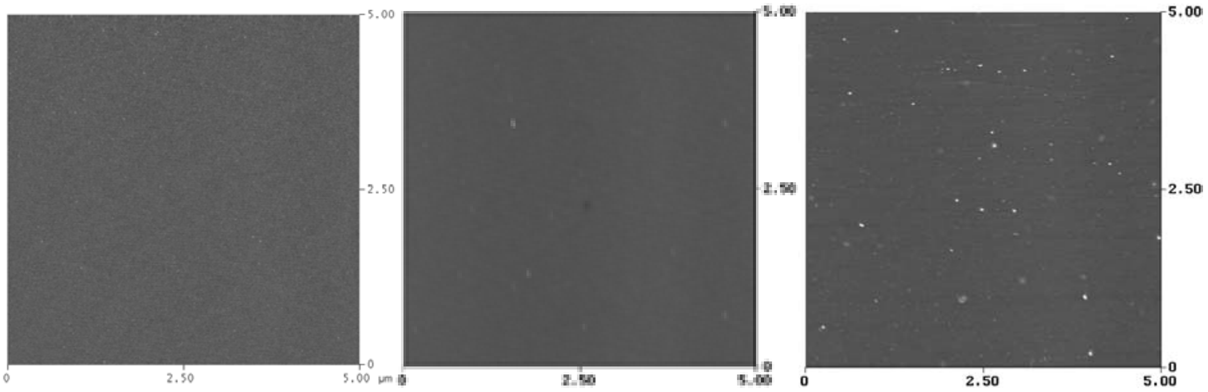

Fig. 2: A comparison of AFM images of the DDMS monolayers prepared by various methods. (From left to right) A coating deposited by the vapor apparatus described in the paper (left, rms roughness 0.2 nm), a coating vapor deposited that was previously reported [2] (center, rms 0.4 nm) and a coating deposited by an immersion method (right, rms roughness 2 nm). The z-scale for all 5 micron scans is 10 nm.

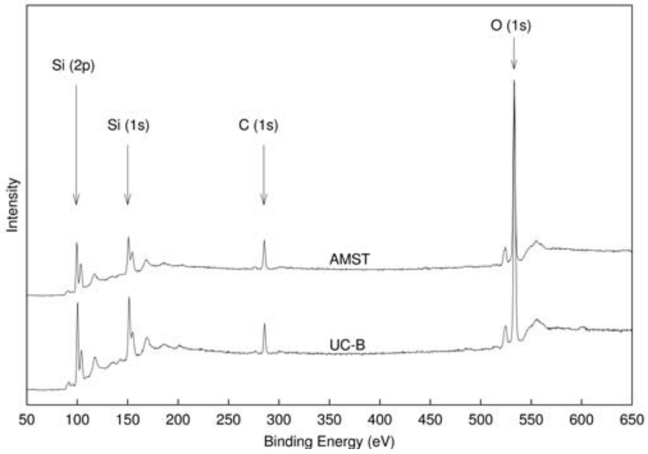

Fig. 3: A comparison of XPS spectra of DDMS monolayers reported in this paper versus an ideal coating.