

Can Trimethylsilanol Make Better Water-Repelling Liners for Computer Chips?

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Abstract

Depending on the incoming metal, chip layers can flake, causing contamination and gaps, unless a liner matches the incoming material's water affinity. Liner chemicals can be costly, smelly, or release strong acids. Strong acids can reverse the reaction; therefore, the contact angle can be lower. We hypothesized acid-releasing chemicals would give a lower contact angle than trimethylsilanol (TMS), which releases only water. TMS won (110.6° vs. 98.8°–102.1°): it does not change pH, and its water should not break the siloxane bond. TMS could improve coating uniformity and adhesion.

Key Result

110.6°

contact angle of TMS-treated silicon (untreated: 64.5°).

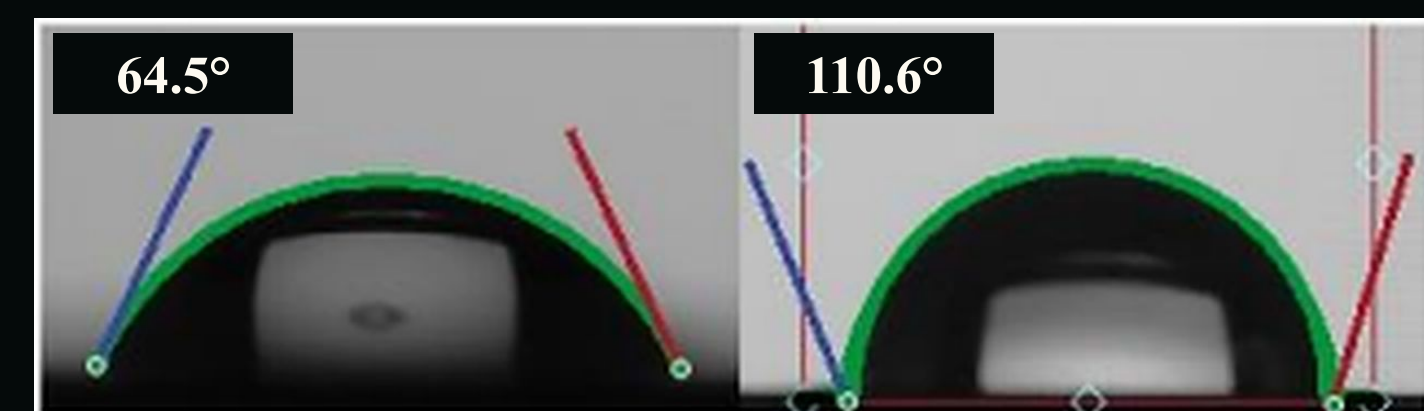


Figure 3. Goniometer (angle meter) images: untreated, 64.5° (left); TMS-treated, 110.6° (right).

Acknowledgments

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Introduction

- Chips pack tiny switches onto wafers; we studied deposition, stacking thin layers of materials on the wafer (1–5).
- A **liner** stops metals that pack poorly from peeling apart (Fig. 1) (6).
- Contact angle:** how a water drop meets a surface; above 90° = **hydrophobic** (Fig. 2) (7).
- The common liner chemical HMDS smells strongly and boils higher (127 °C) than TMS (99 °C) (8, 9). Three alternatives (BTS, CTS, TMS-OMs) make strong acids that can reverse the reaction (10).
- Hypothesis:** acid by-products give a lower angle than TMS, which makes only water.

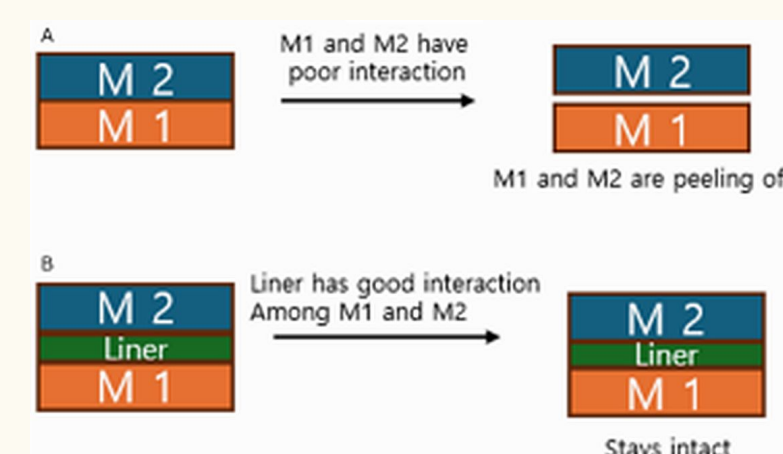


Figure 1. Without a liner, M1 and M2 peel (A); with one, they hold (B).

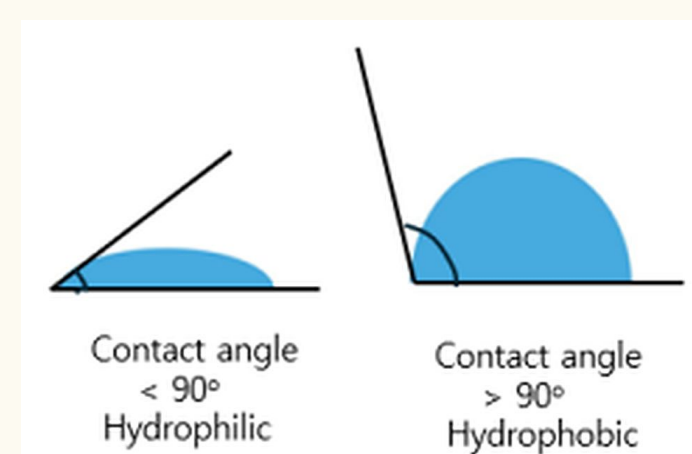


Figure 2. Blue = water drop; above 90° is hydrophobic.

Methods

- Wafer:** 5 mm × 5 mm silicon, 200 nm oxide.
- Chemicals:** TMS (makes water), TMS-OMs (methanesulfonic acid), CTS (HCl), BTS (HBr).
- Tests:** TMS alone, one factor at a time.

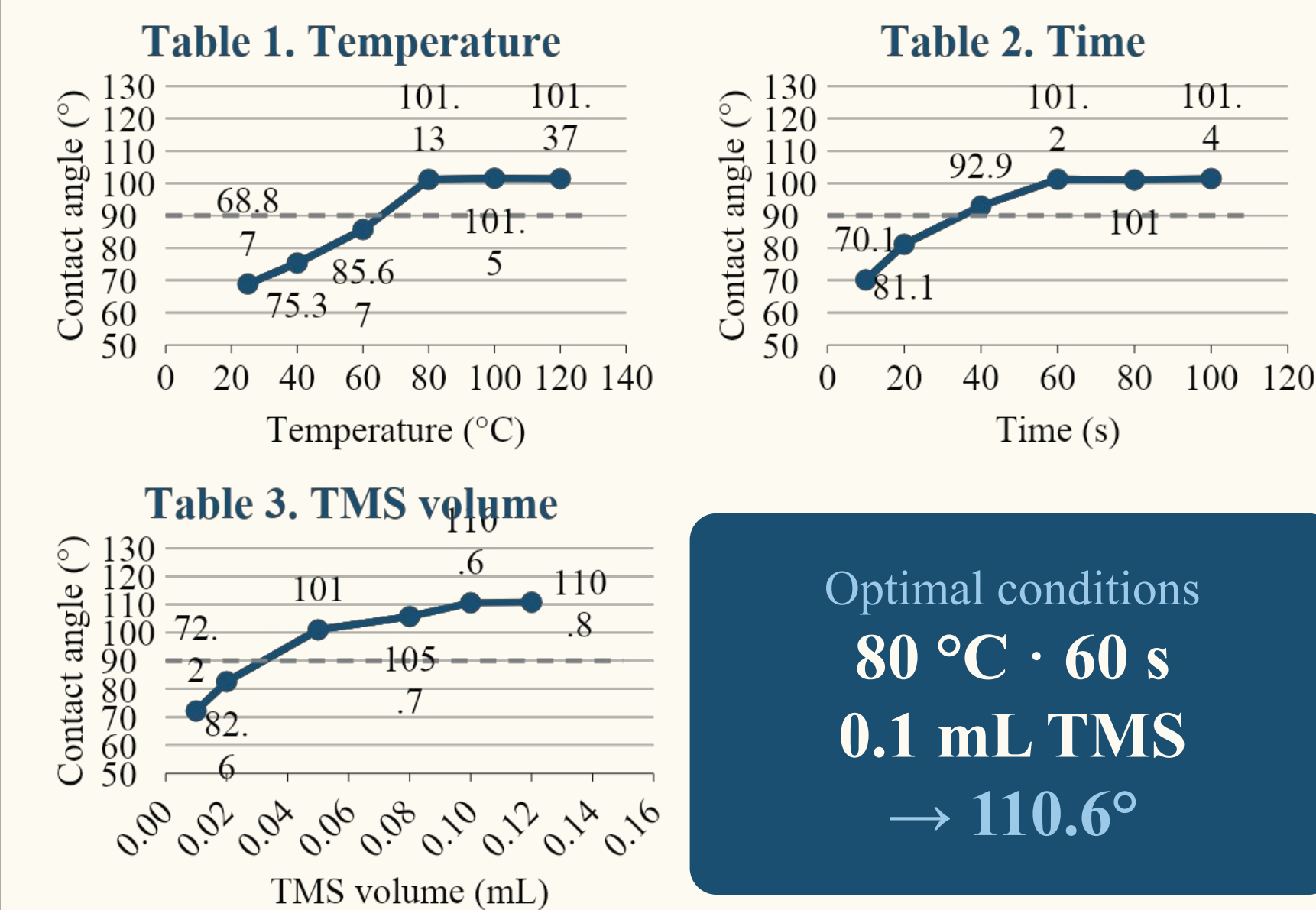
Steps (all four chemicals):

- Heat wafer to 80 °C.
- Add 0.1 mL chemical.
- After 60 s, rinse with water, then acetone; air-dry.
- Measure contact angle (10 µL water drop).
- Test rinse-water pH (indicator strip).

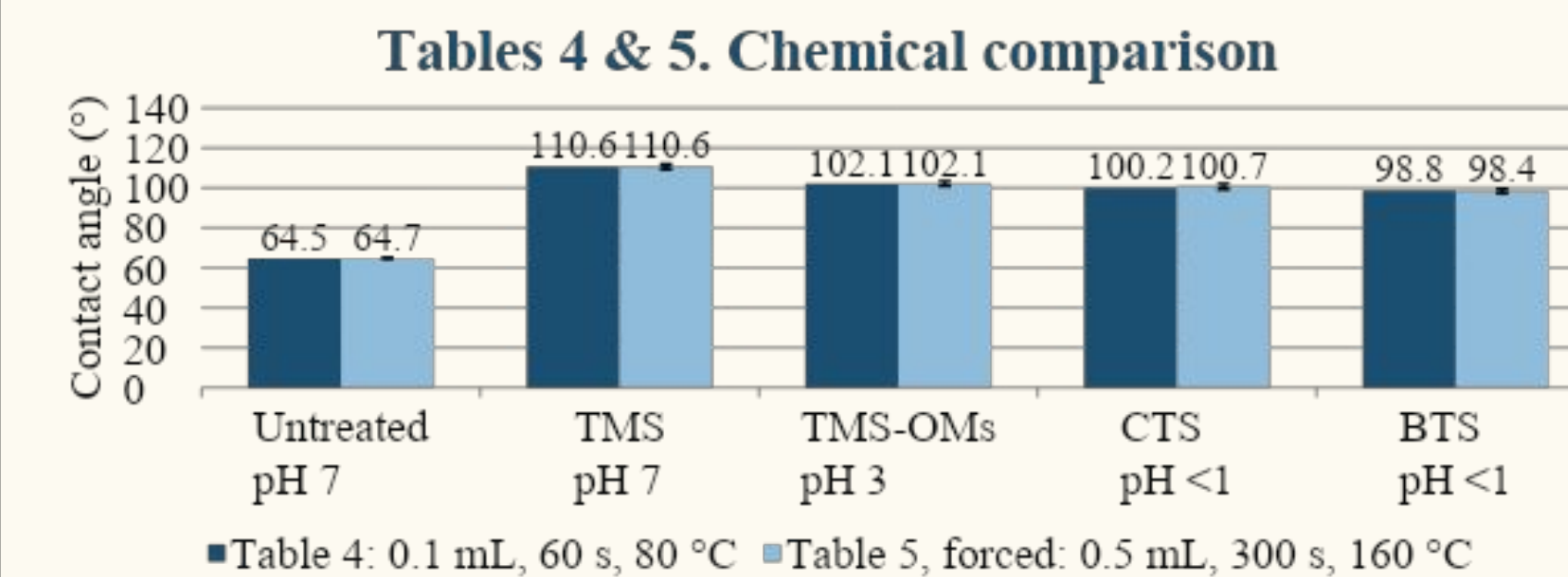
- Safety:** mask, goggles, gloves; adult present.

Results

- Angle rose, then leveled off (Tables 1–3).
- Same conditions: TMS 110.6°, TMS-OMs 102.1°, CTS 100.2°, BTS 98.8° (Table 4).
- Rinse-water pH: TMS 7, TMS-OMs 3, CTS and BTS <1 (Fig. 4). pK_a (lower = stronger): HBr –8.3, HCl –6.3, methanesulfonic –1.6.
- Consistent with our prediction, acid by-products can break the siloxane bond; TMS's water should not.



Tables 1–3. Mean ± SD, n = 3. Table 1: 0.05 mL, 60 s. Table 2: 0.05 mL, 80 °C. Table 3: 80 °C, 60 s.



Tables 4–5. Optimized vs. forced; bars = SD (Table 4: not reported).

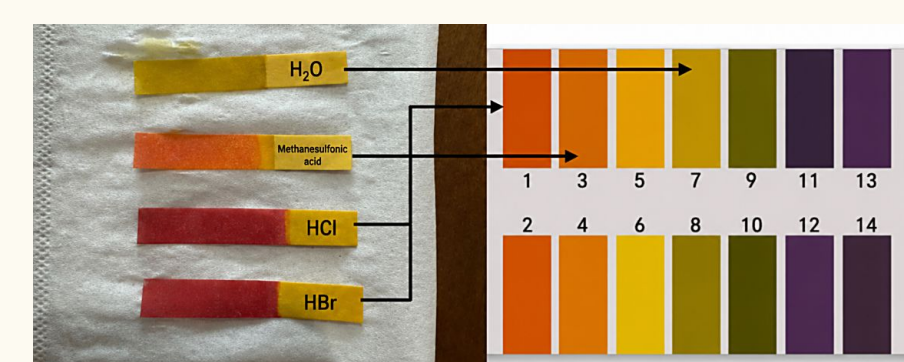


Figure 4. Rinse-water pH: H₂O 7, methanesulfonic acid 3, HCl <1, HBr <1.

Discussion

- Conditions:** below 80 °C conversion was incomplete; above it the angle was unchanged, even when forced (Table 5).
- Mechanism:** TMS makes only pH-neutral water, which should not reverse the reaction; the others make strong acids that do (Fig. 5) (11).
- Acid by-products, lower angle:** TMS (110.6°) beat all three acid-releasing chemicals by 8–12°. Among those three, the angle order follows acid strength, but the gaps are within error (n = 3), so this is a trend, not proof. Oily residue does not change pH, so should not change the angle.

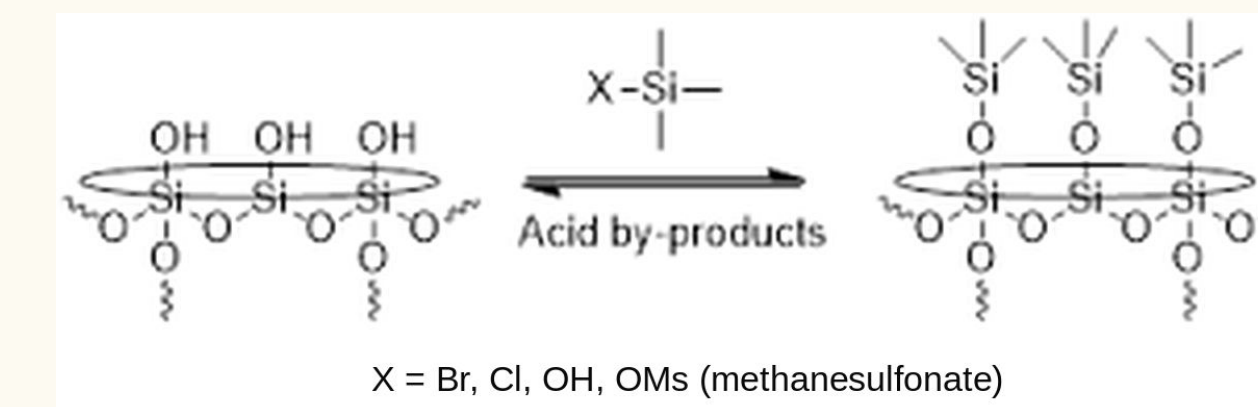


Figure 5. Acid favors breaking the siloxane bond.

Conclusion

- TMS gave the most hydrophobic liner (110.6°); its only by-product, water, should not reverse the reaction. This could mean more uniform coatings and lower costs.
- Limits:** bare silica only; TMS is moisture-, heat-, vacuum-sensitive; cheaper, more stable options exist; others may react faster.
- Next:** test metal binding with CVD/ALD; add a base (triethylamine) to capture acid; study TMS removal.

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