OMNIPHOBIC PROPERTIES OF THIN-FILM PLASMA COATINGS FOR IMPROVED RELIABILITY

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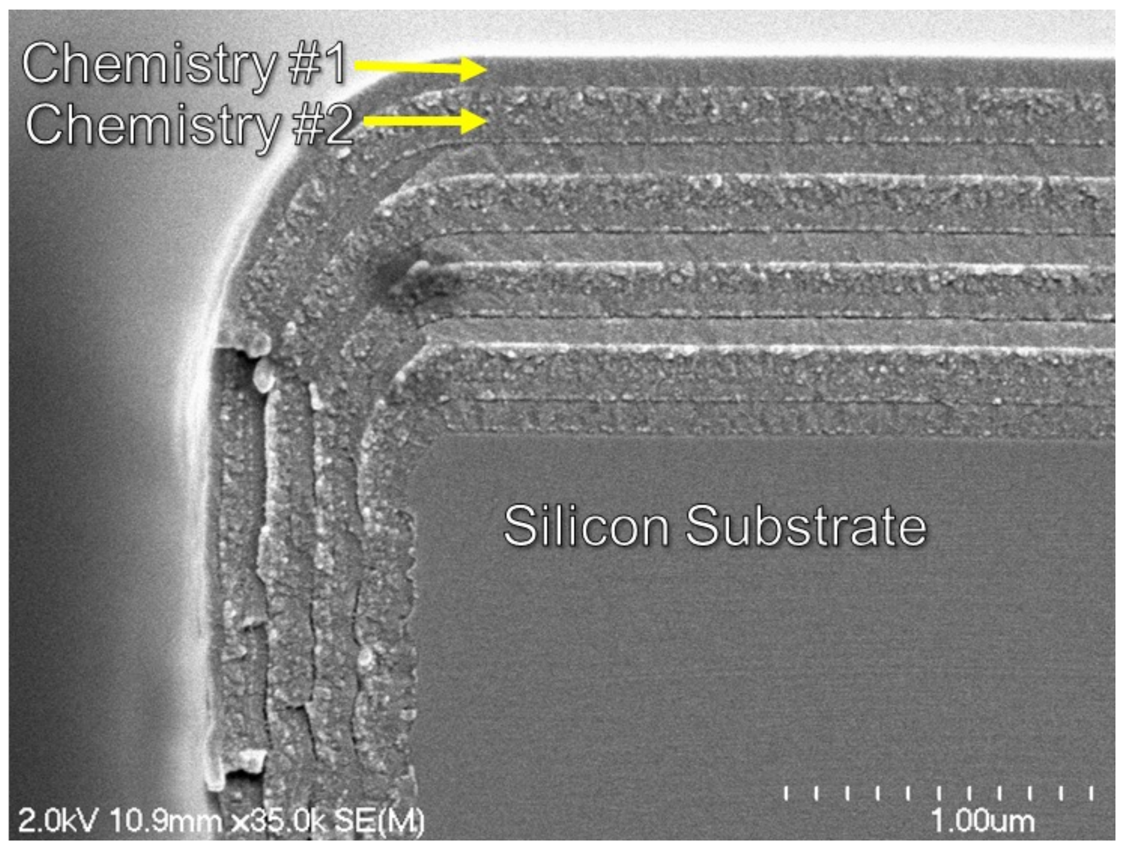
ABSTRACT

Thin film nano-coatings can protect critical electronic circuitry that is used throughout a variety of applications and can be a powerful solution to implement to ensure reliability. Requiring only nanometers- to microns-thin coatings, plasma-deposited coatings are dense, highly cross-linked, multi-layer films that create a physical/chemical barrier around components and sub-components. Plasma-enhanced film deposition technology leverages various chemistries and precise control of deposition environments to deliver fast, repeatable, and scalable processes to meet the demands of projects of different sizes, use environments, and performance standards. Hydrophobicity and lipophobicity are two important features that coatings can possess and are critical to prolonged device operation in high moisture or humid applications. These properties and how to effectively measure them, are imperative to evaluating material selection when exploring coating technology in greater detail.

EXPERIMENTAL METHODOLOGY

- Single-layer and multi-layer films were deposited under vacuum by plasma-enhanced chemical vapor deposition (PECVD). A cross section is shown in the micrograph.



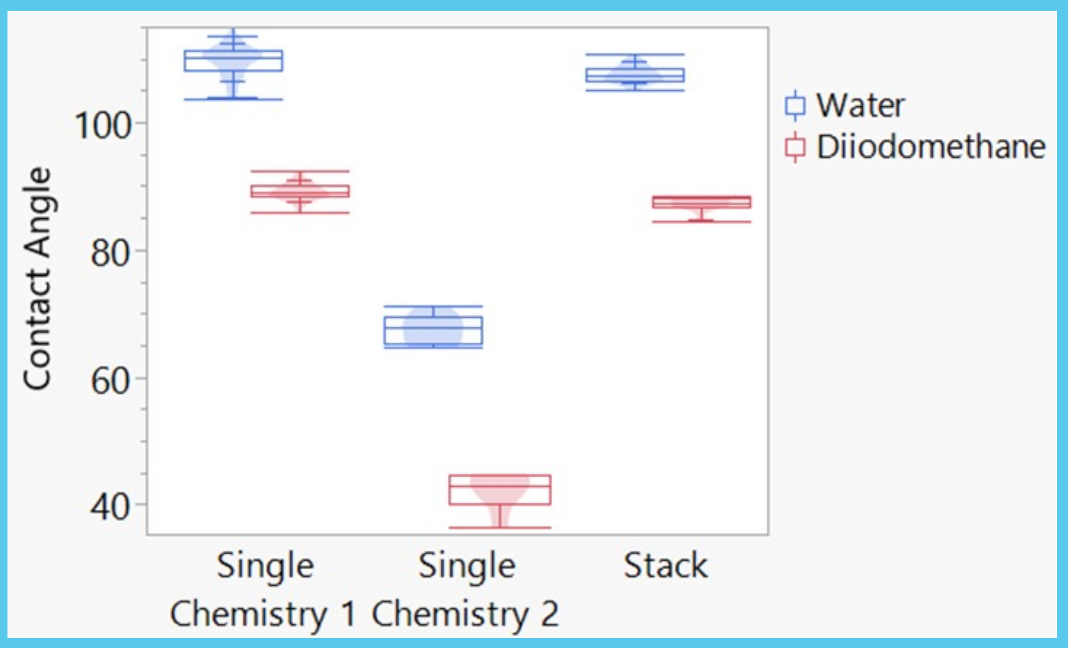
- Multi-layer films are comprised of alternating layers identified as Chemistry #1 and Chemistry #2. The final (exposed) layer in the stack is Chemistry #1.
- The hydro- and lipophobicity of single and multi-layer films are quantified and compared.
- Thickness of single-layer films were measured using a J. A. Woollam Alpha-SE ellipsometer. Thickness of multi-layer film stacks was measured using a Bruker DektakXT stylus profilometer.
- Hydrophobicity was evaluated by static water contact angle (WCA) measurements, performed on a Krüss DSA25E goniometer using de-ionized water. Lipophobicity was evaluated using diiodomethane to measure the oil contact angle (OCA).
- OCA and WCA measurements were performed on both multi-layer stack films and single-layer films.

RESULTS

- The measured thickness range for each of the samples are shown in the table.

Film Type	Chemistry	Min Thickness	Max Thickness
Single	#1	18nm	103nm
Single	#2	280nm	733nm
Multi-Layer	Both	943nm	1,922nm

- Chemistry #1 demonstrates higher WCA (>104°) and OCA (>85°) than Chemistry #2. WCA results are consistently higher than OCA for all surfaces.
- Chemistry #1 and the multi-layer ilms can be considered omniphobic (WCA > 90°, OCA > 60°).



DISCUSSION

- Film thickness and structure are not factors in film omniphobicity.
- Higher contact angles are indicative of increasingly hydro- and lipophobic surfaces that will shed or repel liquids. The more omniphobic (both hydro- and lipophobic) a coating is, the less likely foreign material is to contaminate or adhere to the surface.
- Omniphobic surfaces thus demonstrate a self-cleaning behavior as foreign material tends to be carried away by liquids repelled by the surface.
- Such coatings improve device reliability by shedding foreign material which may corrode, degrade, or otherwise contaminate sensitive surfaces.
- Multi-layered PECVD films have demonstrated improved performance over single-layer films of similar thickness in preventing electrical conduction through long-lived water droplets or pooling water in other more stringent testing methodologies.
- In such films, the stacked structure presents a tortuous path where molecules and ions would have to traverse before impacting device performance. [1]
- While omniphobic coatings alone can enhance device reliability, reliability can be further improved by combining multiple chemistries in a thicker coating with an appropriate structure.
- Here, we have demonstrated omniphobic surfaces can be combined with multi-layer film stacks without degrading liquid repellency.

CONCLUSIONS

Engineered PECVD films can improve device reliability by preventing contamination of critical surfaces by a self-cleaning effect. Such omniphobic coatings are demonstrated here and shown to be compatible with multi-layer film stacks, resulting in a high-performance plasma coating suitable for a range of challenging environments.

REFERENCES

[1] Pulsipher, Dan, et al. “Engineered Reliability – Safeguarding Electrical Components and Products with Nano-coating Technology.” SMTAI 2022.
[2] Ameduri, Burno, et al, ” Opportunities for Fluoropolymers: Synthesis, Characterization, Processing, Simulation, and Recycling.” Elsvier Science, p. 212, 2020.
[3] Park, Jin-Seong, et al. “Thin Film Encapsulation for Flexible AM-OLED: A Review.” Semiconductor Science and Technology, vol. 26, no. 3, 14 Feb. 2011, p. 034001. https://doi.org/10.1088/0268-1242/26/3/034001.