

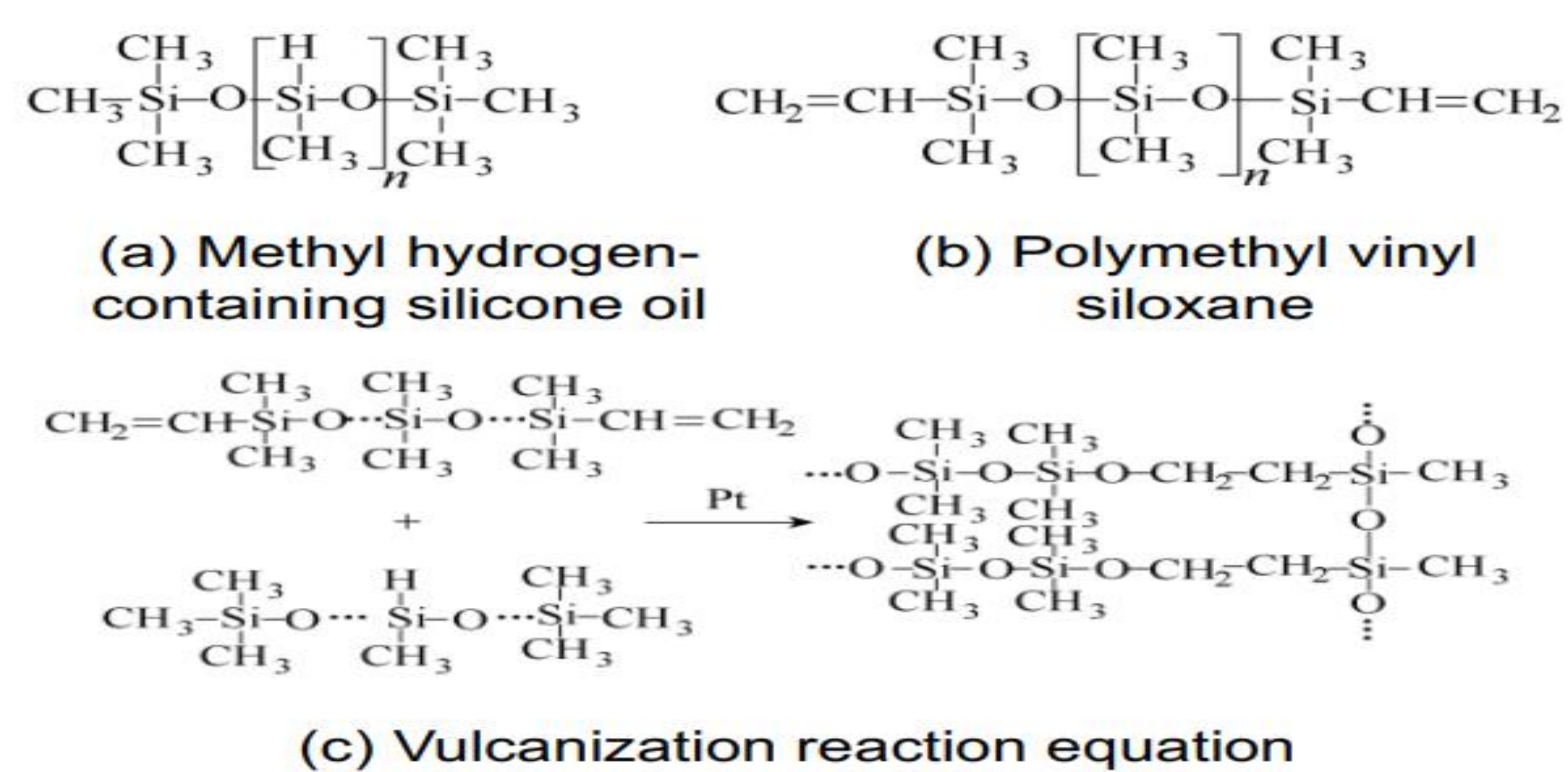
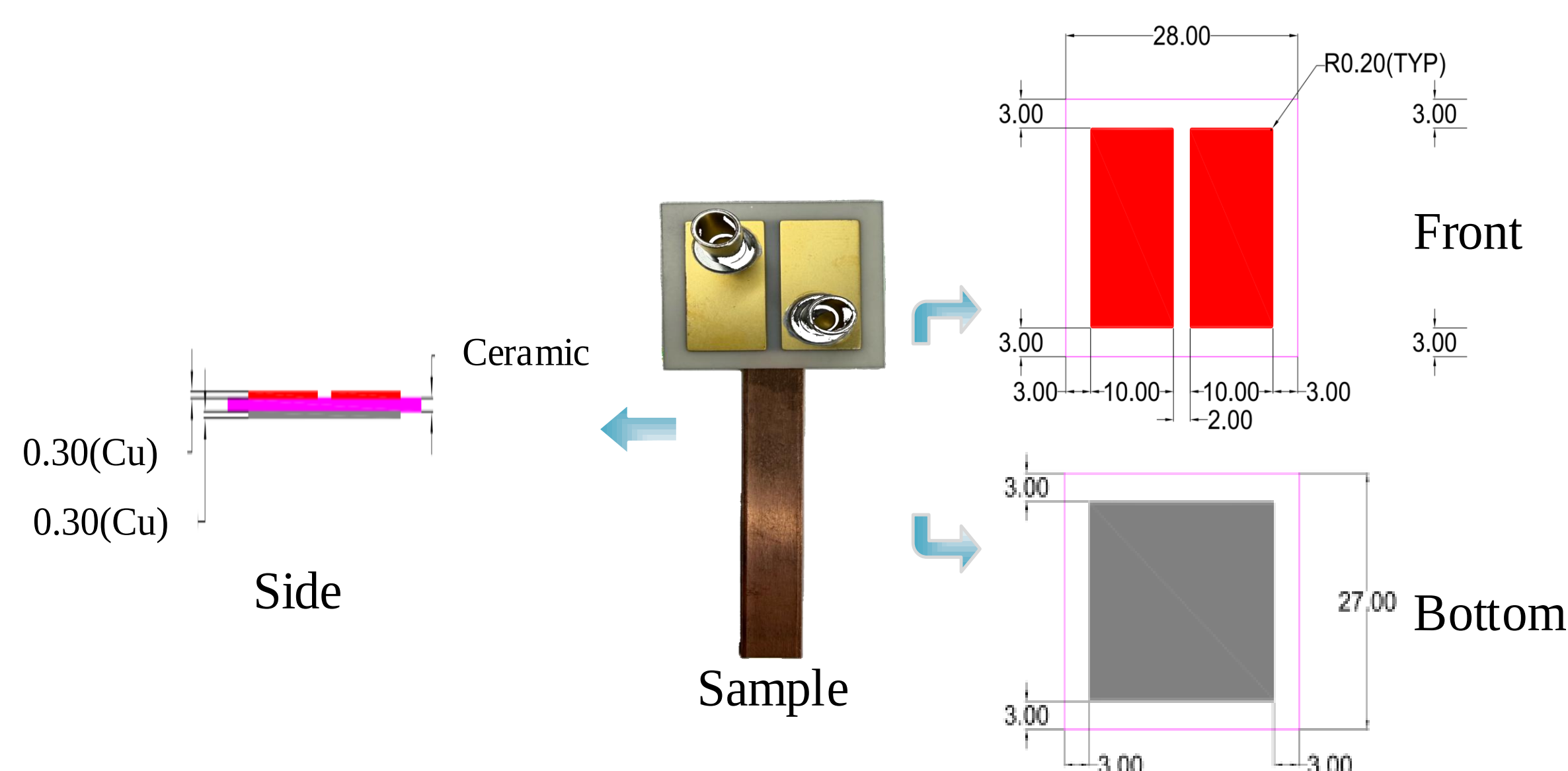
Research on the Optimal Combination of Plasma Cleaning for Power Modules under Square Wave Voltage

Yuntian Gao, Lingyu Zhu, Yingbin Li, Hao Sun, Xia Gong

Department of Electrical Engineering, Xi'an Jiaotong University, Xi'an, China

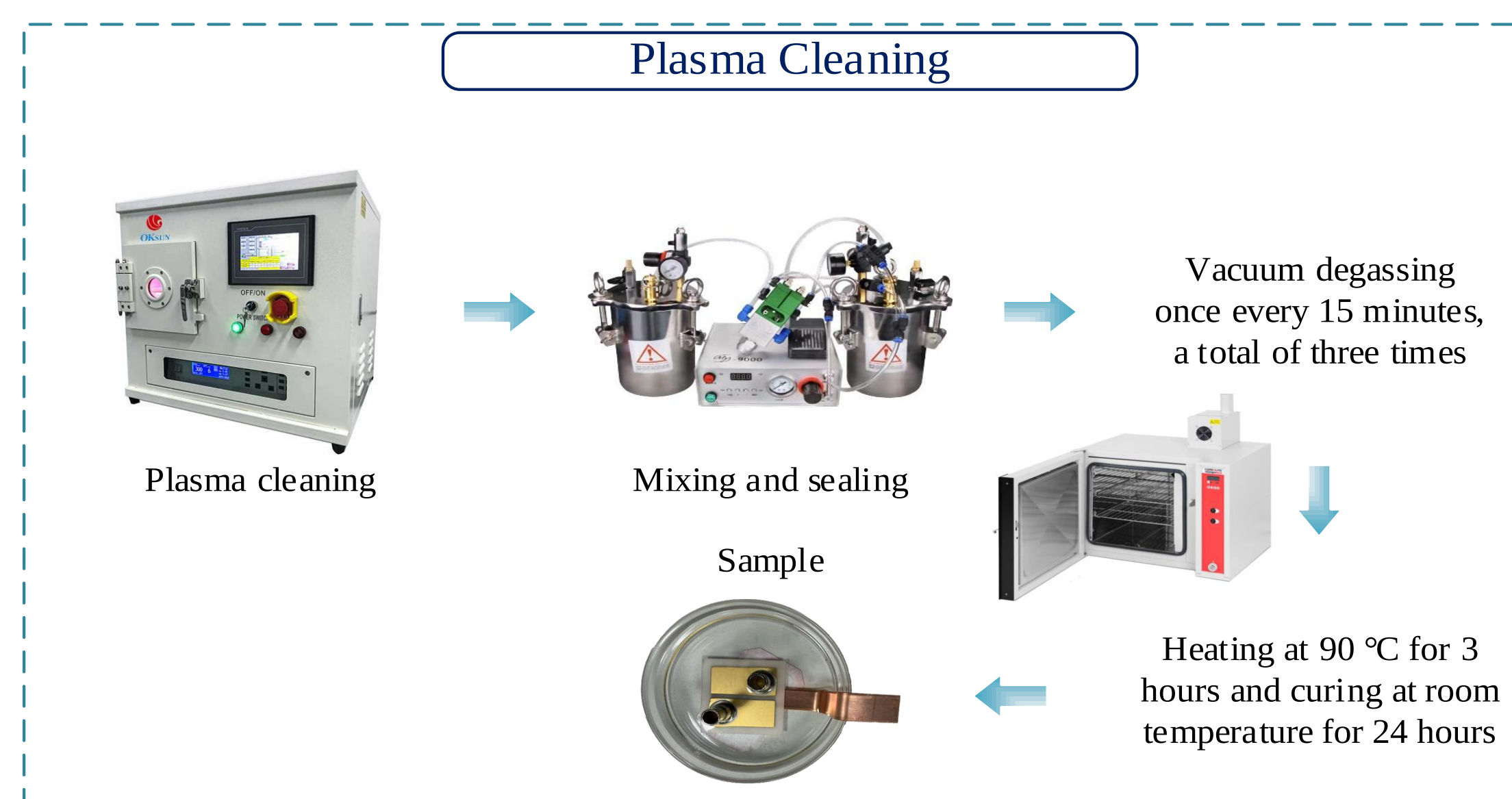
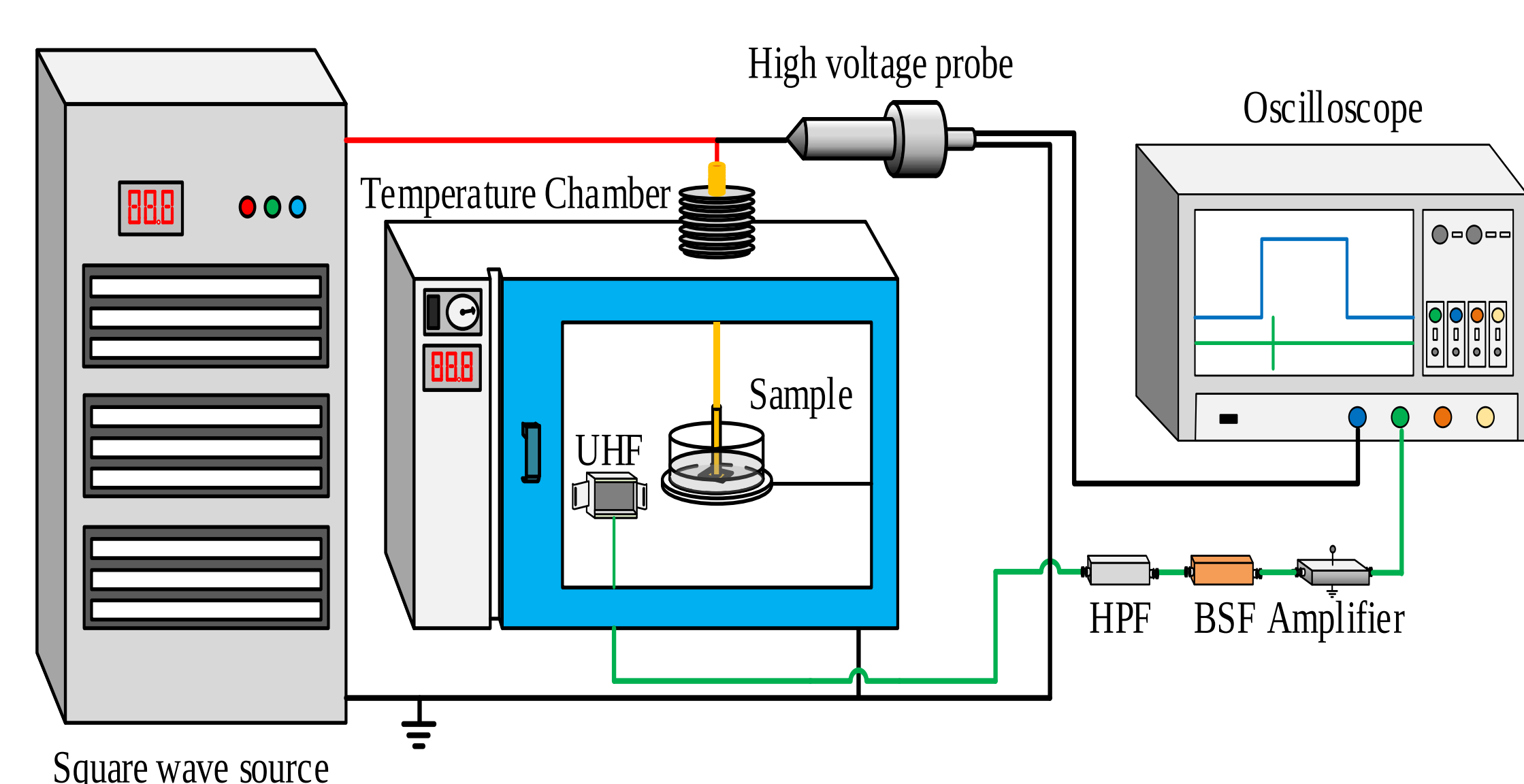
Introduction

- Used as:** Wide-bandgap (WBG) power modules in high-voltage applications.
- Subjected to:** Square wave voltages and plasma cleaning parameter combination.
- Resulting in:** PD occurring at the triple points (TP), leading to insulation failure.



Aim: maximize PD Inception Voltage (PDIV) by optimizing plasma-cleaning parameters.

Methods



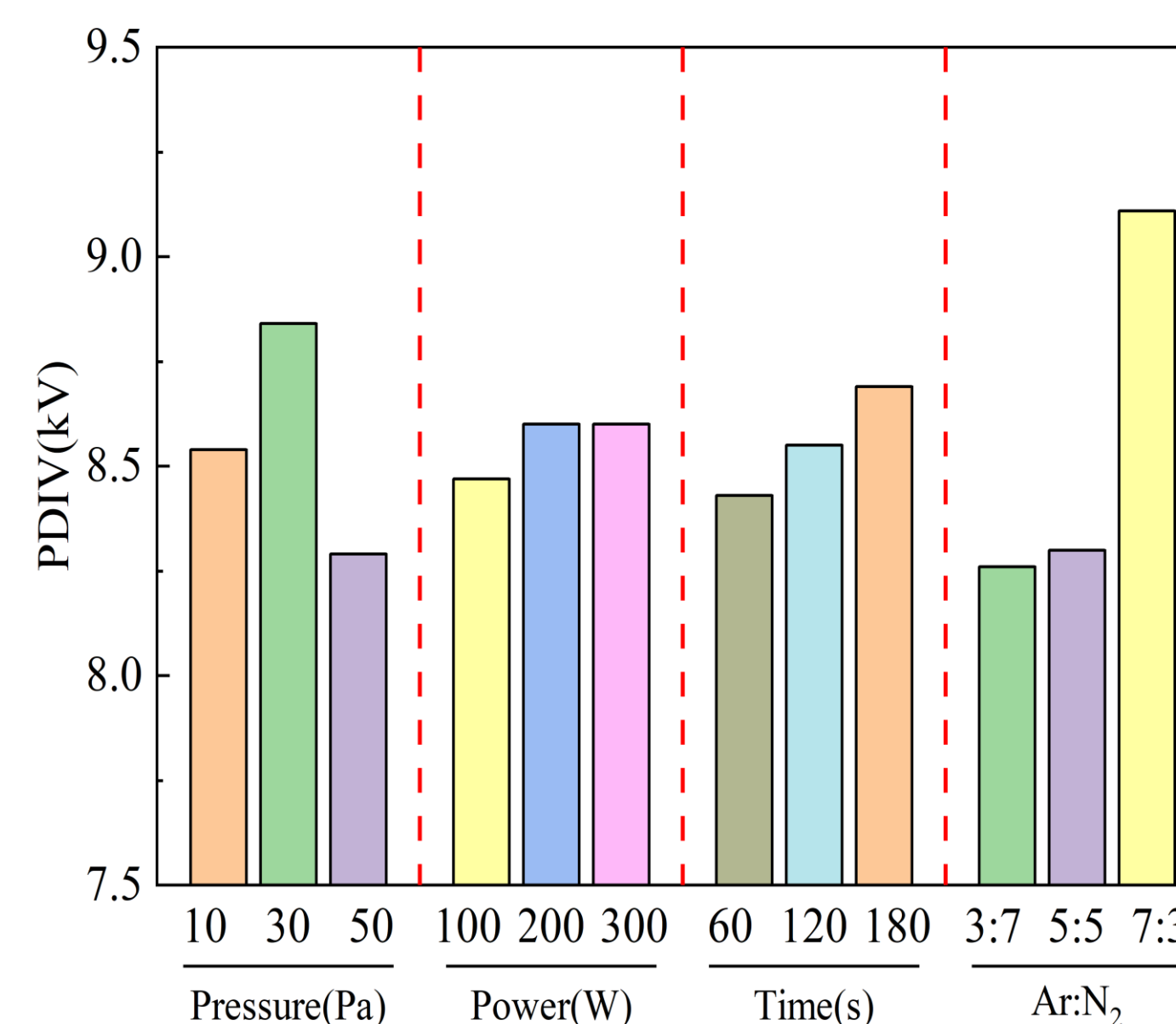
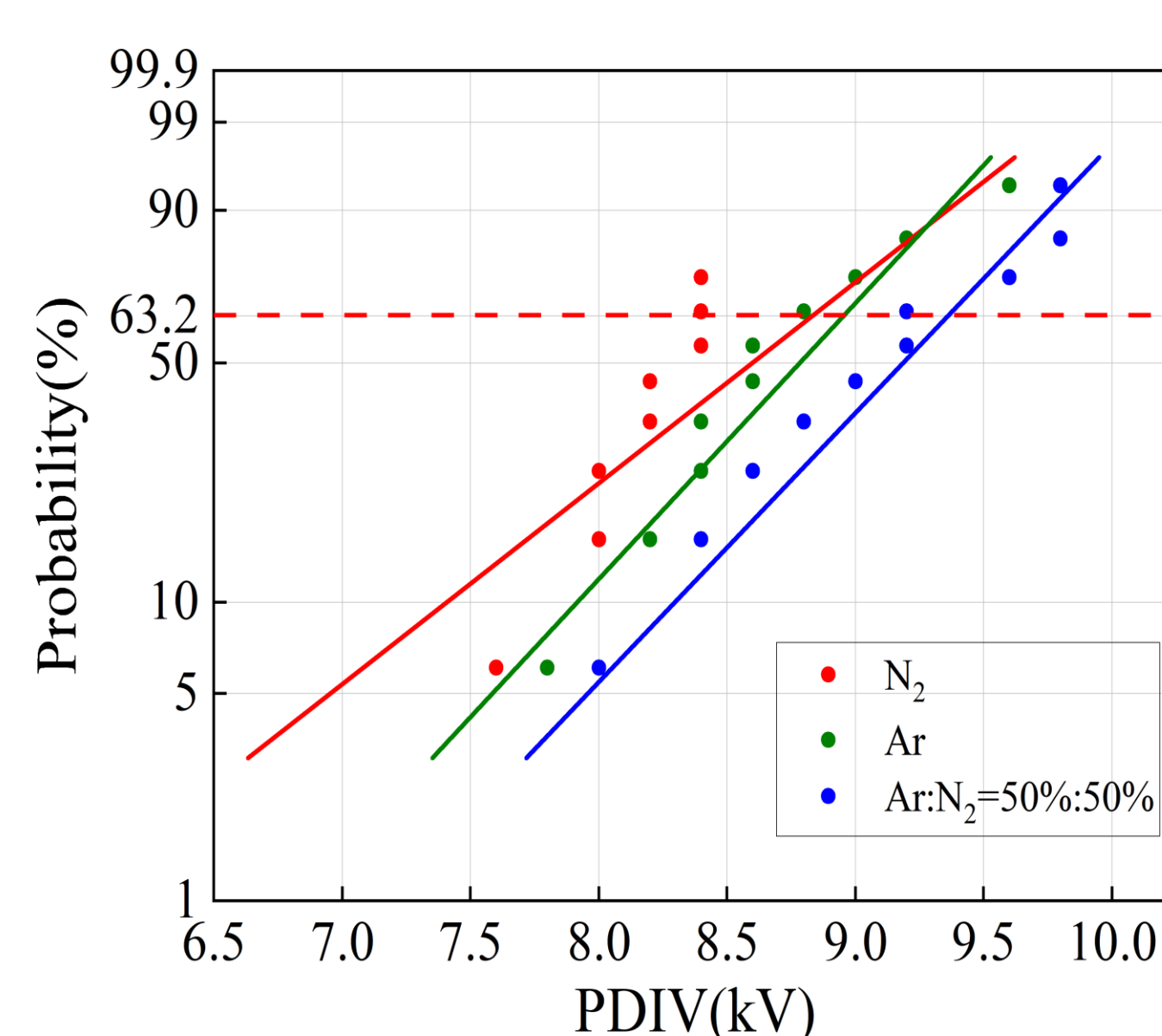
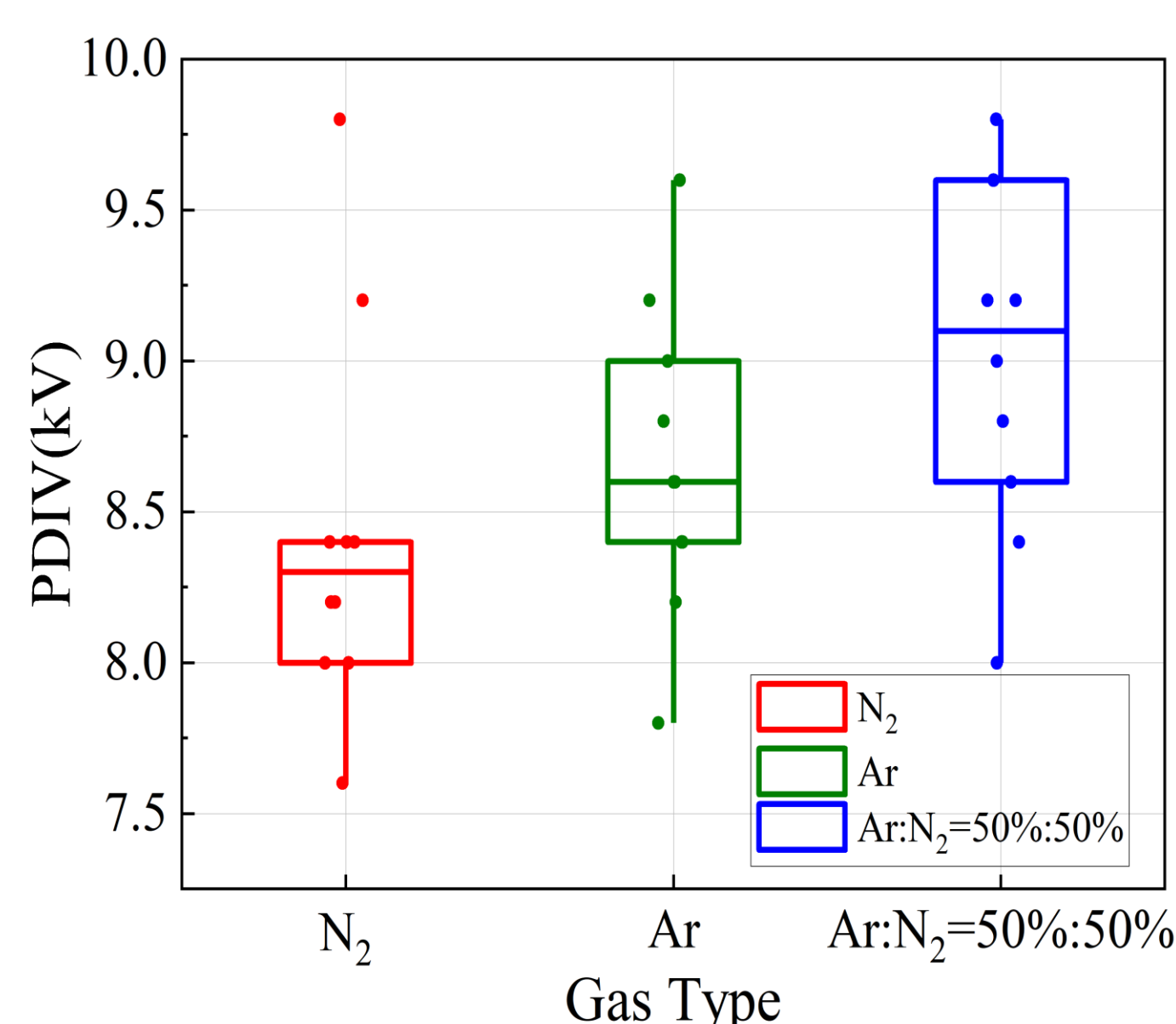
$$\text{PDIV} = \frac{1}{10} \sum_{i=1}^{10} \text{PDIV}(i)$$

$$P_{\text{PDIV}}(V) = 1 - \exp\left(-\left(\frac{V}{\alpha}\right)^\beta\right)$$

Factors: Pressure, power, time and gas ratio

Methods: Range analysis and ANOVA

Verification and Results



Factor	SS	MS	F	Significance
Pressure	4.60	2.30	12.95	Not significant
Power	0.36	0.18	1.00	Not significant
Time	1.01	0.51	2.85	Not significant
Gas ratio	13.69	6.85	38.51	significant

- The argon-nitrogen mixed gas yields a higher average PDIV than the single-gas cases.
- Gas ratio is the dominant and only statistically significant factor in the tested window.
- Optimal process:** 30 Pa, 200 W, 180 s and Ar:N₂ = 70:30.

Conclusion

- The optimized cleaning combination supports reliable, standardized high-voltage power module packaging, while future studies should examine diverse materials, aging conditions, breakdown voltage, and microscopic mechanisms.