FIGURES AND GRAPHS

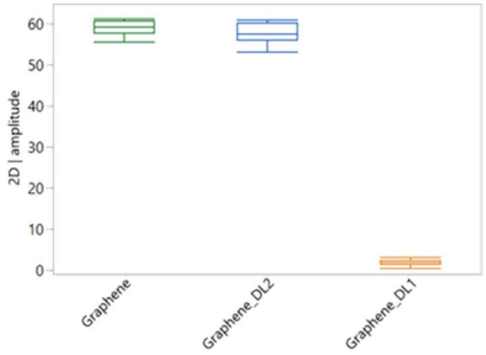


FIGURE 1. A pronounced reduction in the 2D peak intensity, suggesting damage to the graphene structure is seen for the plasma on Graphene case. The elevated Raman background signal for this case is attributed to photoluminescence, originating from the DL1 layer.

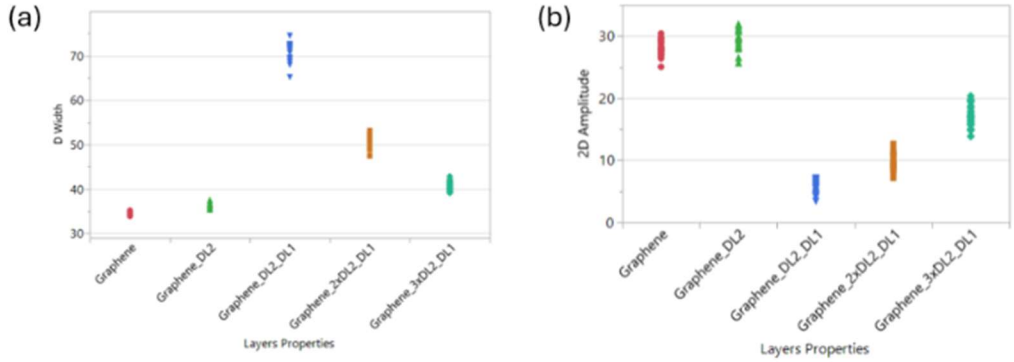
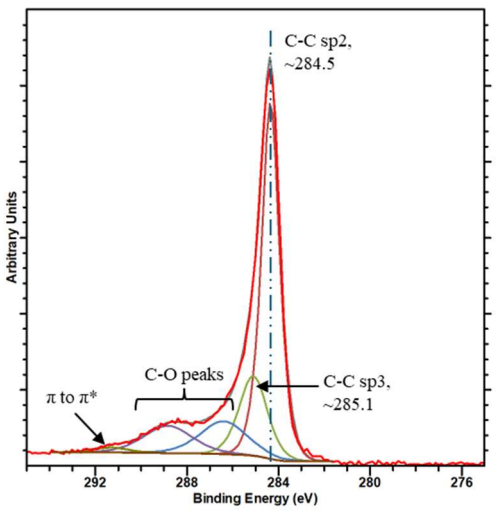


FIGURE 2. D peak's width (a), 2D peak's amplitude (b) and other (not plotted) spectral attributes across the wafer indicate that the thermal dielectric layers introduce an increasing level of protection for the graphene against the plasma deposition process, with DL2 thickness. However, for the three right-most samples, the thermal DL2 layers' thickness were not enough to completely prevent the plasma damage to graphene film.

a.



b.

Stack	*sp2*	*sp3*	*sp2*/*sp3*
Cu/graphene	51.8	15.9	3.26
Cu/graphene/DL1	24.2	25.8	0.94
Cu/graphene/DL2	50.0	27.8	1.80
Cu/graphene/DL2/DL1	43.2	30.7	1.41
Cu/graphene/2xDL2/DL1	44.3	29.5	1.50
Cu/graphene/3xDL2/DL1	45.0	28.8	1.56

FIGURE 3. (a) C1s core-level spectrum of undamaged graphene. The strong sp^2–C peak and minimal sp^3 or oxide-related contributions confirm that the film retains high-quality graphitic bonding before plasma processing. (b) Quantitative comparison

of sp^2 and sp^3 components for various Cu/graphene stacks. The sp^2/sp^3 ratio decreases with plasma or DL1 processing and improves with optimized thermal (DL2) layers.

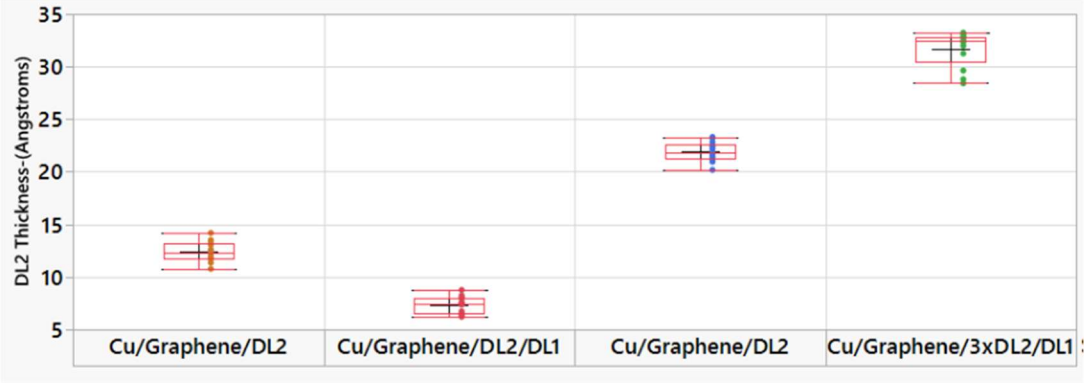


Figure 4. DL2 thickness variability across wafers for different Cu/graphene stacks. Each data point represents a measurement site on the wafer, showing consistent within-wafer uniformity and distinct mean thickness values for each process condition.

REFERENCES

1. K. Kim et al., Graphene as a metal capping layer for Cu interconnects, *Nature Nanotechnology*, **6**, 575-579 (2011).
2. J. W. Suk et al., Enhancement of the electrical properties of Cu by graphene capping, *ACS Nano*, **7**, 269-276 (2013).
3. A. C. Ferrari et al., The nature of graphene–metal bonding probed by Raman spectroscopy: The special case of cobalt, *Nano Letters*, **11**, 4667-4673 (2011).
4. A. C. Ferrari et al., Raman Spectrum of Graphene and Graphene Layers, Phys. Rev. Lett. **97**, 187401 (2006)
5. M.M. Lucchese, et al., Quantifying ion-induced defects and Raman relaxation length in graphene, *Carbon*, Vol. 48, Issue 5, 1592-1597 (2010)

KEYWORDS

Graphene, Inline XPS spectroscopy, Raman spectroscopy, Plasma damage, Di-electric films