Multilayer Amorphous Carbon as Ultralow-k Dielectric

Barbaros Özyilmaz

Department of Physics; Department of Materials Science and Engineering; Institute for Functional Intelligent Materials (I-FIM), National University of Singapore (NUS), Singapore
Contact e-mail: barbaros@nus.edu.sg

Abstract

Continued scaling of CMOS interconnects and emerging two-dimensional electronic platforms requires dielectric materials that remain mechanically robust, electrically reliable, and diffusion-resistant at sub-3 nm thicknesses. Existing ultralow-k dielectrics typically fail at these dimensions because porous films are mechanically weak, while dense amorphous films often lose ultralow-k performance or require separate barrier layers. Here we report wafer-scale ultralow-k amorphous carbon films that address these constraints in a single atomically thin material platform. Direct low-temperature growth below 300 C yields substrate-independent, conformal films with precise thickness control down to 0.8 nm, corresponding to monolayer amorphous carbon. Structural and chemical analysis shows a predominantly sp2-bonded amorphous network with uniform coverage across dielectric and metallic surfaces. Electrical measurements on metal-insulator-metal capacitors demonstrate a thickness-independent dielectric constant of ~ 1.35 with minimal bias and frequency dependence. The films also exhibit high dielectric strength of 28-31 MV cm^-1 and effective leakage suppression. In addition, they act as highly effective Cu diffusion barriers, with projected time-to-failure exceeding 10^10 s even at 0.8 nm, outperforming benchmark barriers by more than two orders of magnitude. This combination of ultralow dielectric constant, dielectric strength, conformality, and barrier integrity suggests 2D amorphous carbon as a potentiall route toward simplified interconnect stacks, monolithic 3D integration, and future beyond-CMOS two-dimensional electronics.

References

[1] C.-T. Toh et al., Nature, 577 (2020) 199-203.
[2] C.-T. Toh et al., Ultralow Dielectric Constant Atomically Thin Amorphous Carbon, in press.
[3] S. Hong et al., Nature, 582 (2020) 511-514.
[4] IEEE IRDS, More Moore, 2022 edition.