Superstrong encapsulated monolayer graphene and prevention of water permeation by strong adhesion between graphene and SiO2

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Abstract

We report a superstrong adhesive of monolayer graphene by modified anodic bonding[1]. In this bonding, graphene plays the role of a superstrong and ultra-thin adhesive between SiO2 and glass substrates. As a result, monolayer graphene presented a strong adhesion energy of 1.4 Jm^{-2} about 310% that of van der Waals bonding (0.45 Jm^{-2}) to SiO2 and glass substrates[2]. This flexible solid state graphene adhesive can tremendously decrease the adhesive thickness from about several tens of mm to 0.34 nm for epoxy or glue at the desired bonding area. As plausible causes of this superstrong adhesion, we suggest conformal contact with the rough surface of substrates and generation of C–O chemical bonding between graphene and the substrate due to the bonding process, and characterized these properties using optical microscopy, atomic force microscopy, Raman spectroscopy, and X-ray photoelectron spectroscopy. Additionally, this thermo-electrostatic bonding method could increase the adhesion energy of graphene to the substrate for reducing the influence of water permeation between graphene and its substrate. We characterized humidity effects on graphene using resistance measurements, atomic force microscopy and Raman spectroscopy. The results indicated that the strongly bonded graphene could be used to significantly reduce water permeation and improve device durability[3].

References

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Figures

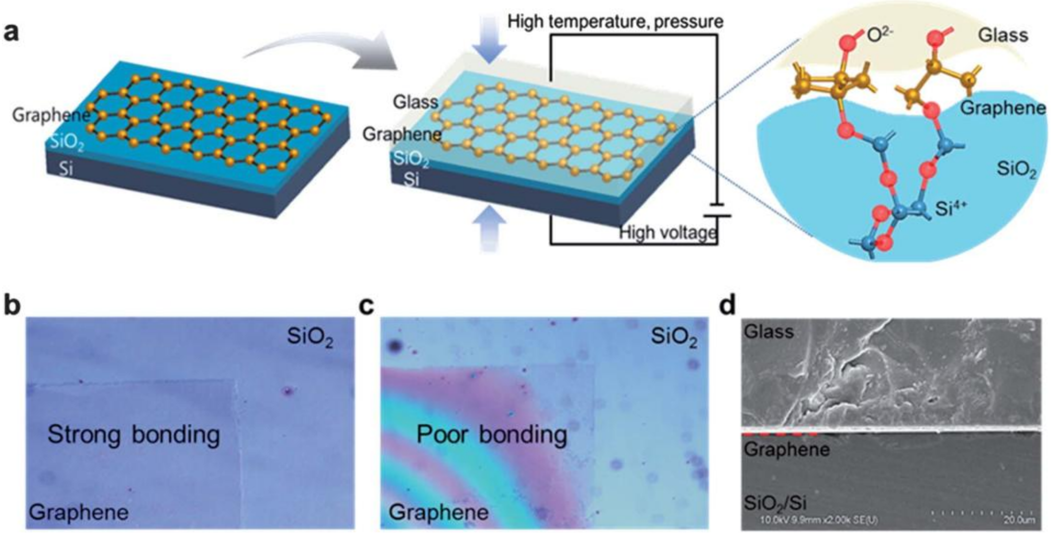

Fig. 1 Modified anodic bonding using monolayer graphene adhesive: (a) schematic description of the newly suggested bonding method. (b) The case of strong bonding shows the transparent graphene area on the SiO2. (c) On the other hand, if the sample is not bonded or has low bonding energy, there is a Newton’s ring at the graphene area. (d) This cross-sectional image shows the composition of the sample and flexible interaction of graphene between the glass and SiO2/Si.

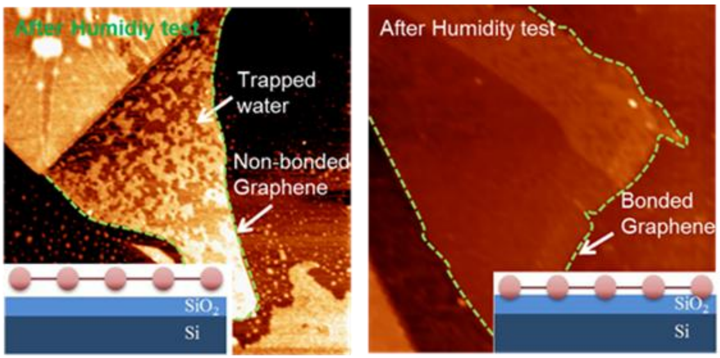

Fig. 2 After 8585 humidity test (85 °C, 85 % relative humidity), while non-bonded samples exhibited significant changes in properties, the bonded graphene samples maintained their initial properties.