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Enhancing the Strength of Graphene by a Denser Grain Boundary

From device application point of view, extreme mechanical strength of graphene is highly desirable. However, unavoidably polycrystallinity of graphene films produced by chemical vapor deposition (CVD) will lead to significant fluctuations in mechanical properties.[1,2] Although the effects of atomic defects or grain boundaries (GBs) on its strength have been studied and some treatments can enhance their stiffness, they all become much fragile with remarkably reduced breaking strength.[3,4] Here we report a systematic study on the elastic modulus and breaking strength of graphene films with a controlled density and distribution of GBs grown by inductively coupled plasma CVD method. We find their mechanical strength will become much stronger if there are hardly any triple junction exists in the GB structure, in analogy to the two dimensional plum pudding structures. The optimal comprehensive performance of 436 N/m (~1.3 TPa) Young's modulus and 43 N/m (~128 GPa) breaking strength from the nonlinear model can be reached when the average grain size of 20 nm. Moreover, the graphene films also show various tear performances due to their line defects types when indenting tears. All these quantitative studies for GBs will provide a guideline to obtain the bespoke mechanical performance of two-dimensional materials through engineering GB structures.

References

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Figures



Figure 1: Illustration of C150, C50, C30, and C20. Elastic modulus and breaking strength as a function of GB density inside