High-Quality Graphenes via a Facile Quenching Method for Field-Effect Transistors

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Single- and few-layer graphene sheets with sizes up to 0.1 mm were fabricated by simply quenching hot graphite in an ammonium hydrogen carbonate aqueous solution. The identity and thickness of graphene sheets were characterized with transmission electron microscopy, atomic force microscopy, and Raman spectroscopy. In addition to its simplicity and scalability, the present synthesis can produce graphene sheets with excellent qualities in terms of sizes, purity, and crystal quality. The as-produced graphene sheets can be easily transferred to solid substrates for further processing. Field-effect transistors based on individual graphenes were fabricated and shown to have high ambipolar carrier mobilities.
Method

- Quenching of hot graphite in an ammonium hydrogen carbonate aqueous solution (NH₄HCO₃)
  - Bend high quality graphene sheet multiple times
    - to introduce small cracks
  - Heat to 1000ºC within 5 min
    - to weaken VdW-forces between graphene layers and decompose
      \[ \text{NH}_4\text{HCO}_3 \rightarrow \text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O} \] (large amount of vapor)
  - Quickly quench to RT in a water bath containing 1% NH₄HCO₃
    - fast heat strain relaxation and steam pressure inside the cracks
      overcomes VdW-forces
  - Use solid substrate to “scoop” supernatant on water surface
Method

Supernatant containing graphene sheets
Verification Methods

- AFM
- High resolution TEM
- Raman Spectroscopy

\{ single layer? \}

\{ quality \}
Verification Methods

- AFM
  - sizes up to 100 μm
  - height 0.4 - 2.0 nm
Verification Methods

- TEM
  - Electron diffraction: good crystallinity
  - Folded edges: \#lines = \#layers

![](image1.png)  
monolayer

![](image2.png)  
bilayer
Verification Methods

- **Raman**

  - Disorder-induced peak missing
  - 2D band: sharp and symmetric
  - Graphene oxide
Quality measurements

- **FET**

\[ g_m = \frac{dI_{DS}}{dV_G} = (W/L)\mu C_0 V_{DS} \]

\[ \mu_h = \sim 7791 \text{ cm}^2/(\text{V s}) \]

\[ \mu_e = \sim 6765 \text{ cm}^2/(\text{V s}) \]

Graphene

Source → Drain

SiO₂

Si
Summary

- Simple and fast and cheap method
- Free of contaminations (scotch tape, solvents, etc.)
- High quality and large sizes
Thank you for your attention!