Evaluation of Adhesive and Cohesive Energies of Reduced Graphene Oxide on Substrates

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Motivation
- Quantitatively measure bonding force between micro/nano layers.
- Characterize failure modes: adhesive or cohesive energies.
- Evaluate the mechanical stability of reduced graphene oxide (rGO).
- Investigate the critical factors affecting adhesive/cohesive failures.

Challenges
- Measuring bond force between layers is difficult because it is tiny.
- Bonging failures between layers can be adhesive, cohesive, or both.

Objective
- To quantitatively measure and identify bonding failures of rGO thin film.

Approach
- A testing method was introduced to measure bonding forces.
- An image processing method used to characterize bonding failures.
- To optimize the critical factors affecting bonding force.

Methods
- **Consistent Testing Platform (Fig 1)**
  - Peel Rate: Controlled by MTS automatic system.
  - Acquire Data: Output via a high precision load cell (0.25~10 lbf)
  - Peel Angle: Controlled based on kinematic analysis at 90° using a 45° inclined plane.

Overall Cohesive Failure (OCF) defined by ratio of the total area of detached rGO to the overall sample area. Evaluated using digital imaging.

Investigate Parameter Effects
- Effects of GO area density, APTES surface treatment, and GO sonication time on average adhesive energy, cohesive energy, and OCF ratio were investigated.

- **Methods**
  - **Investigate Parameter Effects**
    - A testing method was introduced to measure bonding forces.
    - An image processing method used to characterize bonding failures.
    - To optimize the critical factors affecting bonding force.

- **Results**
  - Cohesive Energy vs OCF
    - Cohesive energy was significantly affected by OCF ratio.
  - Average Adhesive Energy vs OCF
    - The average adhesive energy has a lower growth rate than cohesive energy.
  - A higher cohesive energy/average adhesive energy is resulted from a lower OCF ratio.
  - GO Area Density
    - GO area density had the most significant effect among all the factors.
    - 178 μg/cm² showed a higher bonding energy than other area densities.

- **Conclusion**
  - OCF is viewed as the indicator of adhesive & cohesive failure energies.
  - GO area density shows the most significant effect on both adhesive and cohesive failure energies.

- **Future Work**
  - Look further into each factor and seek optimal parameters that results in the largest bonding strength.
  - Seek optimal parameters on different substrates that leads to a larger bonding strength.

**Literature cited**
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