Assessment of Quali and Takayanagi models for evaluation of 2D membrane mechanical properties.

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Abstract
The purpose of this research is to assess the Quali and Takayanagi models for calculation of elastic modulus on 2D Buckypaper membranes and comparison of elastic modulus to values found using Atomic Force Microscopy. With the interphase between the CNT network and the surrounding polymer is categorized by Atomic Force Microscopy.

Manufacturing
- Constructing 2D membrane by assembling CNTs into a thin film buckypaper (BP) infiltrating with polymer creates a high CNT membrane
- A. Dry Buckypaper
- B. Dry bp under scanning electron micro
- C. Infiltrated Buckypaper.
- D. Infused Buckypaper scanning electron micro

Data
- Histogram of Reduced Modulus
  - Abnormal distribution due to AFM tapping on CNT more local maximum values.
- Histogram of Adhesion
  - Peaks show uneven distribution of epoxy and CNT.
  - First peak shows little epoxy with increased CNT.
  - Second peak shows increased CNT with less epoxy
- Histogram of Deformation
  - Normal distribution with small peaks show inhomogeneity of material particles less than 3nm.

Results
- Quali model
  \[ E = \frac{\varphi_N(1-\varphi_f)E_d\varphi_N+\varphi_N(\varphi_f-\varphi_N)E_m\varphi_N+(1-\varphi_N)^2E_m}{(1-\varphi_f)E_d+(\varphi_f-\varphi_N)E_m} \]
  - \( \varphi_N \) is ~3.28% assuming \( \varphi_f \) and \( \varphi_p \) as 10% and 0.022% for BP PNC. with \( E_d = 3.9 \text{GPa}, E_N = 15.2 \text{GPa}, E_m = 5 \text{GPa} \), from AFM PFQNM.
  - The elastic modulus (E) obtained from Quali model is 5.23GPa which is less than the reduced modulus obtained from PFQNM (6.2~8.2GPa).
  - The Quali model ignores the effects of the interphase.

- Takayanagi model
  \[ E = \frac{\varphi_p(\varphi_f+\varphi_p)(1-\varphi_f-\varphi_p)E_d\varphi_p+\varphi_p(\varphi_f+\varphi_p)(\varphi_f+\varphi_p-\varphi_f-p\varphi_p)E_m\varphi_p+(1-\varphi_f-p\varphi_p)E_dE_m}{(1-\varphi_f-p\varphi_p)E_d+(1-p\varphi_f+p\varphi_p)E_m} \]
  - \( \varphi_f = 0.1, \varphi = 0.3, E_d = 3.9 \text{GPa}, E_N = 15.2 \text{GPa}, E_m = 5 \text{GPa} \), and \( g = 0.305 \),
  - Elastic modulus of BP PNC is ~5.87GPa. It is larger than the elastic modulus obtained from BP PNC films, ~5.5GPa.
  - The average reduced modulus of BP PNC 6.2~8.2GPa is higher than the values from the Quali model.
  - The Takayanagi model is more accurate at calculating modulus then Quali model and AFM

References