Nonlinear ultrasonic evaluation of contaminants mixed into epoxy-adhesive in manufacturing

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Adhesive joints
- Joining similar or dissimilar materials with a non-metallic material (adhesive)
  • Advantages
    ✓ Uniform stress distribution
    ✓ Lower weight
    ✓ Improved fatigue strength
    ✓ Minimized corrosive damage
    ✓ Design flexibility
- Joint forces
  Adhesive
  Ex.: Epoxy

Motivation
- Micro-scale defects in adhesive joints
  - Threat on the structural integrity of adhesive joints
  - Preventing the increase of application in adhesive joints
  - Limitations of conventional NDE for detection of micro-scale defects
  - Contaminant mixed poor cohesion remained as a characterization challenging for NDE

Objective
- Determine the effect of contaminant on mechanical and thermal properties of epoxy-adhesive using a nonlinear ultrasonic technique

Second harmonic generation (SHG)
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SHG system
- Measure current signals of $A_1'$ and $A_2'$

Epoxy-adhesive samples
- Pure
- 0.5%
- 1.0%
- 1.5%
- Contaminant

Other measurements
- Rockwell hardness testing → Mechanical hardness
- Differential scanning calorimetry (DSC) → Curing reaction

Comparison of ultrasonic parameters and mechanical hardness
- Correlation between $\beta'$ and material properties
  - $T_g$ (glass transition temp.)
    - Contaminant can be miscible with epoxy
    - Contaminant lowers cross-linking density
    - Contaminant reduces curing reaction
  - Nonlinearity parameter
    - Contaminant causes incomplete curing
    - Incomplete curing increases impurities
    - Impurities induce micro-structural change
    - Nonlinear parameter increased

Conclusions
- Effect of contaminant on mechanical and thermal properties of epoxy-adhesive was investigated with ultrasonic parameters
- The SHG method using the nonlinearity parameter ($\beta'$) has potential for use in a quantitative method for evaluation of bond quality of epoxy-adhesive

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