Cure-Kinetics Modeling and Process Optimization for Next-Generation Interlayer Dielectrics - II

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OBJECTIVE

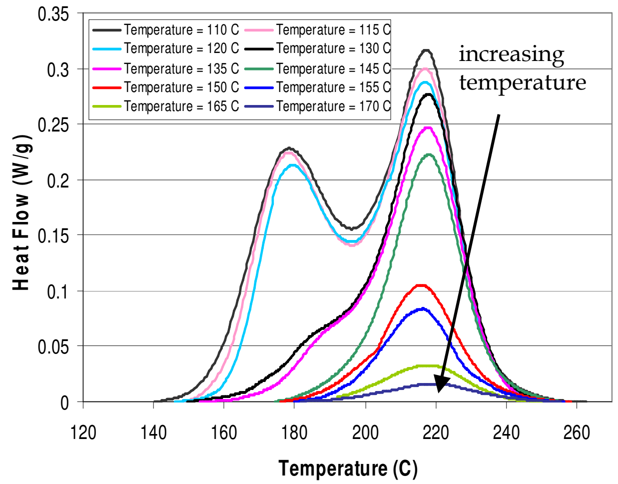
- To conduct comprehensive thermal and mechanical characterization of the photo-dielectric-dry-film (PDDF) material. This includes:
  - development of a cure-kinetics model to aid in the understanding and optimization of the curing schedule, as well as to understand structure-property relationships
  - mechanical characterization of partially and fully cured material
- Fabrication of high-density features (lines, microvias, etc.) with reduced thermal bake times
- Note: the characterization information will be input into the integrated cure-thermal-stress analysis module, which is being developed concurrently to predict the evolution of stresses and warpage during SOP substrate fabrication

APPROACH

- Study the effect of UV exposure on the rate of curing, and select a suitable value to reduce cure processing times
- Use multiple heating rate as well as isothermal DSC experiments to develop a phenomenological cure kinetics model. Two modeling approaches were implemented to predict the evolution of DOC:
  - based on dynamic DSC data, using a model-free method involving the cure-dependence of the activation energy
  - based on isothermal DSC data, using a modified auto-catalytic model with temperature-dependent kinetic parameters
- To optimize the microvia fabrication process, the post-exposure bake time at 110 ^{o}C is reduced using a trial-and-error experimental approach, while the final thermal bake time is reduced using the cure kinetics model
- Determine the CTE, bulk modulus and cure-dependent stress relaxation modulus using the TMA, PVT dilatometer and DMA respectively

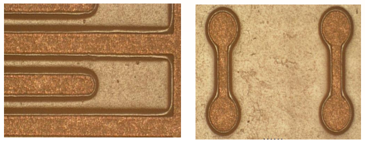
ACCOMPLISHMENTS

- Understood the complex 2-peak cure mechanism of the PDDF (attributed to the long lifetime of the cationic photoinitiator catalyst), and developed cure-kinetics model's based on both multiple heating rate and isothermal DSC experiments
- Selected an increased exposure dose of 2000 mJ/cm^2, which caused a significant reduction in the post-exposure bake time, as well the final thermal bake time
- Demonstrated the fabrication of microvias, as well as other complex features using the optimized cure processing schedule
- Completed the mechanical characterization of the PDDF, which included determination of the CTE and bulk modulus of the fully cured material, and the cure-dependent viscoelastic stress relaxation modulus
- Papers published in J. of App. Polymer Science, IEEE Trans., ECTC, and IMAPS conferences



Subsequent DSC scan data at 10 ^{o}C/min of samples cured isothermally at the temperatures shown in the legend box (Exposure dose = 2000 mJ/cm^2

Representative microvias



Representative lines and features

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