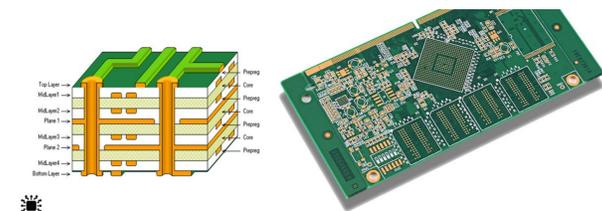


# CHARACTERIZING ADHESION OF POLYIMIDE (PI)-SILICA COMPOSITES TO COPPER FOR APPLICATIONS IN MICROELECTRONICS

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## Introduction and Motivation

- Modern electronics → high functionality, small size, high reliability



Use of multilayer circuit boards for miniaturization of electronics. Contains multiple layers of copper separated by dielectrics (generally polyimide)

- Conductive layers of copper separated by dielectric – polyimide with silica used. Silica to control CTE
- Adhesion between copper and dielectric crucial for superior performance and durability

## Objectives

- Investigate the bonding mechanisms between nodulated copper and PI
- Study the influence of silica particles on adhesion
- Characterize the effect of processing conditions on adhesion

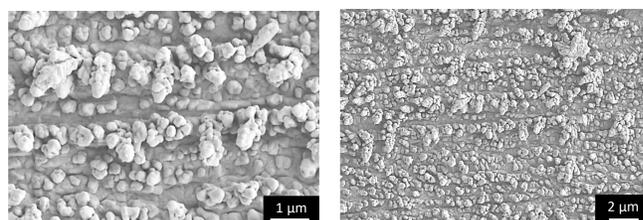
## Background → 90-degree peel test



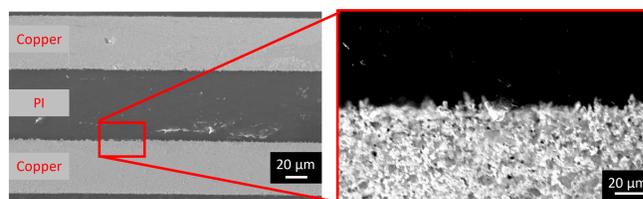
90-degree peel test → Photograph and schematic of a 3-layer Cu-PI-Cu specimen provided by DuPont

## Copper Surface Characterization

- Traditionally, copper electrodeposited on dielectric for improved bonding
- For flexibility and scalability, rolled annealed (RA) copper use is growing
- Surface of RA copper is smooth, nodules added separately

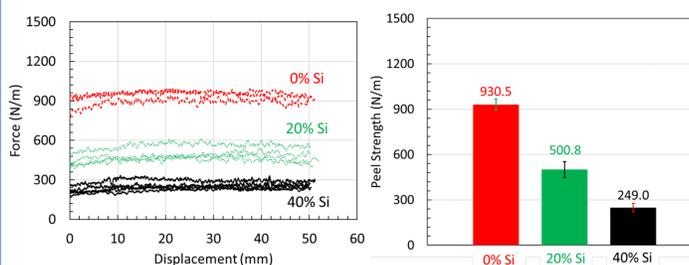


Nodules on the surface of copper (looking at top view)

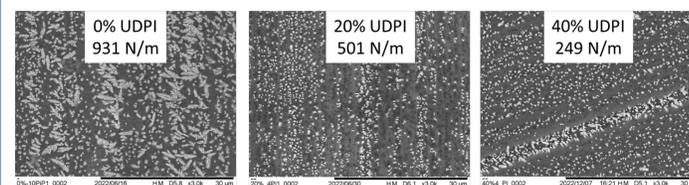


Cross-section of Cu-PI-Cu laminate showing nodules at the interface

## Influence of Silica on Peel Strength

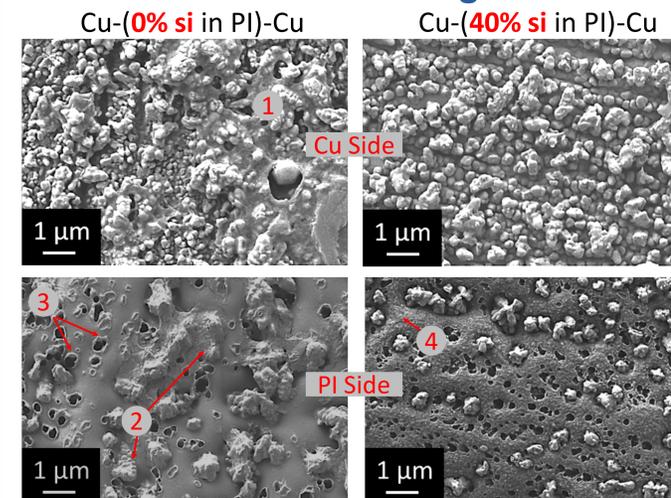


Peel strength as a function of silica loading in PI. Silica loading affects the viscosity and penetration of PI into the Cu nodules



SEM images of failed surface on the PI side. Bright regions showing Cu particles. 0% showing more particles than 40%

## Failure Surface and Bonding Mechanisms



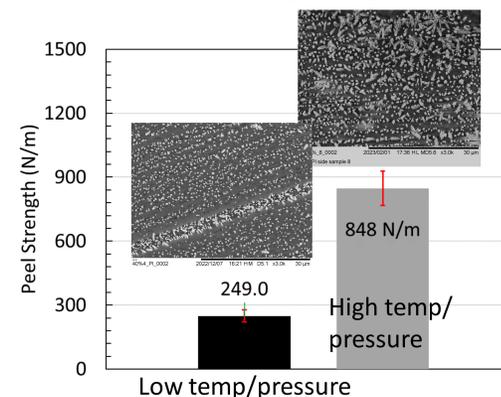
High magnification SEM imaging of failure surfaces after peel strength of 0% silica (left) and 40% silica (right)

Reasons for higher peel strength of 0%:

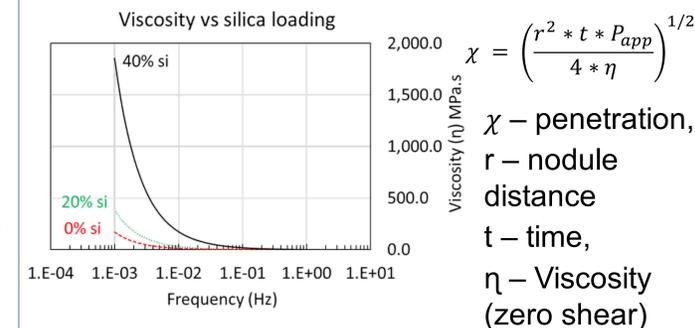
- Presence of PI on Cu side, indicating partial cohesive failure
- Larger Cu particles, lower viscosity → more penetration into nodules
- 0% (unfilled) PI has higher failure strain and tougher, therefore localized yielding when Cu nodules pulled out
- Silica particles visible in PI for 40% sample, less toughness, more viscous

## Effect of Processing Conditions on Peel Strength (Adhesion)

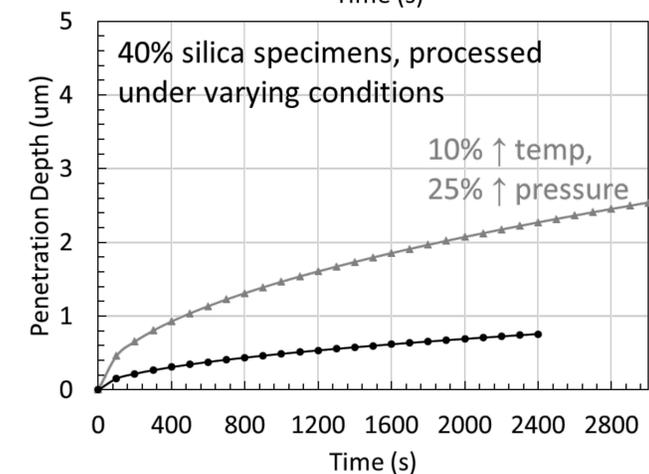
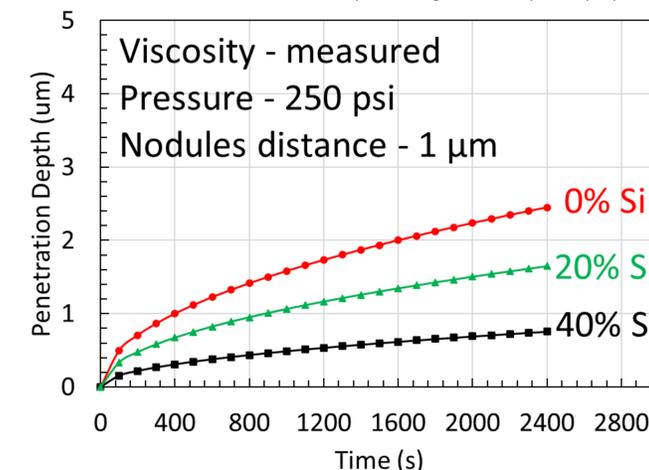
40% si samples were processed at 10% higher temp, 25% higher pressure/time



## Penetration of PI into Cu Nodules – Parametric Modeling



This model has been adapted and modified from Steven H. McKnight's dissertation, used for pore filling of thermoplastic polymers



## Conclusions

Penetration of PI into Cu nodules key for adhesion. Viscosity and processing temperature critical for the penetration of PI into Cu