## SHORT COURSE ON DURABILITY OF ADHESIVE JOINTS

**TITLE: TESTING AND DURABILITY OF ADHESIVE JOINTS**

When you make an adhesive joint as part of some device or product there is always the concern of joint durability whether the product is something as prosaic as a cereal box or as high tech as a jet aircraft. The consequences of joint failure can range anywhere from an annoying nuisance to the endangerment of lives. Thus this seminar series will give an overview of the technology and tools available for evaluating beforehand the expected performance of adhesive joints subjected to the environmental and load conditions under which they must survive.

**Audience:** Scientists, technicians and professional staff in R&D, manufacturing, processing, quality control/reliability involved with applying adhesives to a range of practical applications

**Level:** Introduction and technical overview

**Suggested Prerequisites:** General background In chemistry, physics or materials science.

**Duration:** 1 day
**How you will benefit from these lectures:**

**Understand** advantages and disadvantages of a range of test methods for adhesive joints

**Gain insight** into mechanics of adhesion testing and the role adhesive material properties

**Explore** the full range of phenomena affecting joint reliability including: adhesion to substrate, thermal-mechanical properties of adhesive and the effect of residual stress.

**Review** most important non-destructive inspection methods for discovering flaws in joint formation

**Gain perspective** from detailed discussion of actual case studies of product manufacturing and development problems

## INTRODUCTION

## PART ONE: OVERVIEW OF TEST METHODS

### I. Two Aspects of Adhesive Action

A. Interfacial bonding between adhesives and adherends
B. Bulk thermal-mechanical performance of adhesives

### II. DURABILITY OF ADHESIVE JOINTS

A. **Stress and Deformation in Material Bodies, a quick overview**:

1. Stress and deformation are the primary engines driving failure of nearly all material artifacts including adhesive joints, so it is a good idea to review at least the rudiments.

    a. Continuum Theory (CT): Most fundamental and rigorous approach but unfortunately rather involved.
    b. Strength of Materials Theory (SOM): Less fundamental and rigorous than Continuum Theory but does the job in many practical instances.
    c. Fracture Mechanics: Extends both CT and SOM theory to cases where cracks and other sharp flaws are present. Most effective method for predicting catastrophic failure in structures of all kinds including adhesive joints.

B. **Direct Measurement of Joint strength**

1. Lap shear test
2. Double cantilever beam test
3. Four point bend test
4. Wedge test
5. ... etc

C. **Tests That Measure Practical Adhesion Between Adhesive and Adherend**

1. Peel test
2. Blister test
3. Indentation debonding test
4. Self loading tests

## D. Measuring Adhesive Thermal-Mechanical Properties

1. The mechanical strength and temperature stability of any adhesive clearly limit its performance capabilities. Thus we need to understand the following:

    a. Elastic properties
    b. Viscoelastic properties
        (1) Creep behavior
        (2) Concept of time-temperature superposition

## E. Role of Residual Stress

1. If the residual stress in an adhesive gets too high then it can self destruct without further provocation from outside influences. The following are useful methods for estimating the buildup of residual stress in a material due to curing conditions, thermal cycling, solvent swelling, ... etc.

    a. Cantilevered beam methods
    b. Ultrasonics
    c. Photoelasticity
    d. Strain relief methods

## F. Nondestructive Inspection

1. Any flaws left behind in the adhesive joint due to bubble formation, dewetting phenomena, undetected contamination, ... etc. will form the foci of joint failure since such defects act as stress risers and also serve as initiation points for delamination and cracking. The following can serve as effective flaw detection methods:

    a. Xray
    b. Thermography
    c. Shearography
    d. Ultrasonics

## PART TWO: DETAILED LOOK AT SPECIFIC TESTS AND CASE STUDIES

I. **A Closer Look at Interfacial Adhesion Through the Peel Test**

A. Peel testing on a shoe string

1. A fully functional peel test setup can be put together using equipment found in nearly any chemistry lab.
2. Multiple strips on a single substrate are an efficient and versatile way to test interfacial adhesion.
3. Peel testing is a handy way to perform ranking and comparative studies.

B. **The Peel Test in the Development Lab and Manufacturing Line**

1. The peel test can be a very useful tool for testing adhesion improvement schemes and for analyzing and improving manufacturing processes. The following are a few examples:

a. Ranking effectiveness of adhesion promoters
b. Evaluating the effect of manufacturing procedures on bond durability
c. Developing improved process steps

II. **A Closer Look at The Thermal-Mechanical Properties of Polymers**

A. Nearly every adhesive formulation involves the use of a polymer resin either as a binder or as the main adhesive agent. Thus the thermal-mechanical performance of most adhesives will be dominated by the polymer component so we need to understand more about the thermal-mechanical response of these materials.

B. Common Test methods

1. Creep/stress relaxation experiments
2. Dynamic mechanical experiments
a. Determination of glass transition, $T_g$
b. Relaxation processes below $T_g$

C. Case Study on rubber modified epoxy structural adhesives

1. Time-temperature superposition for epoxies
2. Variation of fracture toughness with loading rate and temperature

## III. **Putting it All Together: A Guide to the Evaluation and Prediction of Bond Durability**

A. Structures that survive in the long term are in a state of unconditional stability.

B. Stability maps: An engineering tool for putting it all together.

1. Case study: Adhering pins to a multi-chip module: When you require the electrical reliability of 1000 pins and absolutely positively cannot afford a single failure

    a. Pathology of pin failure, outline of the problem
    b. Modeling virtual crack propagation
    c. Creating a stability map