Semiconductor Die Attach Adhesive Introduction

Shanghai | Dec ,2017

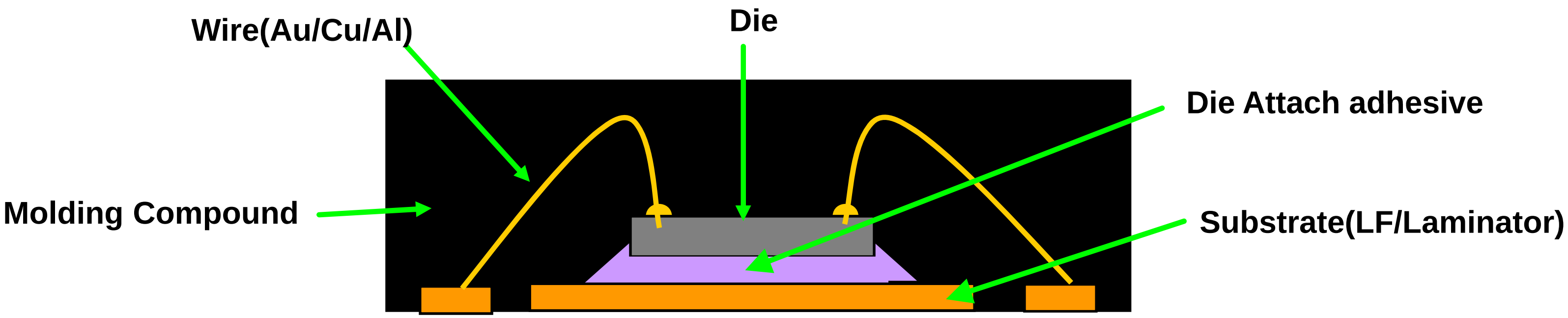
Henkel

Agenda

- Why for DA
- Basic DA Knowledge
- Uncured Properties
- Cured Properties
- Case Sharing

Why for DA

- The function for the Die Attach adhesive
  - Adhesie the Die to the substrate
  - Provide the electrical/thermal conductive performance
  - Ensure the high reliability performance



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- Cured Properties
- RBO introduction

Basic DA Knowledge
Adhesive Type

- Thermoplastic Adhesives
  - Contain polymers that do not gel or cross-link
  - Require heat or both heat and pressure upon application
  - Maybe reflow at higher temperatures (mostly films)

- Thermoset Adhesives
  - Undergo irreversible chemical reactions
  - Become cross-linked to form a network of polymer structures
  - Most curing/polymerization initiated by heat
  - Cure typically at 75C~220C,however some products may be cured at RT

Basic DA Knowledge

Adhesive System

- One Part Adhesives
  - Resin and curing agents supplied premixed
  - Require frozen storage to slow down the reaction rate and/or to prevent physical seperation
    - -40 ℃ typically recommended for paste products
    - 5 ℃ typically recommended for film products
- Two Part Adhesives
  - Resin and curing agents supplied separately
    - Requires customer mixing
    - Questionable Uniformity and quality
  - Room temperature storage

Basic DA Knowledge
Adhesive Components

- Resins
- Filler

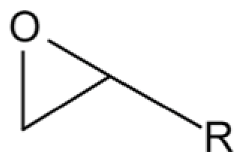
  Filler surface and surface treatment
- Additives

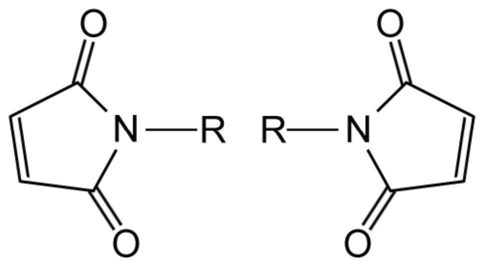
  Rheology modifier | Adhesion promoter | Coupling agent | Anti-bleed
- Curing agent and polymerization initiators

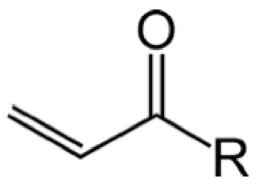
  Curing agent and catalysts | Initiators and catalysts | Sensitizers | Synergistics

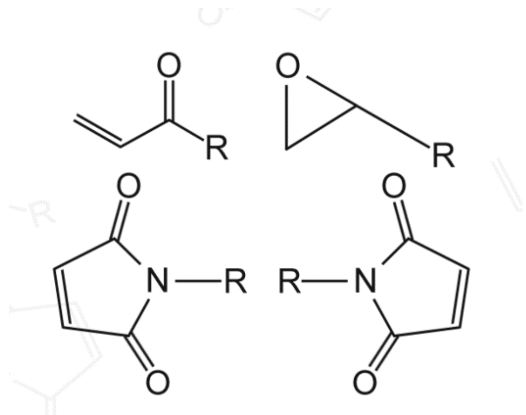
Basic DA Knowledge
Adhesive Components

- Resins
  - Epoxy
  - Acrylate
  - BMI









Basic DA Knowledge
Adhesive Components

- Filler
  - Electrically conductive fillers
    - ➢ Metals (i.e. silver, copper, SPC, aluminum, nickel, gold)
    - ➢ Carbon black
  - Non-electrically conductive fillers
    - ➢ Silica (Silicon oxide) [SiO_2]
    - ➢ Alumina (Aluminum oxide) [Al_2O_3]
    - ➢ Boron nitride [BN]
    - ➢ Aluminum nitride [AlN]
    - ➢ Diamond
    - ➢ Teflon [$-(CF_2-CF_2)_n-$]

Basic DA Knowledge
Adhesive Components

- Filler Shape
  - Silver flake

    Metal : Ag | Ductile | Electrically & thermally conductive
  - Silica

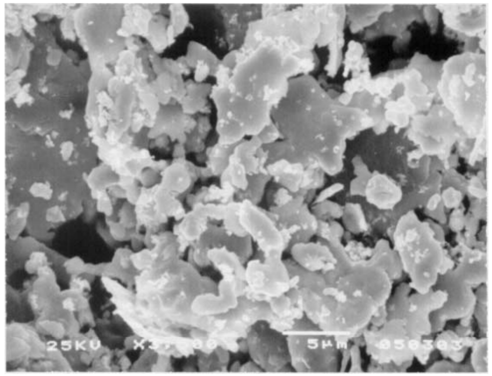
    Inorganic : SiO_2 | Electrically nonconductive
  - Teflon

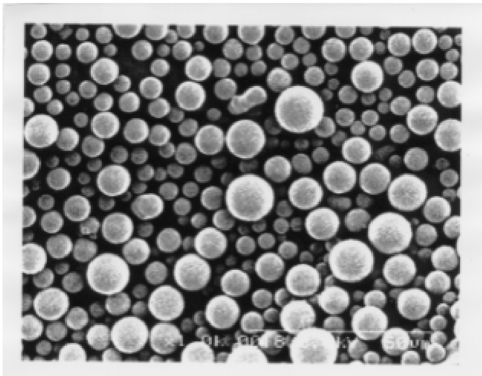
    Organic : $-(CF_2\text{-}CF_2)_n-$

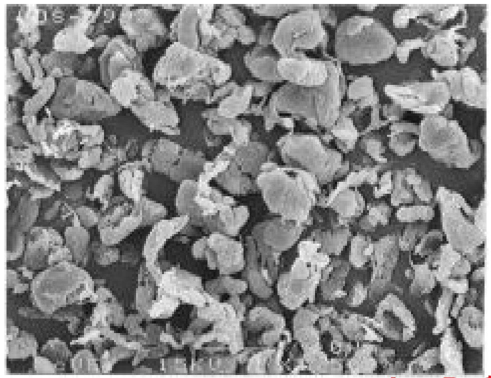
    Electrically nonconductive

    Flexible

    Tm = 330℃







Basic DA Knowledge
Adhesive Components

- Additives
  - Key PropeCuring Agent (or Hardener)
    - ➢ Initiate polymerization of the epoxy resin and control reactivity of cure
    - ➢ Can take the form of catalysts.
  - Diluents (Reactive or non-reactive)
    - Control the viscosity of the paste mixture during formulation
    - Act as plasticizer in adhesive layer and lower the Tg of adhesive
    - Possible react with the epoxy groups during the curing process (reactive diluents)

Basic DA Knowledge

Curing Stages of Thermoset Adhesives

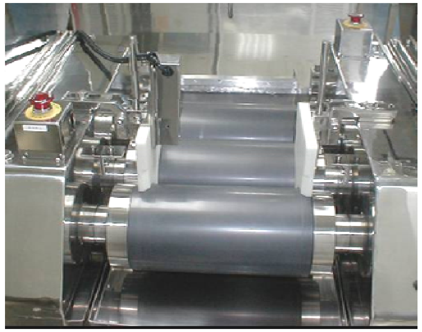
- A-stage (uncured state)
- B-stage (partially cured state)
  - Not all adhesives are B-Stageable
  - Intermediate stage of the curing process
  - Material is in solid state,relatively tack free at RT,but softens and flows when heated
  - Material can absorb solvents and swell
- C-stage (fully cured state)
  - Material is solid and fully cross-linked
  - Material is relatively insoluble in solvents and infusible.

Basic DA Knowledge

Process flow

称量

树脂混合



三滚研磨

加填料混合

挤出

灌装针管

Heading

- Why for DA
- Basic DA Knowledge
- Uncured Properties
- Cured Properties
- Case Sharing

Uncured Properties
Viscosity

- Viscosity Newtonian Fluids
  - Viscosity is independent of shear rate and time
  - Gases, simple fluids

- Non-Newtonian Fluids
  - Viscosity varies as function of shear rate or stress
  - Viscosity will be different under different conditions, such as equipment, spindle speed, temperature and spindle type
  - Viscosity measured under specific parameter is called “apparent viscosity”

Uncured Properties
Viscosity

- Viscosity is a measure of a fluid's resistance to flow
- Example of a layer of fluid (gas or liquid) between two parallel plates of area A

$$\frac{F}{A} = \eta \frac{dv}{dx}$$

- F/A = force per unit area required to produce the shearing motion (shear stress)
- dv/dx = velocity gradient (shear rate)
- η (viscosity) = shear stress / shear rate
- Typical units = cP or Pa-s

Uncured Properties
Rheology-Thixotropic Index (T.I.)

- Normally defines thixotropic index as the ratio of viscosity at 0.5 rpm and viscosity at 5.0 rpm.
- Pressure dispensing model
  - At 0.5 rpm (1.92 1/sec), the adhesive is virtually at rest or low shear stress
  - At 5.0 rpm (19.2 1/sec), the adhesive undergoes a certain amount of stress as dispensed through a nozzle

$$\text{T.I.} = \frac{\text{Viscosity @ 0.5 rpm}}{\text{Viscosity @ 5.0 rpm}} = \frac{44{,}800\ \text{cP}}{8{,}000\ \text{cP}} = 5.6$$

- A thixotropic index of 3.0 or greater has shown to give good high speed needle dispensing (application specific); high viscosity at rest to prevent dripping, while low viscosity when pressure is applied during dispensing

Uncured Properties
Work life

- As defined by Henkel, the length of time that the material may be used at ambient conditions, including thaw time from freezer temperature to ambient temperature, without degradation of material performance
  - Two criteria are examined, then the limiting criteria is listed as the work life on the technical data sheet
    - ✓ Chemical work life
    - ✓ Physical work life
- Note that the worklife method used by Henkel is primarily used to compare reactivity or filler settling between adhesives and is an indication of how long the adhesive can be used by the customer. The actual worklife (dispense life) observed by the customer can be increased or decreased by dispense method used and is also dependent on the application the adhesive is being used in.

Uncured Properties
Work life-Chemical Work Life

- As defined by Henkel, the time in which the material experiences a 25% increase in viscosity at 5.0 rpm due to chemical reaction /advancement at room temperature
- Adhesives that exceed the chemical work life may exhibit a difference in performance
  - For example, the initial dispense parameters may not be applicable at higher viscosities (re-optimization of dispense parameters may be necessary)

Uncured Properties
Work life- Physical Work Life

- As defined by Henkel, the time in which the material experiences a significant change in cured properties as a result of filler separation(2% change) at room temperature
  - Ash test: the filler content is measured at both the top and bottom of a 10cc syringe of material, which is exposed to ambient conditions in a vertical position
    - ✓ Higher filler content at the bottom of the syringe (tip) reflects filler settling due to density difference (also known as a silver-rich layer for silver-filled adhesives)
    - ✓ Lower filler content at the top of the syringe reflects a resin-rich layer

Uncured Properties
Storage Life

- As defined by Henkel, the recommended time that the material may be stored in a freezer at a recommended storage temperature, then used without degradation of material performance
  - Estimated storage life at -40ºC is typically listed as 6 months or 1 year on the technical data sheet, depending on the chemical reactivity and/or physical separation over time
  - Alternate storage temperatures are not usually recommended due to possible freeze thaw voids, chemical reactivity, and/or physical separation over time

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Cured Properties
Overview

- A variety of physical properties are characterized for adhesives and encapsulants
- The importance of each physical property is dependent on the application being considered
- The following properties are typically considered for material selection:
  - Coefficient of thermal expansion (CTE)
  - Glass transition temperature (Tg)
  - Modulus
  - Moisture absorption
  - Ionics
  - Thermal & electrical properties
  - Adhesion & Reliability

Cured Properties

Glass Transition Temperature (Tg)

- Definition of Tg
  - A narrow temperature range (though typically reported as a specific temperature), at which the material changes from a rigid, glassy state to a soft, rubbery state[1]
  - The temperature at which increased molecular mobility results in significant changes in the properties of a cured resin system[1]
- Typically desired to be outside of the operating range of the package
- Cure dependent
  - Higher cure temperature may increase Tg
- Test method dependent (at least 6 methods used by Ablestik)
  - Measured Tg may vary as much as 50° C

1) Source: Engineered Materials Handbook (Adhesives and Sealants), P. 14, 1990

Cured Properties
Modulus

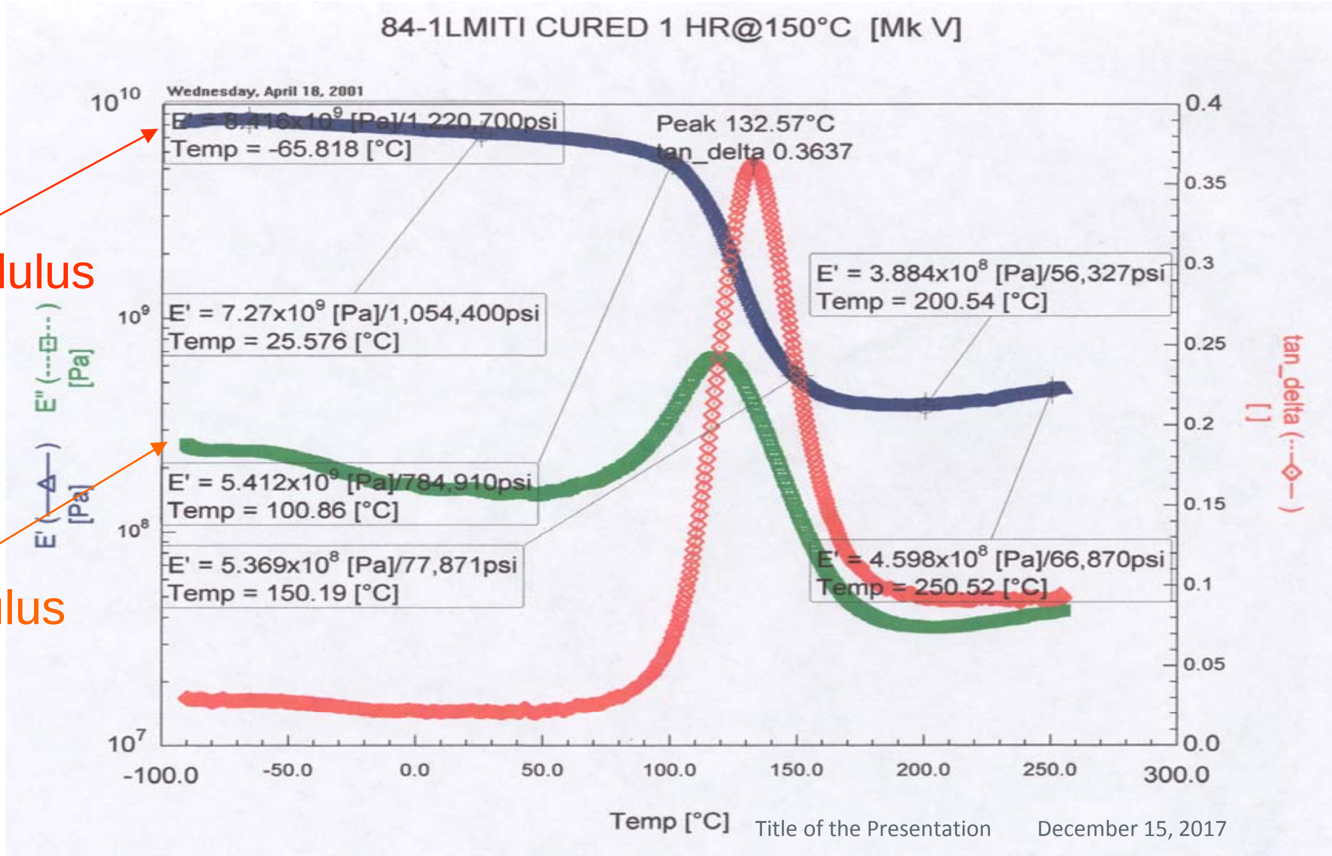
- Henkel uses Dynamic Mechanical Thermal Analysis (DMTA) to measure the viscoelastic properties of a material as a function of temperature
  - ➢ storage modulus of elasticity (E')- typically reported at different temperatures, such as -65 to 250℃
  - ➢ frequency: 10 Hertz
  - ➢ tan delta (tan Δ)
- Testing mode: tensile (typical), flexural
- A DMTA scan from Ablestik typically shows storage modulus and tan delta curves plotted against temperature
- Modulus is used to determine how "stress absorbent" an adhesive is.
  - ➢ Typically lower modulus adhesives are used to bond adherends having higher CTE mismatches
  - ➢ Reduces warpage and prevents delamination leading to higher reliability

Cured Properties

Modulus-Dynamic Mechanical Thermal Analysis (DMTA)

Storage modulus

Loss modulus



Cured Properties

Coefficient of Thermal (CTE)

- Dimensional change in material per unit change of temperature, typical units ppm/° C
- Henkel uses TMA (Thermal Mechanical Analysis) by expansion mode to measure CTE as a function of temperature
  - sample is heated at a constant rate, typically 10° C/min
- As the material is heated beyond the Tg, the material expands at a higher rate
  - CTE below Tg (alpha 1 or CTE 1)
  - CTE above Tg (alpha 2 or CTE 2)

Cured Properties
Moisture Absorption

- Henkel uses Dynamic Vapor Sorption (DVS) to measure moisture absorption of a cured adhesive sample
  - Water weight gain during 85° C/85%RH exposure at saturation is typically expressed as % weight gain
  - Higher moisture absorption can decrease popcorn (MRT) performance

Cured Properties

Ionic Purity

- Moisture from the environment or organic sources may extract chloride and other ionic species from the cured adhesive, forming corrosive acids which may harm vital device metallization, resulting in premature device failure
- Extractable ions from cured material are measured by ion chromatography (IC)
- Typically reported: Cl^-, Na^+ & K^+
- By current standards, adhesives that have ionics less than <10ppm can be considered as ionically clean

Cured Properties
Adhesion

- **Die Shear**
  - The measure of the amount of shear force needed to cause an adhesive and/or cohesive failure. The force is applied parallel to the adhesive plane
- **Lap Shear**
  - The measure of the amount of shear force needed to cause an adhesive and/or cohesive failure. The force is applied parallel to the adhesive plane
- **Stud Pull**
  - The amount of tensile force needed to cause an adhesive and/or cohesive failure. The force is applied perpendicular to the adhesive plane
- **Peel**
  - The amount of peel force needed to cause an adhesive and/or cohesive failure. The force is applied to a narrow section of the adhesive typically resulting in lower adhesion values

Cured Properties
Electrical Properties

- The electrical properties of an adhesive are measured using two tests at Ablestik
  - Bond joint resistance
    - Measures the resistance through the adhesive plane (perpendicular to the adhesive plane)
  - Volume resistivity
    - Measures the resistance across the adhesive plane (parallel to the adhesive plane)
  - Rdson Test
    - Measures resistance performance with the MOSFET device(Special for high EC request).

Cured Properties
Thermal Properties

- The thermal conductivity of an adhesive is a measurement of the ability of the adhesive to conduct heat away from a heat source
- Henkel uses two methods to measure thermal conductivity
  - Puck method (bulk conductivity)
    - Bulk conductivity measured at 121° C
    - Sample size not representative to adhesive geometry. Sample is approximately 0.5” thick with a ~2” diameter
  - Laser flash
    - bulk conductivity
    - interfacial resistance
    - sample bond line thickness more representative to adhesive geometry in package

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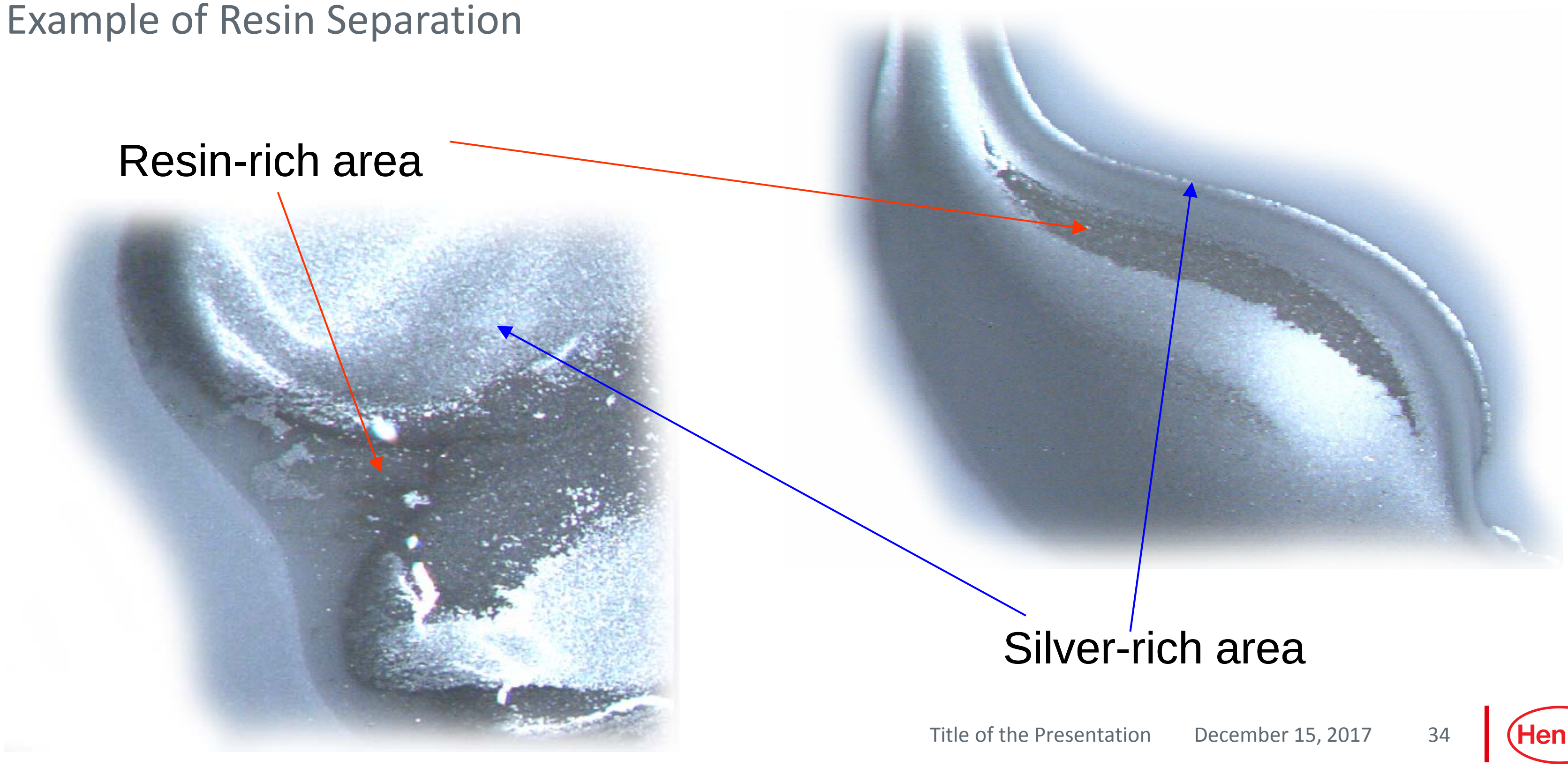
Uncured Properties
Resin separation

- Example of Resin Separation



Uncured Properties
Resin separation

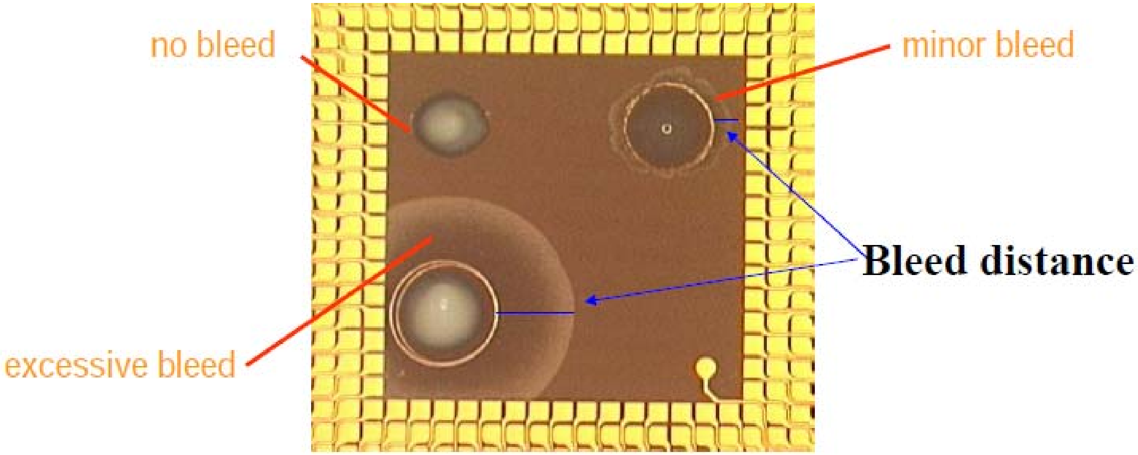
- Possible causes
  - Exceeded storage life or physical work life
  - Improper storage or handling
- Possible effects
  - Variable dispensing
  - Variable cured properties, such as thermal or electrical performance, adhesion, etc.

RBO introduction

Examples of Resin Bleed

- Different adhesives have different levels of resin bleed on the same substrate.
- Resin Bleed comparison of 3 adhesives on flex substrate. Bleeding is formulation dependant.

• Condition: uncured, 20hrs @ RT



RBO introduction

- Bleed is the migration of, typically, low molecular weight organic components of the adhesive onto the surrounding surface due to surface energy differences between the resin and substrate.
- Possible causes
  - Surface condition (roughness, cleanliness, etc)
  - Process condition (dwell time before cure & cure profile)
- Possible effects
  - Bleed onto bond surface may cause poor wire bond ability and/or poor adhesion of molding compounds
- Possible solution
  - Reduction of dwell time, cure optimization, substrate modification, plasma cleaning, liquid etching, etc

FTV-Freezing Thawing Void

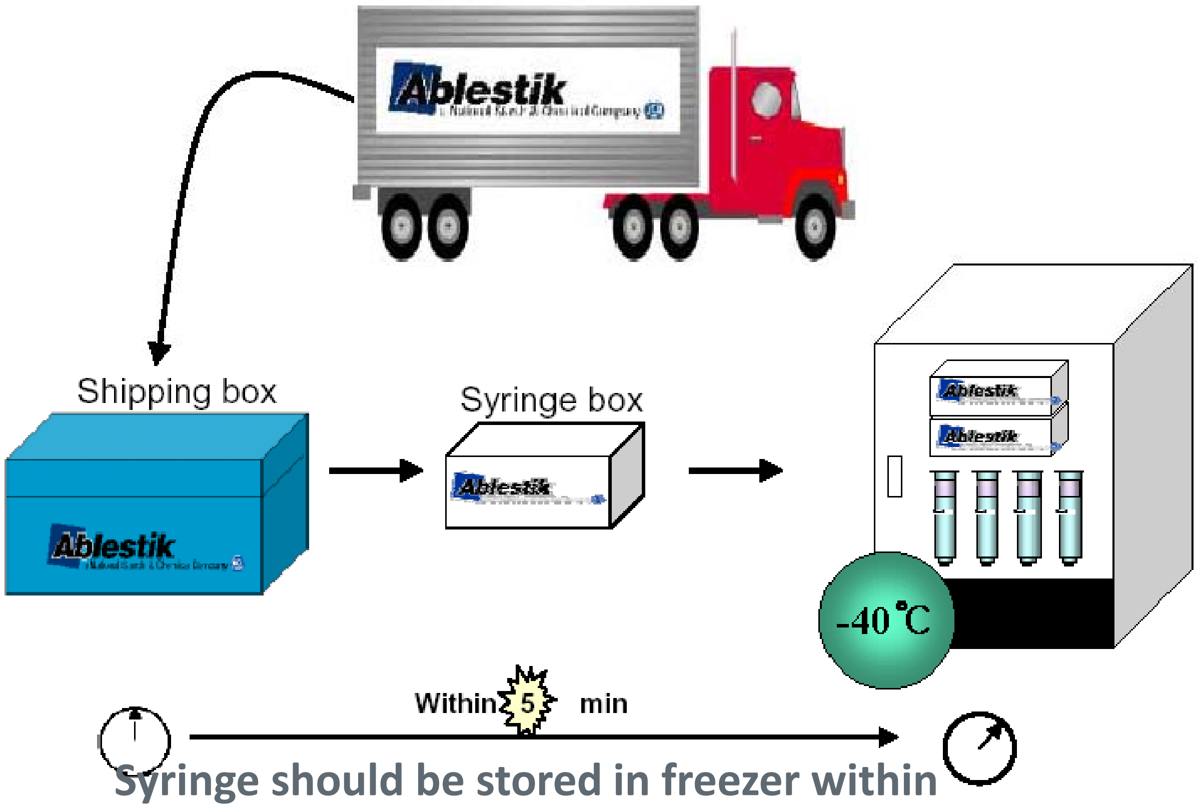
Background

- Most adhesives are one part adhesives which means resin and curing agents supplied premixed, so they should be packed and shipped in dry ice (-80℃) and after received, the paste should be stored in the freezer which is not higher than –40 ℃ to slow down the reaction rate and/or to prevent physical separation.

- This presentation gives customer handling and thawing recommendation for the pastes from Henkel to let our customer handle Henkel products correctly.

- This presentation introduces the Henkel process control to reduced freeze-thaw voids.

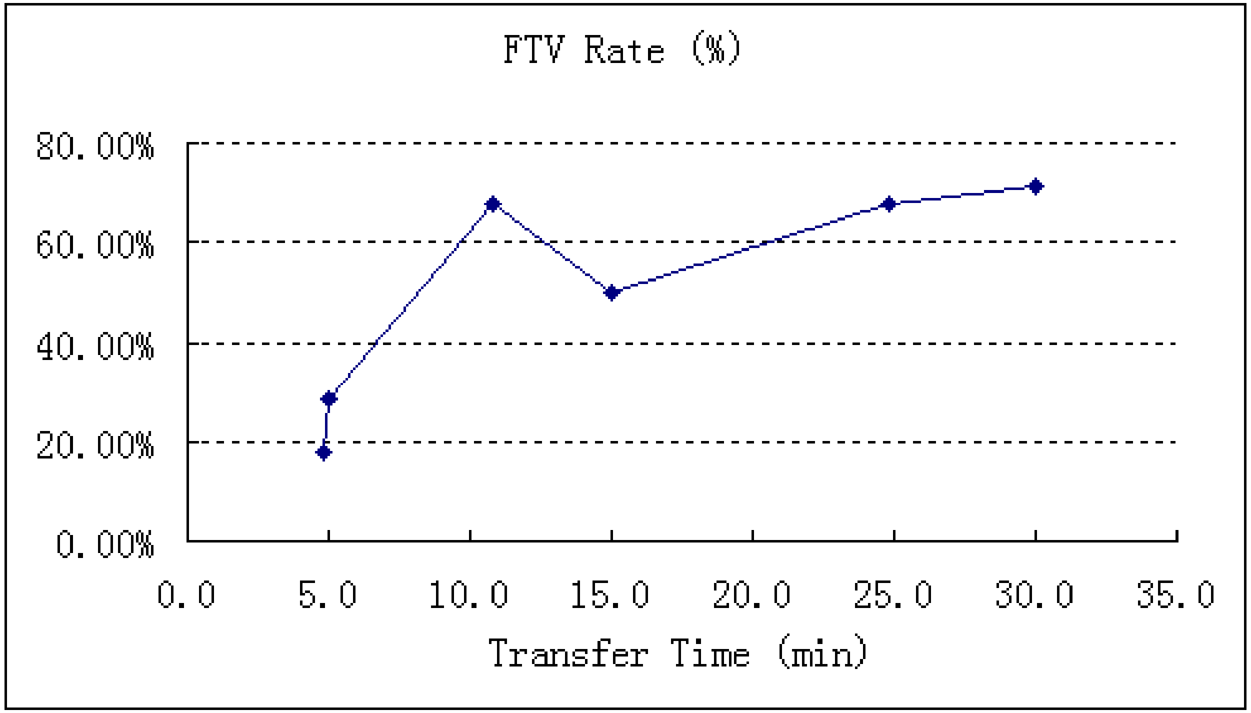
FTV-Freezing Thawing Void



Syringe should be stored in freezer within five minutes to prevent thermal shock.

FTV-Freezing Thawing Void

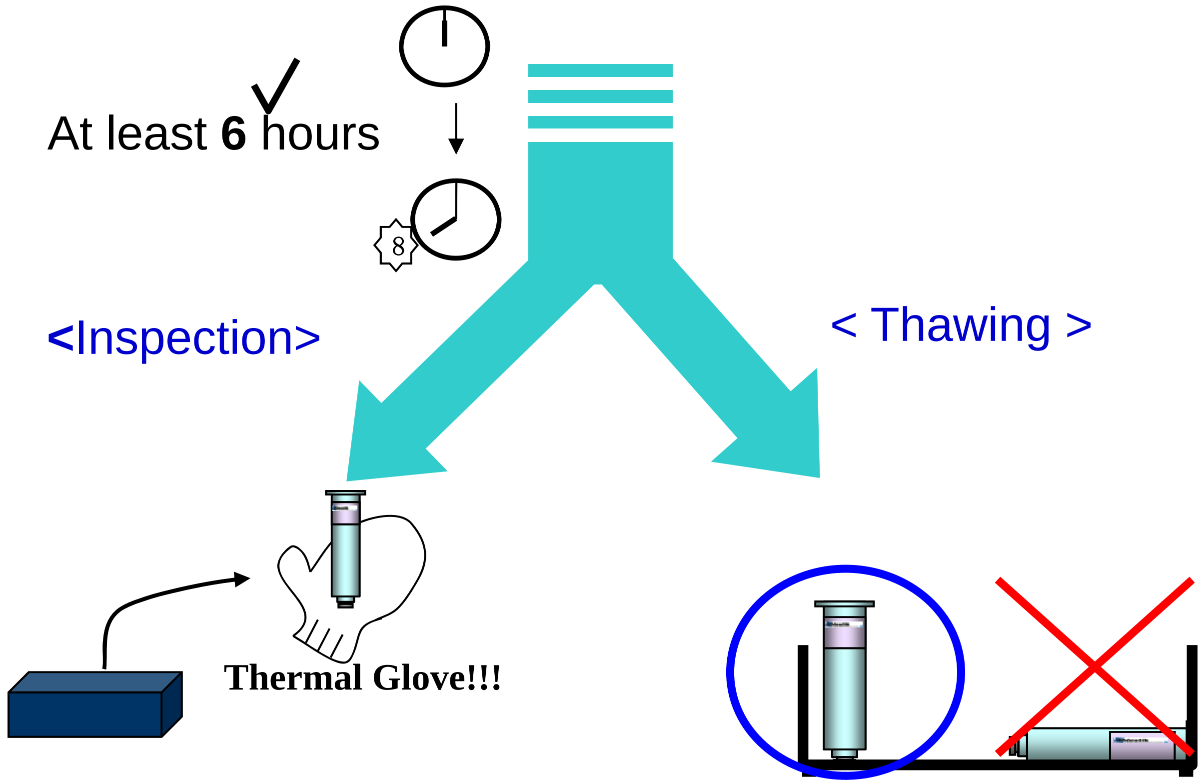
- Transfer time is important to the FTV performance, and the FTV performance can be improved effectively if syringe box is transferred within 5min.



Product:
Ablebond 3230

FTV-Freezing Thawing Void

* Before thawing, the syringe should be stored in the –40℃ freezer at least for 6 hours .



Thank you!

Henkel