Anaerobic adhesive jetting for microelectronics packaging applications

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Overview

Application objective

Background on anaerobic adhesives

Application challenge

Dispense solution

- List of key parameters
- Design of experiment
- Feasibility and optimization
- Applied in production

Summary

Objective

Dispense anaerobic adhesives

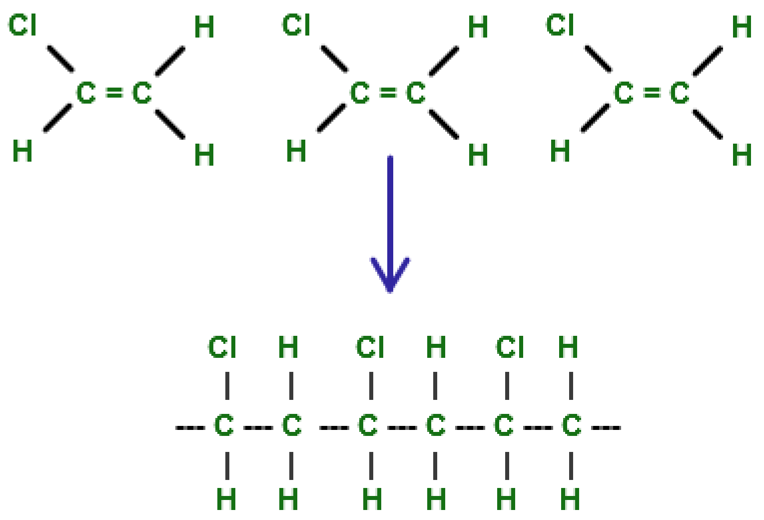
Bond small metal components

Novel use on: MEMS device and optical sensor

Final products: automotive, portable consumables electronics

Customer request: accuracy and throughput

Polymerization chemical reaction process needed for most adhesives to cure; reacting monomer molecules together to form polymer chains; radical and ionic polymerizations.



Anaerobic adhesive cures by radical polymerization

Radical polymerization initiator monomer activates the reaction, creates free radicals/unpaired electrons, which react with the resin monomer to form the polymer. Process is temperature dependent.

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Anaerobic adhesive cure mechanism [1][2][3]

Property: remain liquid when exposed to air, harden when confined between metal surfaces.

Example: Loctite 661/638, cumene hydroperoxide (initiator) + Urethane methacrylate (resin) + iron (metal in substrate) in confined space w/o oxygen

(1) $$Fe^{2+} + ROOH \rightarrow Fe^{3+} + RO\cdot + OH^{-}$$
$$R = C_6H_5C(CH_3)_2$$

(2) $$RO\cdot + M = P\cdot$$

(3) $$P\cdot + M = \sim\sim P\cdot$$

(4) $$\sim\sim P\cdot + \cdot P \sim\sim = \sim\sim PP \sim\sim$$

or (5) $$\sim\sim P\cdot + O_2 = \sim\sim P-O-O\cdot$$
$$\sim\sim P-O-O\cdot + M = \sim\sim P-O-O-M\cdot$$

reactions:

(1) Radical formation,

(2) chain initiation,

(3) chain growth,

(4) polymerization w/o O_2

(5) with O_2

References

[1] Richard D. Rich, “Anaerobic adhesive”, Page 761 in “Handbook of adhesive technology” Edited by A. Pizzi & K. L. Mittal, 2003.
[2] D. Raftery and M. R. Smyth, “Effect of copper (II) and Iron Fe (III) ions on reactions undergone by the accelerator commonly used in anaerobic adhesives”, Int. journal adhesion & adhesive, volume 17, 1997
[3] David J. Stamper, “Curing characteristics of anaerobic sealants and adhesives”, British polymer journal, volume 15, March 1983

Background on anaerobic adhesives

Cure fast within confined metal surfaces, w/o O_2

Difficult to handle in scale smaller than millimeter

Broadly used for industrial purposes

Novel applications

	Demo 1:	Demo 2:
Application	seal component on MEMS device	seal component on optical sensor
Customer	Portable consumable electronics	Automotive electronics
Adhesives	Loctite 638, sensitive to steel	Loctite 661, sensitive to stainless steel
Specs	Weight 0.27mg, 3σ=10% Non-contact access to cavity UPH 3600	5mg on each side of tubing, 3σ=10% Non-contact access to cavity UPH 3600

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Challenge

Recent novel application in microelectronics packaging

Accuracy 0.027mg => high precision dispenser

UPH 3600, complex cavity => non-contact jetting

e.g. thread locker

Industrial purpose
Large-small scale > 1mm
Manual/simple dispenser
Accuracy: 1mg
UPH 60

→

MEMS/sensor
Micro- scale < 1mm
High precision dispenser
Accuracy: 0.027mg
UPH 3600

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Challenge

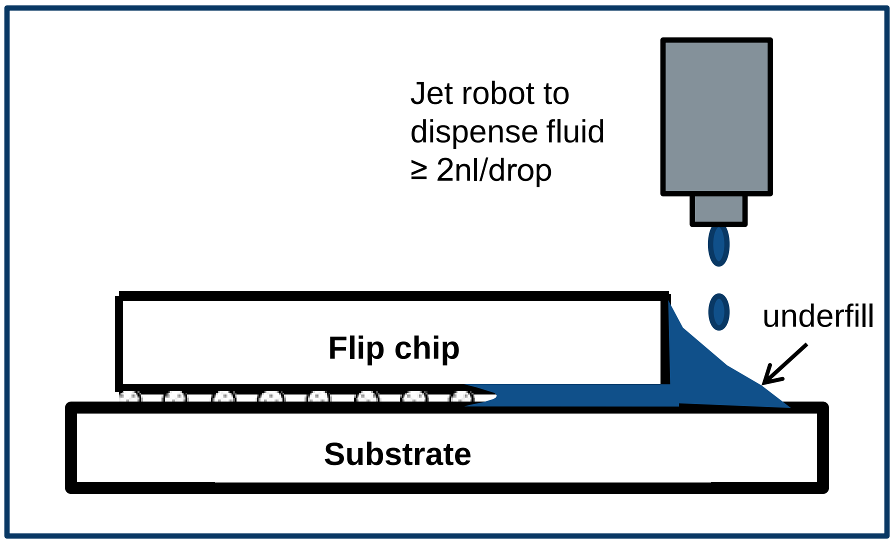
Existing technique: DJ-9500 jetting, precision=2nl/drop, frequency =167Hz

Well established process: underfill, encapsulation, sealing

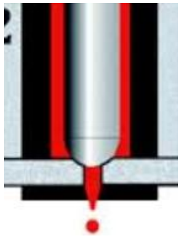
Valve robustness and dimension precision request
⇒Stiff/rigid metal components

Conflict: anaerobic adhesive cures in high-precision valve

Existing technique



Novel application | Challenge



No cure/clog

Cure/bond

Jetting solution DJ-9500:

High precision
High throughput
Non-contact

Optimization target:

No cure/clog
Accurate flow rate
Least maintenance
Affordable price

Test parameters:

Adhesives
Component size
Surface materials
Maintenance
Fluid temperature

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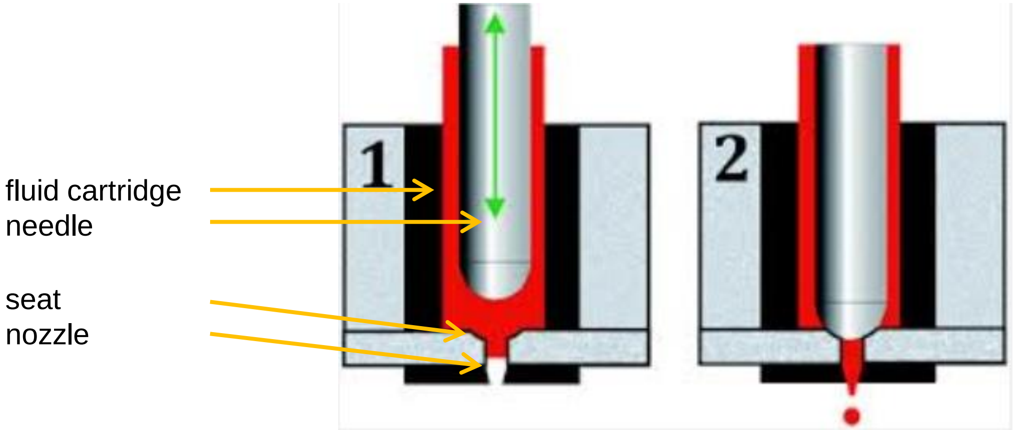
Design of Experiments: total 35 runs

Adhesives: Loctite 661 and 638
Components: fluid cartridge, needle, seat, nozzle
Component size: Medium to small orifice
Surface materials: standard or special
Maintenance: frequent purge or not
Fluid temperature: low to high

Confined dimensions/materials in DJ-9500:



Between chamber and needle:
small gap, stainless steel/carbide surfaces

Between seat & needle:
zero-gap, carbide surfaces

Within seat:
orifice 1.5-0.38mm, carbide

Within nozzle tip:
orifice 0.25-0.1mm, stainless steel, carbide, etc

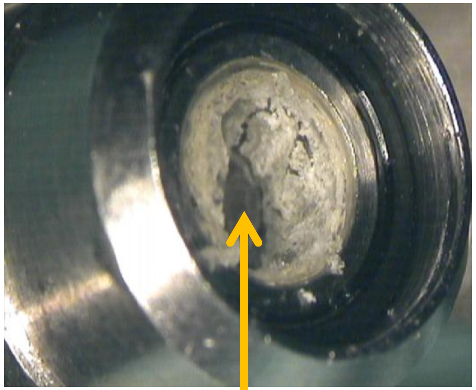
Curing samples:

Fluid cured between chamber and needle:
small gap, stainless steel/carbide surfaces

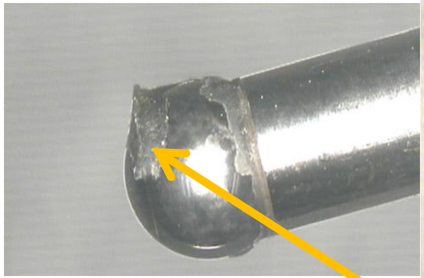
Fluid cured between seat & needle:
zero-gap, carbide surfaces

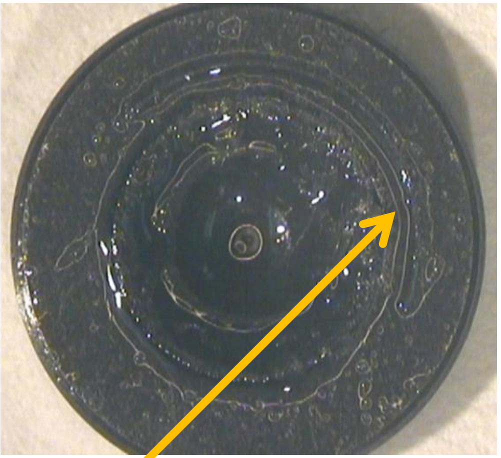
Fluid cured within seat:
orifice 0.38mm, carbide

Fluid clogged at nozzle tip:
orifice 0.1mm, stainless steel, etc.

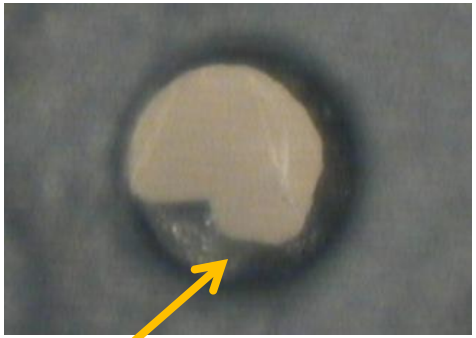


Full gel at bottom of fluid chamber





Full gel along contact rim by needle & seat => clog



partial gel in seat orifice => Q drops

Optimization basics

Less active materials still cure, but slower
Cure faster within smaller space
Rigorous maintenance/self wash to reduce flow stagnation
High fluid temperature promotes curing

DOE results:

Adhesive	Flow rate (mg/shot)	Special surface Yes/No	Fluid temperature (ºC)	Max purge interval (minute)	Clog after 1 Hr idle Yes/No
Loctite 661	0.22	N	28	15	N
661	0.11	N	28	15	Y
661	0.11	Y	28	15	N
661	0.04-0.06	N	28	4	Y
661	0.04-0.06	Y	28	15	N
Loctite 638	0.02-0.06	N	35	4	Y
638	0.02-0.06	Y	35	15	N
638	0.02-0.06	Y	55	N/A, clog immediately	N/A

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Maintenance

purge every 15min or shorter
clean every 12-24 hr

Fluid temperature

28-35ºC

Component

Medium flow rate:
standard, e.g. stainless steel, carbide

Small flow rate/small size orifice
special, e.g. plastic, inactive metal alloys

Non-cure solution
25 production lines, 24hr operation

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Summary

Anaerobic adhesives jetting: ASYMTEK DJ-9500
Application: to bond metal components on MEMS/sensors
Final use: portable consumables, automotives
Jetting advantage: high throughput, high precision, non-contact
Achievement: 25 production lines, 24-hr continuous operation
Goal: to help customers to push limit on their packaging capability as leading suppliers

Contact

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