alpha

Selecting Fluxes for Lead-Free Wave Soldering

Chrys Shea
Sanju Arora
Steve Brown
Cookson Electronics

Cookson Electronics

Lead-Free Transition Experience

- Assemblers have been doing lead-free wave soldering for several years
- Majority of soldering has been on relatively simple assemblies
  - Consumer electronics
  - Single- or double-sided
  - Used original tin-lead flux
- Process settings not significantly different from tin-lead on relativle simple boards

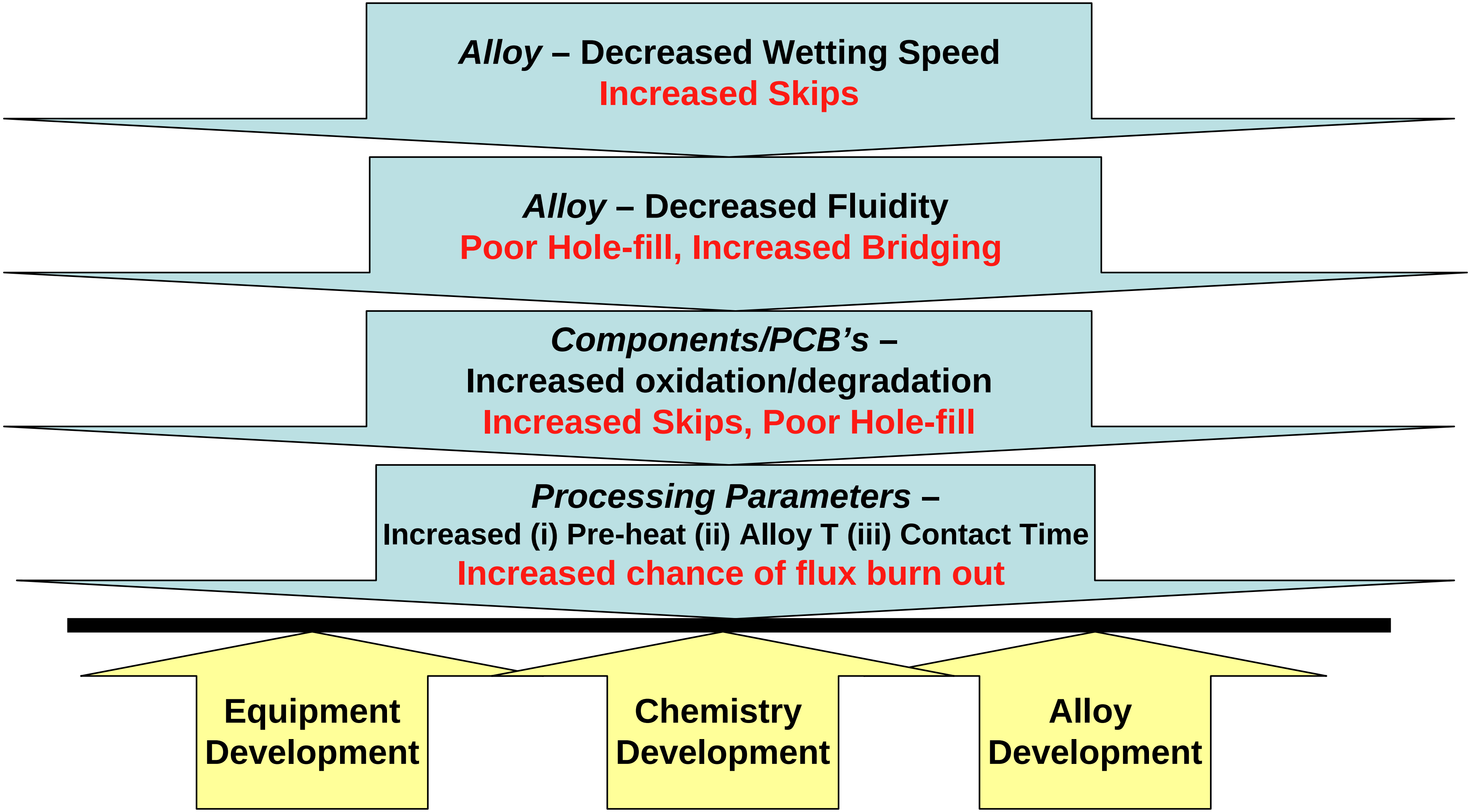
Consortia, Research and Applications Findings

- 0.062” thick boards will experience a tighter process window.
- Preheats do not change that much; most systems are capable.
- Solder temp doesn’t change that much.
- Barrel fill can sometimes be a challenge, especially with OSP.
- Debridging not quite as good as tin-lead.

Moving to Higher Complexity

- Thicker boards increase hole fill challenges exponentially
- High layer counts and numerous ground connections increase hole fill challenge
- These conditions can also create preheat challenge
- Longer dwell times make debridging difficult
- Selective solder pallets can shield areas from preheat exposure, making problem worse

Assemblers’ Challenges With LF



Alloy – Decreased Wetting Speed
Increased Skips

Alloy – Decreased Fluidity
Poor Hole-fill, Increased Bridging

Components/PCB’s –
Increased oxidation/degradation
Increased Skips, Poor Hole-fill

Processing Parameters –
Increased (i) Pre-heat (ii) Alloy T (iii) Contact Time
Increased chance of flux burn out

Equipment Development

Chemistry Development

Alloy Development

When Selecting a Wave Flux

1. Understand the Classification method used by IPC for all fluxes
2. Understand basic formulation approaches and their effects on
   - *- Reliability*
   - *- Activity*
   - *- Residue levels and cosmetics*

   and how they apply to the end-use of the electronic product

IPC Classification

- J-STD-004A
  - Latest revision 2004
  - Classifies fluxes by composition and activity
  - Applies to all fluxes used in electronics assembly:
    - Paste
    - Liquid (wave & rework)
    - Cored wire
    - Cored or coated preforms

J-STD-004A Classification

- First division: 4 composition categories:

Rosin	(RO)
Resin	(RE)
Organic	(OR)
Inorganic	(IN)

J-STD-004A Classification

- Next division: 6 activity levels
  - 3 main activity levels:

L	Low or no flux/flux residue activity
M	Moderate flux/flux residue activity
H	High flux/flux residue activity

J-STD-004A Classification

- Next division: 6 activity levels
  - 3 main activity levels
    - 2 subdivisions to indicate presence of halides (0= absent or 1= present):

L0
L1
M0
M1
H0
H1

J-STD-004A Classification

- Result: 24 classifications
- Table taken directly from J-STD document
- Note: inorganic fluxes are not used in electronics assembly

Flux Materials of Composition	*Flux/Flux Residue Activity Levels*	*% Halide (by weight)*	*Flux Type*	*Flux Designator*
ROSIN (RO)	**Low**	0.0%*	L0	ROL0
		< 0.5%	L1	ROL1
	Moderate	0.0%	M0	ROM0
		0.5-2.0%	M1	ROM1
	High	0.0%	H0	ROH0
		>2.0%	H1	ROH1
RESIN (RE)	**Low**	0.0%	L0	REL0
		< 0.5%	L1	REL1
	Moderate	0.0%	M0	REM0
		0.5-2.0%	M1	REM1
	High	0.0%	H0	REH0
		>2.0%	H1	REH1
ORGANIC (OR)	**Low**	0.0%	L0	ORL0
		< 0.5%	L1	ORL1
	Moderate	0.0%	M0	ORM0
		0.5-2.0%	M1	ORM1
	High	0.0%	H0	ORH0
		>2.0%	H1	ORH1
INORGANIC (IN)	**Low**	0.0%	L0	INL0
		< 0.5%	L1	INL1
	Moderate	0.0%	M0	INM0
		0.5-2.0%	M1	INM1
	High	0.0%	H0	INH0
		>2.0%	H1	INH1

** 0.0% is defined as <0.05% by weight*

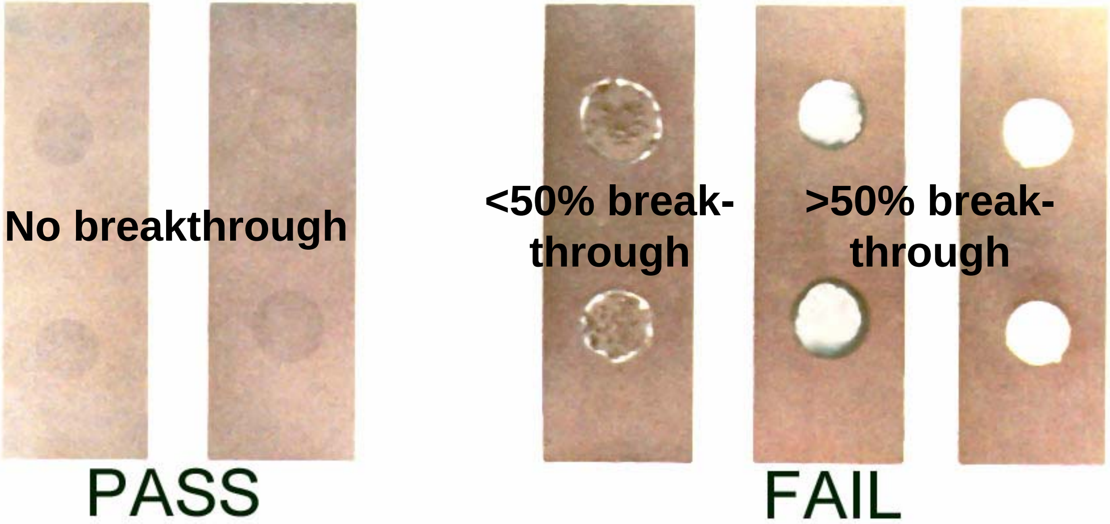
Tests to Determine Activity Levels

FLUX TYPE	COPPER MIRROR	QUALITATIVE HALIDE		QUANTITATIVE HALIDE	CORROSION TEST	CONDITIONS FOR PASSING 100 MEGOHM SIR REQUIREMENTS	CONDITIONS FOR PASSING ECM REQUIREMENTS
		SILVER CHROMATE (Cl, Br)	SPOT TEST (F)	(Cl, Br, F)			
L0	*No evidence of mirror breakthrough*	*Pass*	*Pass*	*0.0%*	*No evidence of corrosion*	*Uncleaned*	*Uncleaned*
L1		*Pass*	*Pass*	*<0.5%*			
M0	*Breakthrough in < 50% of test area*	*Pass*	*Pass*	*0.0%*	*Minor corrosion accpetable*	*Cleaned or Uncleaned*	*Cleaned or Uncleaned*
M1		*Fail*	*Fail*	*0.5 to 2.0%*			
H0	*Breakthrough in > 50% of test area*	*Pass*	*Pass*	*0.0%*	*Major corrosion acceptable*	*Cleaned*	*Cleaned*
H1		*Fail*	*Fail*	*> 2.0%*			

Source: J-STD-004A

Activity Level Test Methods

- Copper Mirror Test
  - Checks the removal effect of the flux on a thin copper deposit. A drop of test flux and a drop of control flux are placed on the copper mirror and conditioned at controlled room temperature for 24 hours. The results are observed and reported.



Activity Level Test Methods

- Qualitative Halide
  - indicates absence or presence of halides. If no halides are detected, the quantitative halide tests are not necessary.
  - *Silver chromate* tests for chlorides and bromides
  - *Spot test* checks for flourides
- Quantitative Halide
  - Ion chromatography

Activity Level Test Methods

- Corrosion Test
  - Checks corrosiveness of flux’s residue under extreme environmental conditions
- Surface Insulation Resistance (SIR)
  - Checks resistance of flux residues under high heat and humidity
- Electrochemical Migration (ECM)
  - Checks propensity of flux residues to allow ECM, such as dendritic growth

Activity Levels

		QUALITATIVE HALIDE		QUANTITATIVE HALIDE			
FLUX TYPE	**COPPER MIRROR**	**SILVER CHROMATE (Cl, Br)**	**SPOT TEST (F)**	**(Cl, Br, F)**	**CORROSION TEST**	**CONDITIONS FOR PASSING 100 MEGOHM SIR REQUIREMENTS**	**CONDITIONS FOR PASSING ECM REQUIREMENTS**
L0	*No evidence of mirror breakthrough*	*Pass*	*Pass*	*0.0%*	*No evidence of corrosion*	*Uncleaned*	*Uncleaned*
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M1		*Fail*	*Fail*	*0.5 to 2.0%*			
H0	*Breakthrough in > 50% of test area*	*Pass*	*Pass*	*0.0%*	*Major corrosion acceptable*	*Cleaned*	*Cleaned*
H1		*Fail*	*Fail*	*> 2.0%*			

J-STD-004A Summary

- Classifies fluxes based on composition:
  RO (rosin), RE (resin), OR (organic)
- Subclassifies based on activity,
  L (low), M (medium), H (high)
- And halide content:
  0 (absent), 1 (present)
- Examples:
  ROL0, ORM0, REL1

J-STD-004A Summary

- Provides classification methods and test methods to determine classification
- We now need guidance on how to select a particular class of flux for a given application.
- Understanding the different formulation options and end uses helps us select the right flux product.

Flux Formulation Categories

Wave Solder Fluxes

Water-Based

Alcohol-Based

Definitions

Alcohol Based

The carrier or solvent which holds all of the other active ingredients in solution for application to PCB

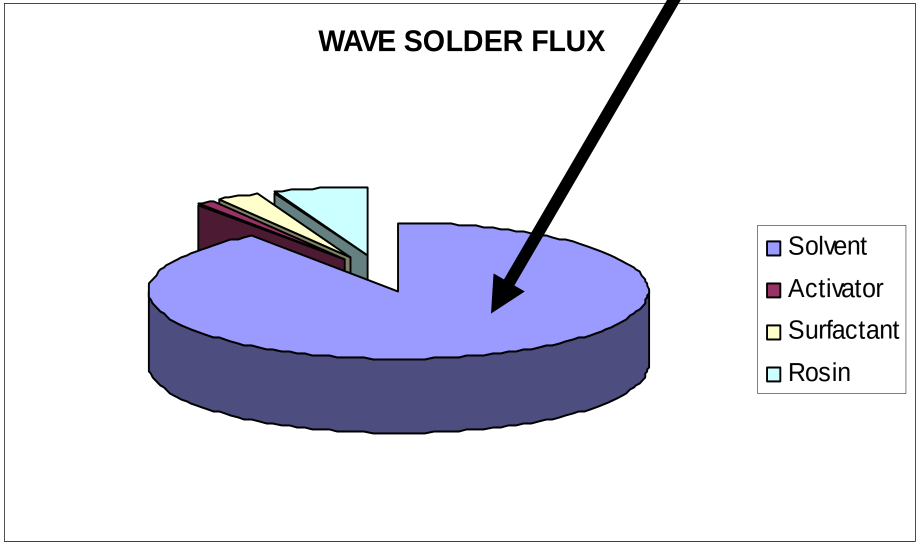
Water Based

+'s

Easy to dissolve ingredients
Good surface wetting
Easy to drive off in preheat

-'s

Flammability Risk
VOC Emissions



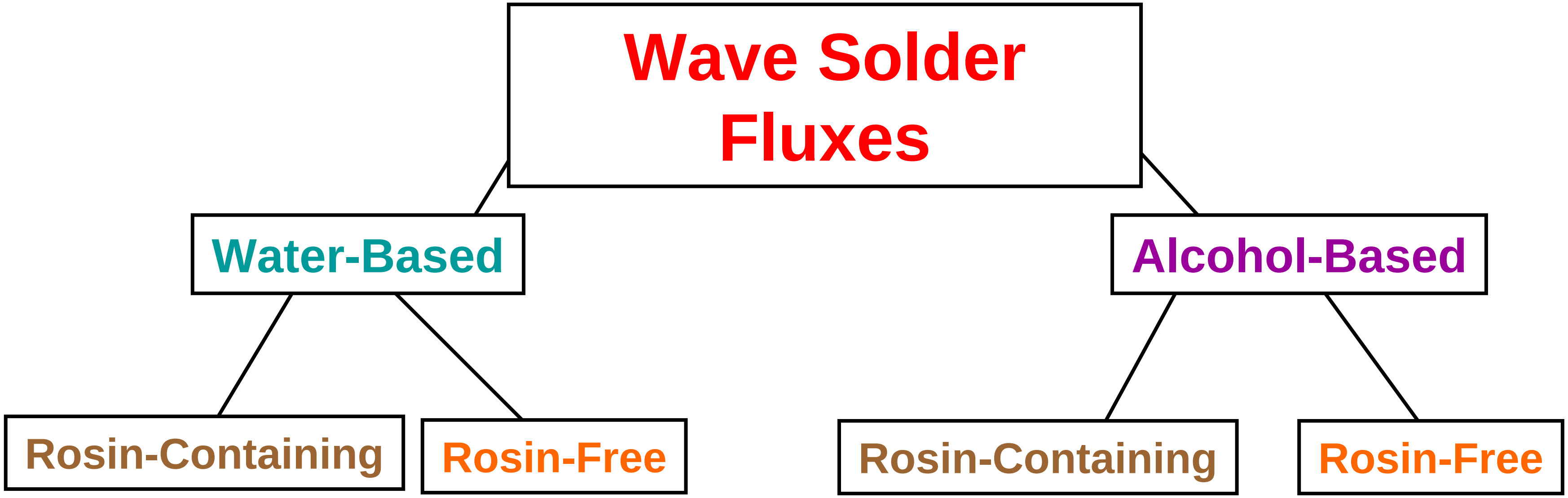
+'s

No fire risk
Vast VOC content reduction

-'s

Higher surface tension
Lower solvency
Harder to drive off in preheat

Flux Formulation Categories



Wave Solder Fluxes

Water-Based

Alcohol-Based

Rosin-Containing

Rosin-Free

Rosin-Containing

Rosin-Free

Definitions

Rosin Free

Rosin inclusion determines the nature of the residue and can act to safely encapsulate any un-reacted acid after soldering

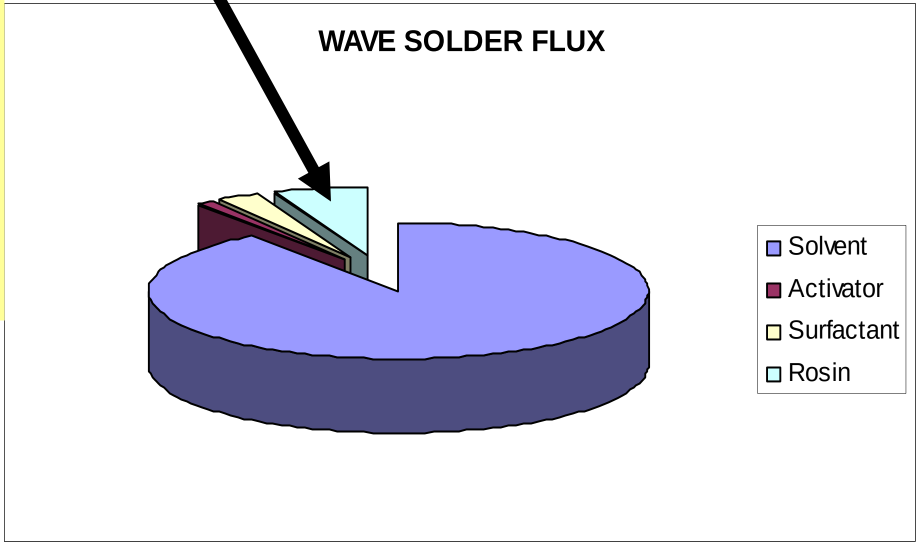
Rosin Containing

+'s

Lowest possible residue levels
Best cosmetics
Best for pin testability

-'s

Need very good process control
Potential reliability hazard in wrong environment/laminate combination



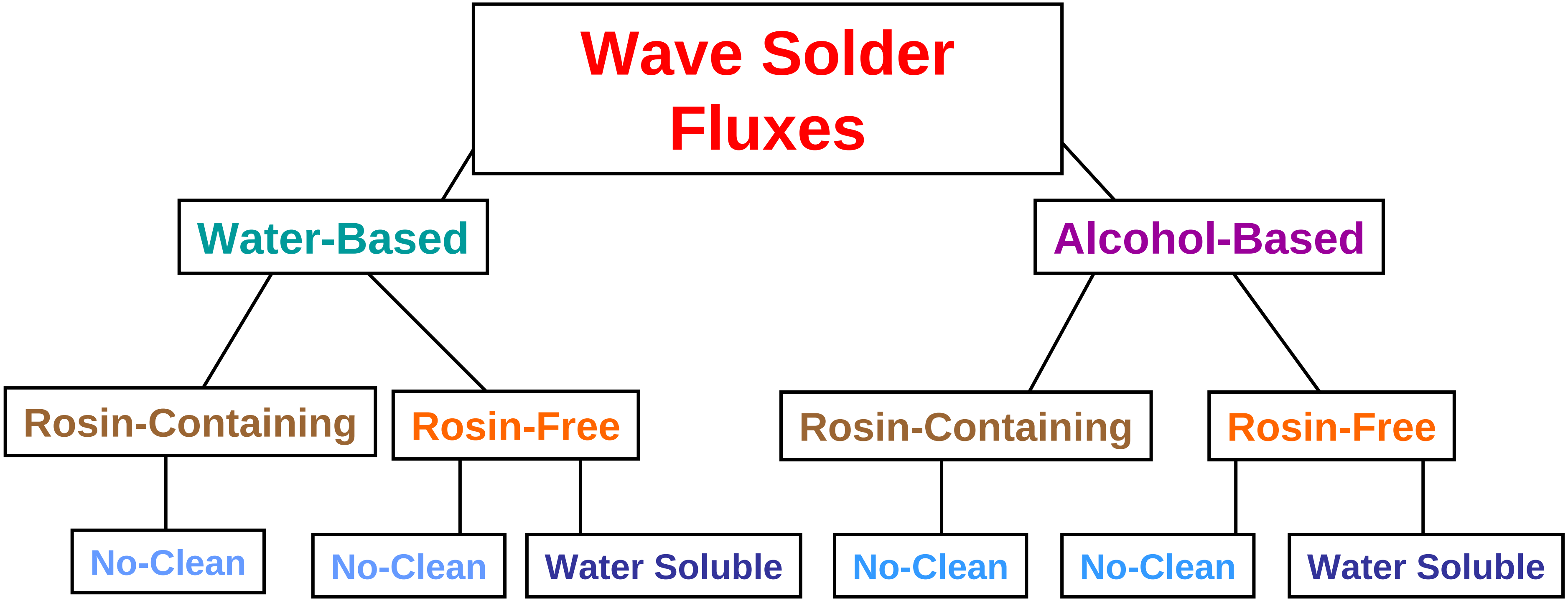
+'s

Allows greater activity with maintained reliability for all laminates

-'s

More visible residue
Reduced pin testability

Flux Formulation Categories



Wave Solder Fluxes

- Water-Based
  - Rosin-Containing
    - No-Clean
  - Rosin-Free
    - No-Clean
    - Water Soluble
- Alcohol-Based
  - Rosin-Containing
    - No-Clean
  - Rosin-Free
    - No-Clean
    - Water Soluble

Definitions

No-Clean

Water Soluble Fluxes are corrosive after soldering and must be cleaned. Most fluxes can be left on the circuit board hence the term 'no-clean'*

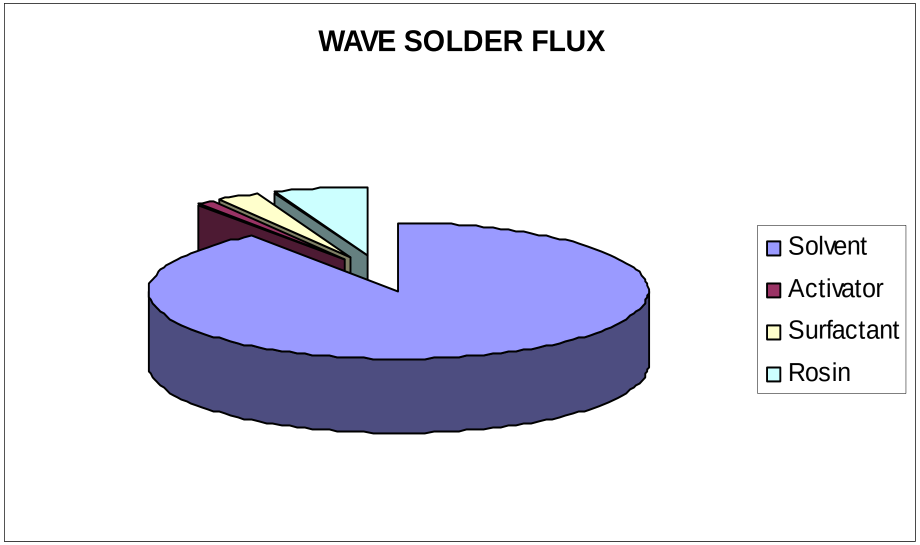
Water Soluble

+'s

Minimize process steps

-'s

Activity levels are limited by need for post soldering reliability



+'s

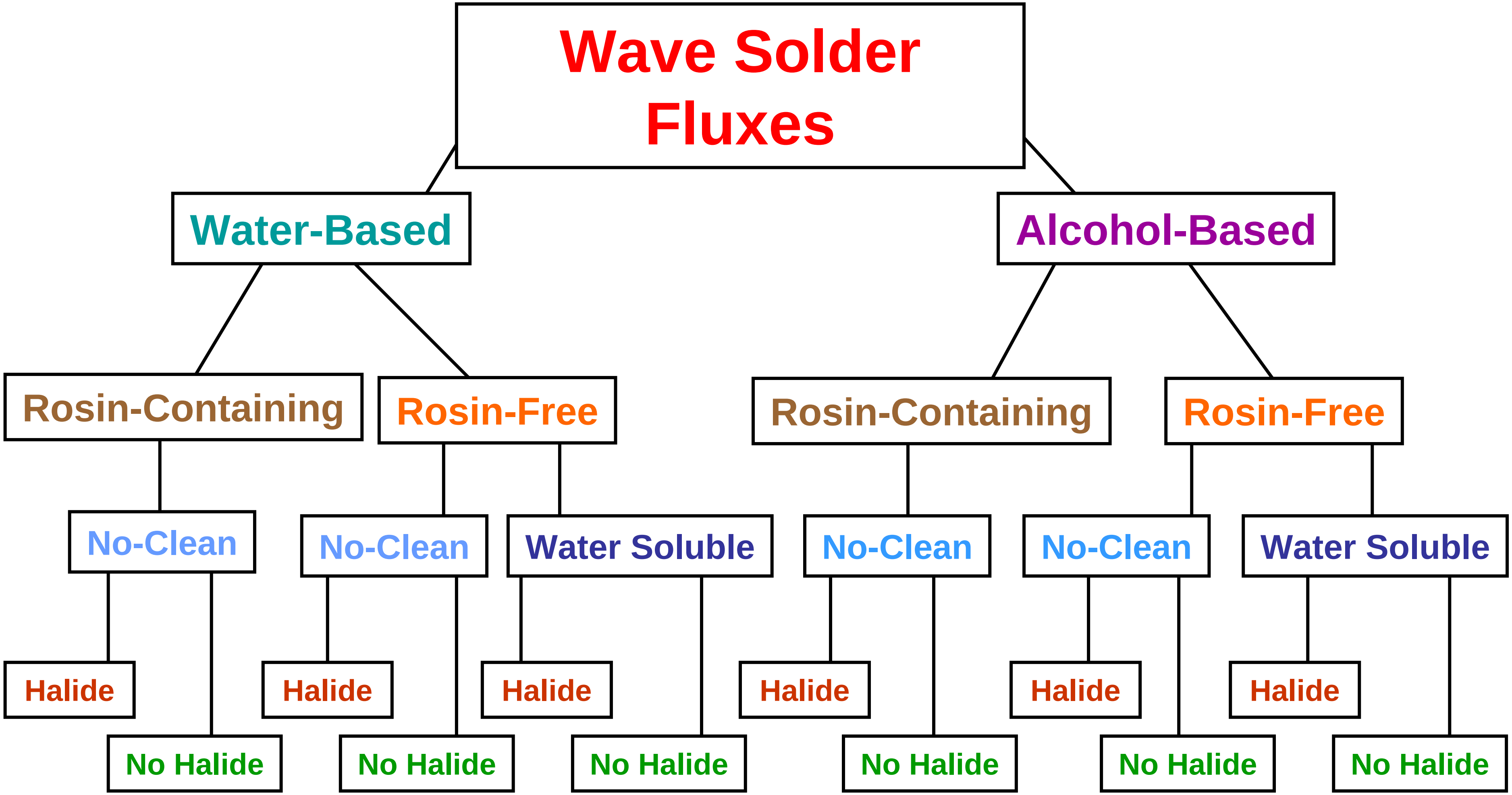
Activity not as limited for formulator

-'s

Cleaning process must be robust

Cleaning process adds cost

Flux Formulation Categories



Wave Solder Fluxes

Water-Based

Rosin-Containing

No-Clean

Halide

No Halide

Rosin-Free

No-Clean

Halide

No Halide

Water Soluble

Halide

No Halide

Alcohol-Based

Rosin-Containing

No-Clean

Halide

No Halide

Rosin-Free

No-Clean

Halide

No Halide

Water Soluble

Halide

No Halide

Definitions

Halide

Halides are often used as activators because of their reactivity and ability to rapidly reduce metal oxides. However, other non-halide options are effective as activators

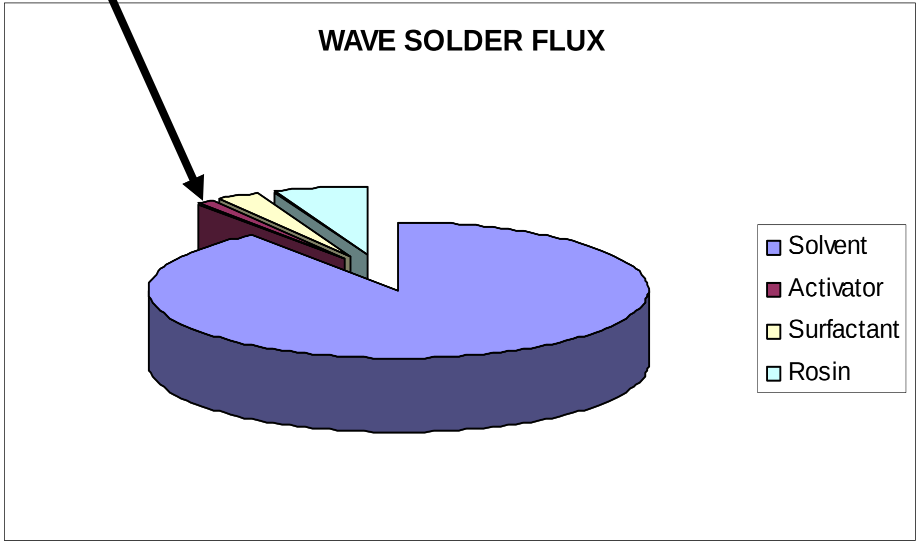
No-Halide

+’s

Use as a high performance activator type

-’s

Can be the cause of post soldering corrosion



WAVE SOLDER FLUX

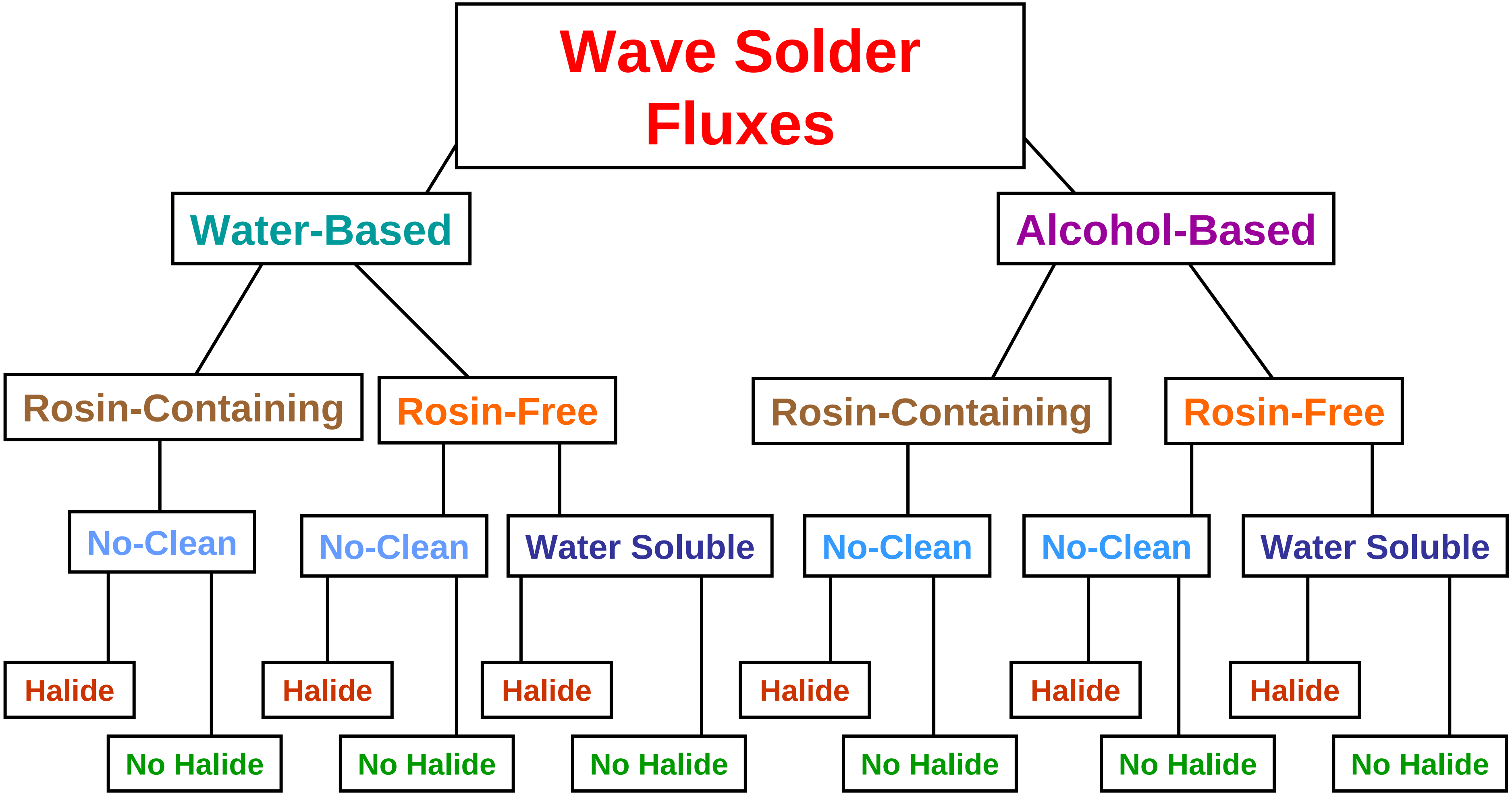
+’s

Perceived as safer

-’s

Generally less active with poorer wetting performance

Flux Formulation Categories

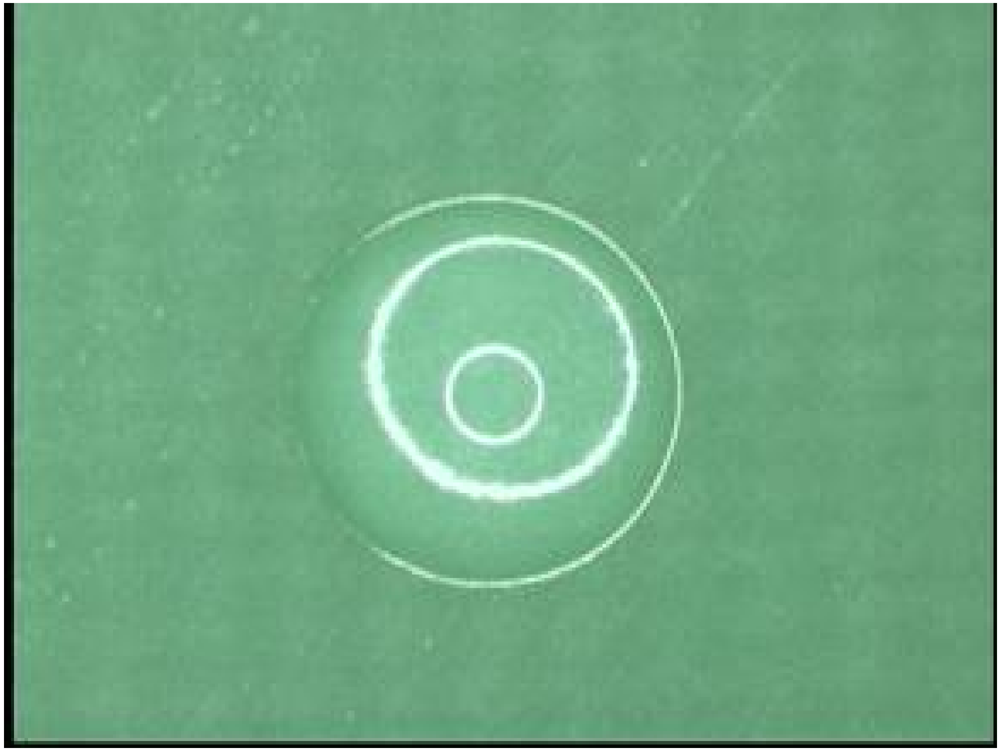


- Wave Solder Fluxes
  - Water-Based
    - Rosin-Containing
      - No-Clean
        - Halide
        - No Halide
    - Rosin-Free
      - No-Clean
        - Halide
        - No Halide
      - Water Soluble
        - Halide
        - No Halide
  - Alcohol-Based
    - Rosin-Containing
      - No-Clean
        - Halide
        - No Halide
    - Rosin-Free
      - No-Clean
        - Halide
        - No Halide
      - Water Soluble
        - Halide
        - No Halide

Other Formulation Considerations

- Surfactants
- Extended thermal and soldering cycles
- Acid Number
- Reliability

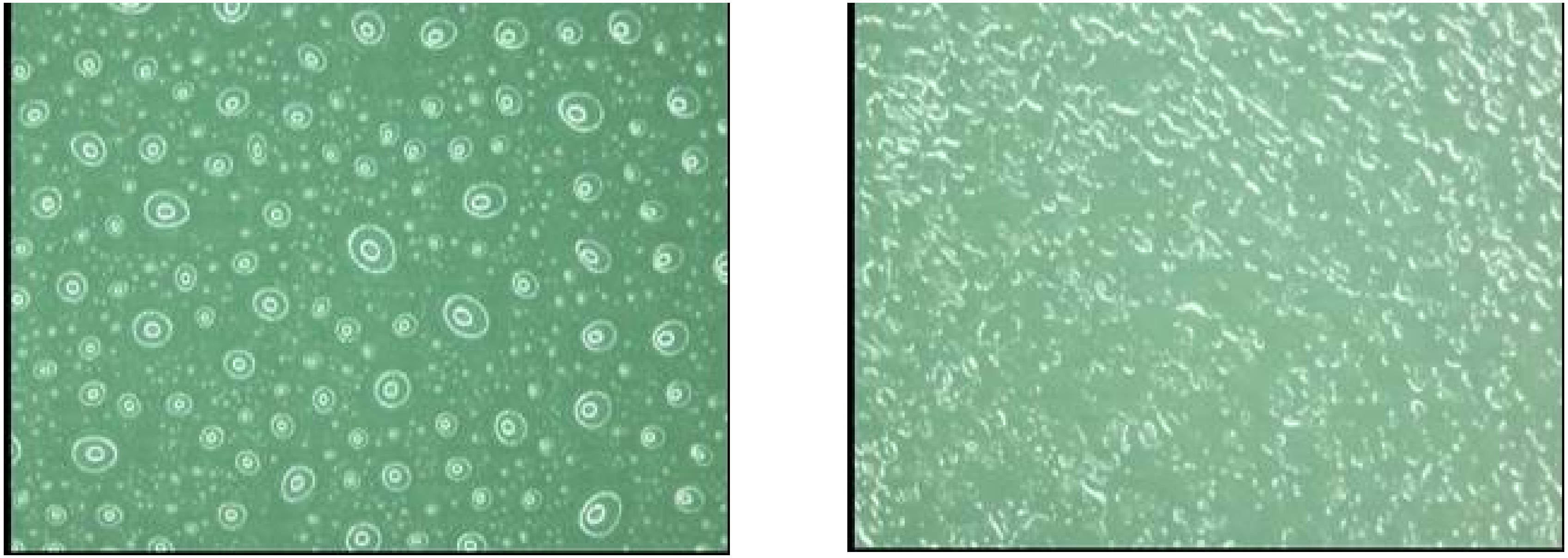
Surface Tension and Surfactants



A single drop of DI water on a commonly used solder mask

We tried a drop of IPA but it spread too fast to photograph

The Effect of Surface Tension on Spread

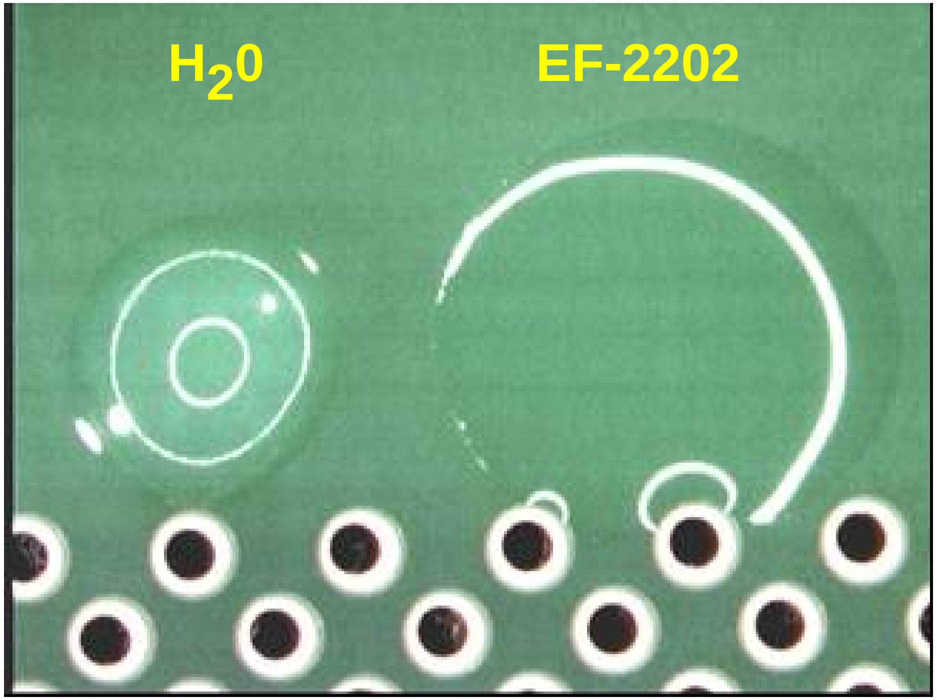


DI H_20 – 73 dynes/cm

IPA –23 dynes/cm

Photograph captured immediately after spraying

The Role of Surfactants



The drop of liquid on the left is DI water and the one on the right is water-based flux, whose surface tension was modified by surfactants.

Extended Soldering Cycles

- Thick or thermally dense boards require longer contact times.
- Longer contact times typically require slower conveyor speeds.
- Slower conveyor speeds create longer preheat times also.
- Fluxes must be able to stand up to longer preheat cycles, longer wave contact, and higher wave temperatures

Same No-Clean Flux for Tin-Lead and Lead-Free?

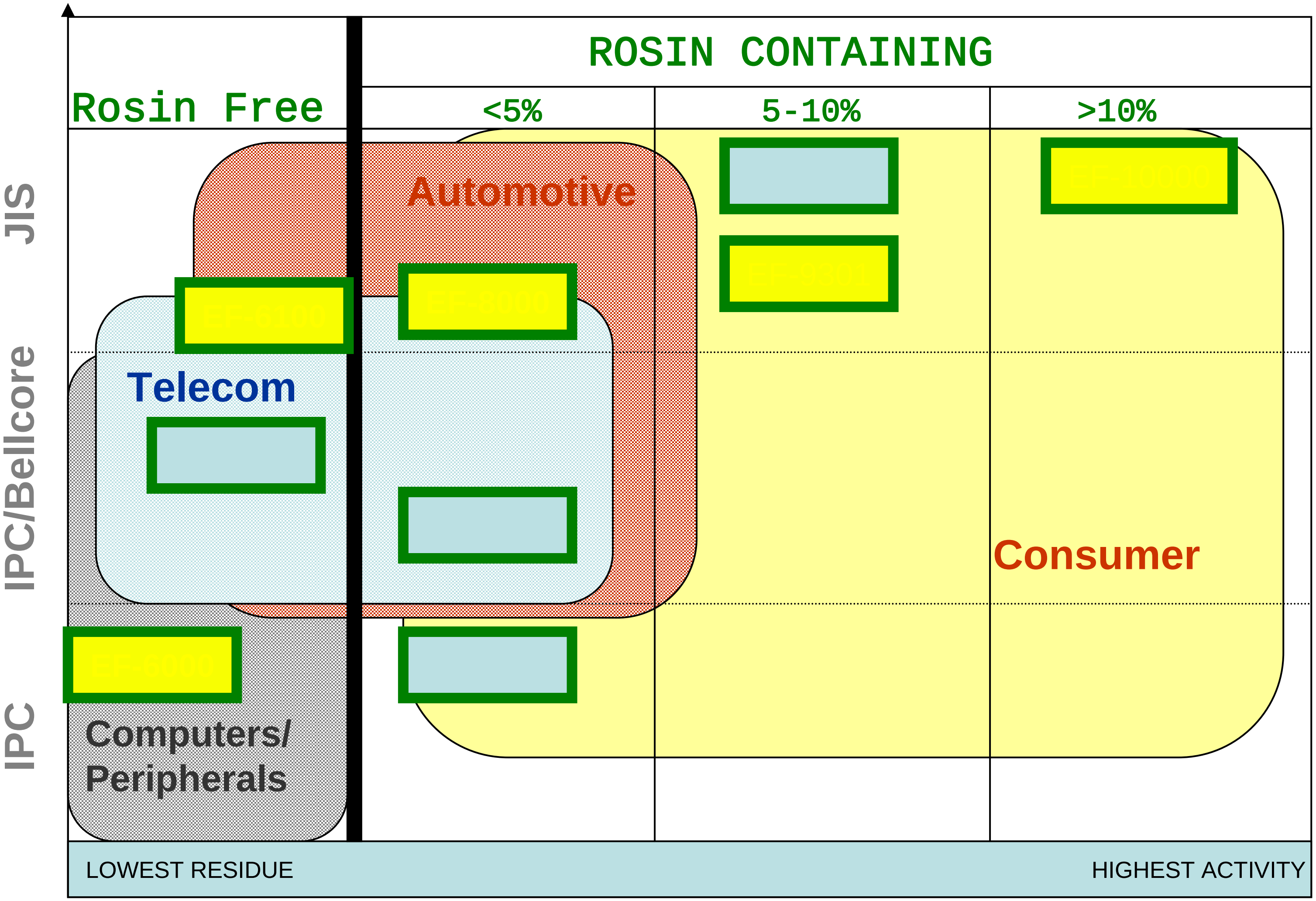
- Requires a delicate balance:
  - Relatively faster, cooler tin-lead thermal excursions must fully activate flux to maintain reliability
  - Activity must sustain the longer, hotter thermal excursions associated with lead-free processing
- Cooler processes bring reliability concern; hotter processes bring activity concern

Acid Number

- Traditionally used as an indicator of a flux’s activity
- No always true anymore
- Some fluxes with high acid number are not thermally stable and burn off early in lead-free process
- Some fluxes with low acid number have other ingredients that help them perform better than high acid number fluxes
- Can no longer be used as a primary indicator

Reliability

- Tests in order of increasing difficulty
  - IPC SIR
    - Telcordia (Bellcore) SIR
      - Telcordia Electromigration
        - » JIS (typically only rosin-bearing fluxes pass this test)



🟦 Water Based Lead-Free Capable

🟨 Alcohol Based Lead-Free Capable

Factors in Flux Selection

- Performance environment/reliability
- Assembly Complexity
- Residue levels and cosmetics
- Geographic location
  - Some areas limit VOC emissions, limiting flux choices to water-based only

Assembly Complexity

- IPC Joint Industry Standards classify assemblies by their performance environments:
  - ***<u>Class 1 - General Electronic Products</u>*** Includes products suitable for applications where the major requirement is function of the completed assembly.
  - Included here would be home consumer electronic products, appliances, toys.

Assembly Complexity

Class 2 - Dedicated Service Electronic Products

- This includes products where continued performance and extended life is required, and for which uninterrupted service is desired, but not critical. Typically the end-use environment would not cause failures.
- Included here would typically be computers, industrial and telecommunications equipment, and automotive electronics (except for engine management, drive-train and safety-related components.)

Assembly Complexity

Class 3 - High Performance Electronic Products

- This encompasses products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required.
- This would typically include military weapon and defense systems, aerospace, life support systems and under-the-hood automotive electronics.

Example of Class 1 Application

- **Home Consumer Electronics**
  - Low cost components & boards
  - Paper-phenolic laminates (FR-2)
  - Low complexity
  - Not the best component solderability
  - Visible residues acceptable
- **Best Flux Choice:**
  - Alcohol-based, rosin-bearing, often including halides
  - Classified ROL0, REL0, ROM0, REM0 without halides
  - Classified ROL1, REL1, ROM1, REM1 with halides

Another Class I Application

- Consumer electronics with higher functionality are using FR-4 laminates
- Rosin is no longer required to insure reliability
- Component solderability still an issue
- Best flux choice may be organic
  - ORL0 or ORM0
- Notice there is no ORL1 or ORM1
  - Without the encapsulation effect of the rosin, inclusion of halides would present long-term reliability issues: a *"recipe for disaster"*

Example of Class 2 Application

- **IT/Telecom Infrastructure**
  - Highest complexity assemblies
  - Prior SMT thermal excursions
  - Thermally dense – high component and layer count
  - FR-4 laminate
  - Visible residues not well tolerated
- **Best Flux Choice:**
  - Water- or Alcohol-based, rosin-free, medium activity fluxes
  - Water-based may be preferred to withstand long preheat cycles
  - Classified ORL0 and ORM0

* OR-- category fluxes should *not* be used on FR-2 laminates

Example of Class 3 Application

- **Automotive**
  - Moderate complexity
  - Conservative designs
  - Typically 1.6mm FR-4, max 8 layers
  - May carry high voltage in harsh environments
  - Typically manufactured with good process control
- **Best Flux Choice:**
  - Alcohol-based, rosin-bearing, halide-free
  - Classified ROL0, ROM0, REL0, or REM0

Summary

- J-STD-004A provides classification method
- No “One size fits all” single best flux
- Fluxes must be selected based on performance environment (reliability), assembly complexity, and residue levels
- User must understand relationships among assembly type, soldering process, and flux formulation to make educated decision.

Thank You

Questions