Modern Methods of PCB Depanelization and the Associated Considerations with a Focus on Low Impact Depanelization for Improved Reliability

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Individual circuit card assemblies have been getting smaller and more densely populated. As such the manufacturing community has recognized that it is easier and more economical to manufacture multiple assemblies simultaneously on a larger panel and then singularize them once they've been populated. PCB depaneling is that critical process in the manufacturing of PCBs that involves removing the individual assemblies from the larger panel. This step is necessary to increase production efficiency, ensure board quality and functionality, and reduce waste. Unfortunately, this penultimate process is often an overlooked one and can result in damage to fragile surface mount components, solder masks, and even the PCB substrate which could ultimately lead to scrapping the entire assembly that we've been so meticulous with up to this point.

However simple it may seem, depaneling introduces its own set of complications to the manufacturing process including mechanical stress, dust, debris, and design restrictions. To overcome these challenges, there are several depaneling methods available, each with its own advantages and disadvantages.

In this presentation, we'll discuss some of the common failures associated with depaneling as well as exploring the various methods of depanelization. The methods we'll be discussing in further detail are, V-scoring, die cutting, hand breaking, pizza cutters, laser depaneling, and PCB routers. We'll discuss the technical aspects of each method, including their speed, accuracy, and impact on the PCB and components as well as some of the design considerations for the different processes. We'll also briefly touch on the upfront and ongoing costs associated with each method.

Additionally, we'll showcase the latest trends and technologies in this field and offer tips on selecting the right depaneling method for your specific application. Whether you're a seasoned professional or new to PCB production, this presentation will provide valuable insights into this essential process. So, sit back, relax, and let's dive into the world of PCB depaneling!

Keywords: SAYAKA, PCB, PCB DEPANELIZATION, PCB ROUTER, PCB SLICER, PCB DICER, PCB V-SCORE, PCB PIZZA CUTTER, PCB DIE PUNCHING, PCB SAWING, LASER DEPANELING, LASER ABLATION, STRESS, STRAIN, DEPANELING INDUCED STRESS, DEPANELING INDUCED STRAIN, MITIGATING DEFECTS DUE TO IMPROPPER DEPANELIZATION.

Best Practices:

- Choose the right depaneling method for your application: There are various depaneling methods available, and it's important to choose the right one for your specific application. Factors to consider include the type and thickness of the PCB material, the size and complexity of the panel, the type and density of the components, and the required accuracy and precision.
- Minimize mechanical stress: Mechanical stress can damage the PCB components and affect the overall performance of the board. To minimize mechanical stress, it's important to use the appropriate depaneling method, to maintain the right cutting speed and pressure, and to properly support the board during depaneling.
- Ensure dimensional accuracy: Dimensional accuracy is critical for the proper functioning of the PCBs and their compatibility with other components. To ensure dimensional accuracy, it's important to use the appropriate cutting tool, to maintain the right cutting depth and width, and to use the appropriate measurement tools to verify the accuracy of the cuts.
- Maintain cleanliness and safety: PCB depaneling can produce dust, debris, and other particles that can damage the components or pose a health hazard. To maintain cleanliness and safety, it's important to use the appropriate dust collection and ventilation systems, to wear appropriate personal protective equipment, and to properly dispose of the waste materials.

- Regular maintenance and calibration: Regular maintenance and calibration of the depaneling equipment can ensure optimal performance and accuracy, and can extend the lifespan of the equipment. Regular maintenance can include cleaning and lubrication of the cutting tools, inspection and replacement of the cutting blades, calibration of the cutting feed and speed, and testing and verification of the accuracy of the cuts.

Common Defects

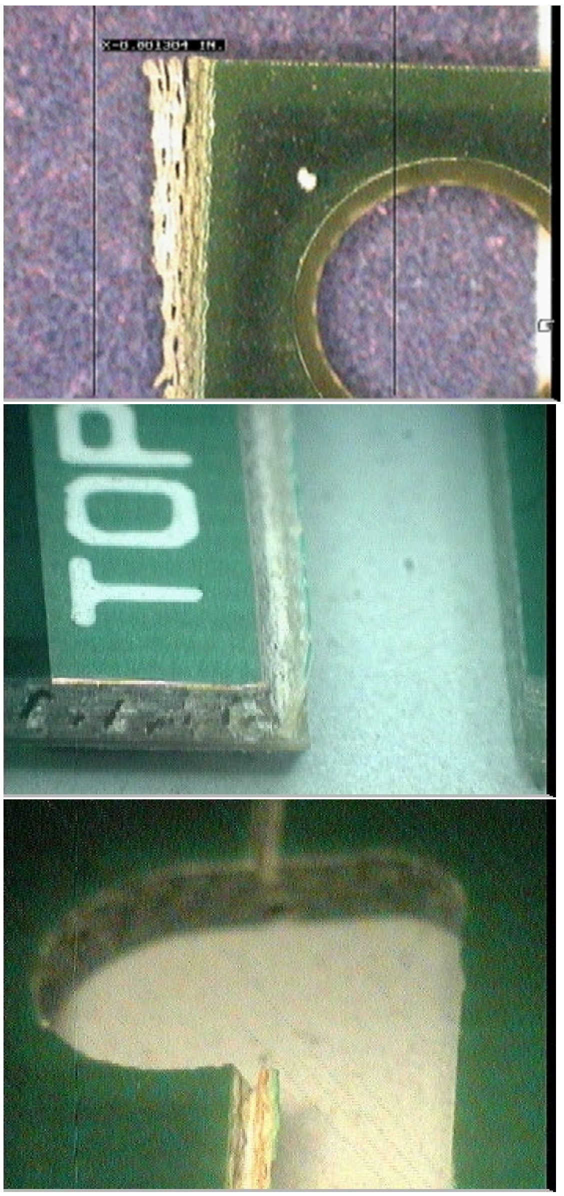

Figure 1: Fraying / Delamination

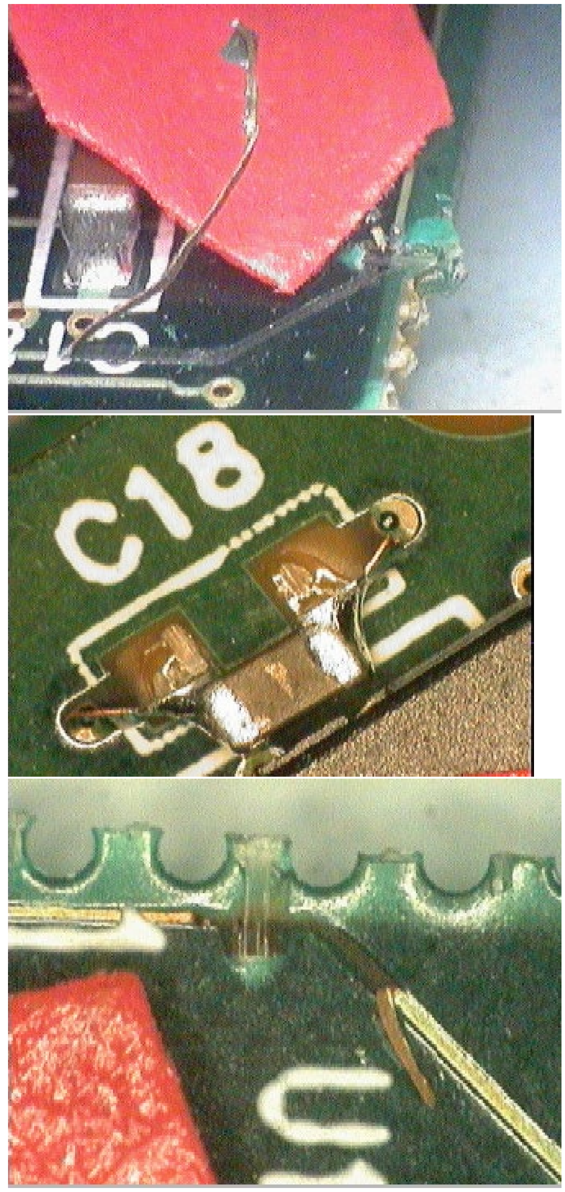

Figure 2: Solder Mask Failure:

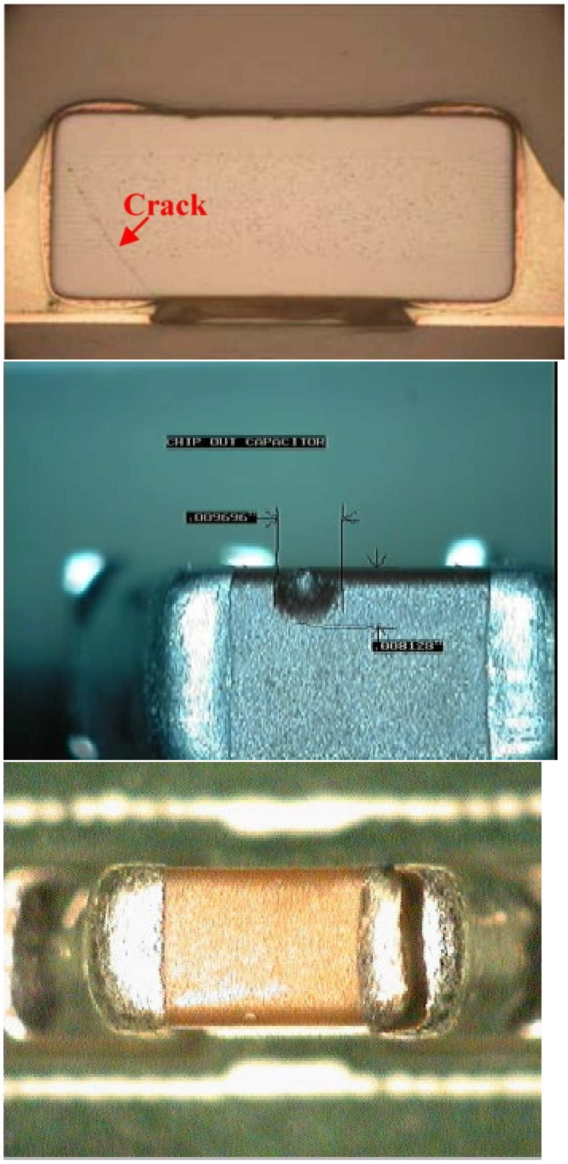

Figure 3: Component Damage

Stress and how we measure it!

Stress is the force or pressure that's applied to a substrate which can cause it to change from its original shape. That change in shape is what we call strain which we can quantify using strain gauges. There are a few different types of strain gauges but the most commonly used strain gauges for our application are bonded foil resistance strain gauges. This type of strain gauge uses a metallic wire in a grid pattern that is bonded to your substrate and as your substrate expands or contracts the electrical resistance of the strain gauge changes proportionally.

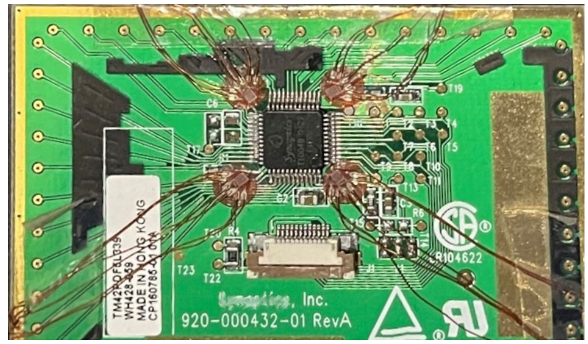

Figure 4: (Strain gauges bonded to PCB around BGA)

Depaneling Method	Direction	Stress Level	Stress Limit of Ceramic Capacitor
Hand Break w/ V-Groove	Parallel to Cut	400 με	800-1800 με
	Perpendicular to Cut	1800 με	
Rolling Blade w/ V-Groove	Parallel to Cut	1700 με	
	Perpendicular to Cut	1600 με	
Router (1.0mm bit 10mm/sec)	Parallel to Cut	110 με	
	Perpendicular to Cut	300 με	
Depaneling Method	**Distance from Cut**	**Stress Level**	**Stress Limit of Ceramic Capacitor**
Rolling Blade w/ V-Groove	3mm	1500 με	800-1800 με
	4mm	500 με	
Router (1.2mm bit 15mm/sec)	3mm	60 με	

Figure 5: Stress Test Condition and Test Data:

Strain gauge: KFG-2-120-L1-11L1M2R (Kyowa Electronic Instruments Co. Ltd.)
Amplifier: DPM-712B (Kyowa Electronic Instruments Co. Ltd.)
Strain meter: HIOKI 8804
Sample PCB: Glass-Epoxy 1.2mm thickness with V-groove
Rolling Blade: Titanium plated two-disc cutter, feed speed 100mm/sec
Router bit: Tungsten alloy 1.2mm diameter, feeding speed 15mm/sec

V-Scoring Method:

Definition: The process of creating a groove or score line on the surface of the PCB panel, which allows the PCBs to be separated by bending or snapping along the groove.

Pros: Simple, fast, suitable for medium to high-volume production, and low cost.

Cons: Limited to straight line separation, not suitable for thicker or more complex boards, and may cause stress on the PCBs near the score lines.

Technical information and limitations:
This process uses a rotary blade or a V-shaped cutter that has an angle of 30° to 45°. The blades are typically 2.5mm thick. The scoring depth is typically 30% of the board thickness on each side. It's also critical to properly space your components inboard of the v-score to reduce component damage. V-Scoring is typically used in conjunction with another depaneling method such as: hand breaking, guillotines, or rolling wheel cutters.

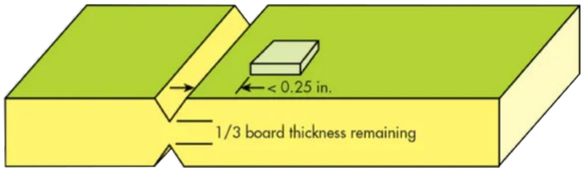

Figure 6: V-scored PCB Design Considerations

Hand Breaking Method:
Definition: The process of manually breaking individual PCBs from the larger panel using hands or pliers. The PCBs are attached to the panels via breakaway tabs or v-score.
Pros: Low cost, simple, and suitable for low-volume production.

Cons: Inaccurate, time-consuming, and can cause mechanical stress or damage to the PCBs. Limited to straight cuts.

Technical information and limitations:
Limited to thinner and less complex boards, requires skilled workers, and not suitable for high-precision applications. Peak strain recorded 1800με

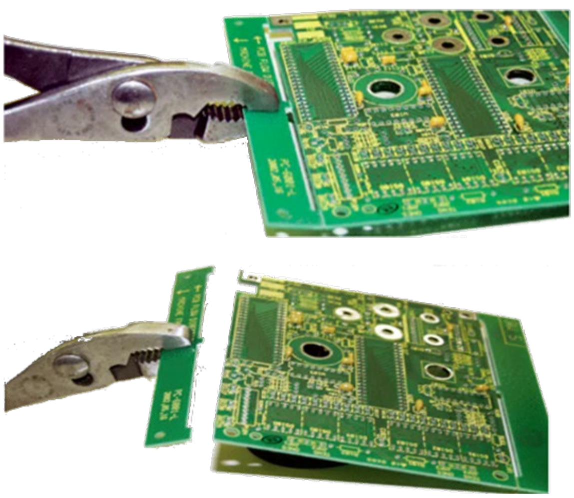
Figure 7: PCB depaneled by hand breaking

Rolling Blade / Pizza Cutter Method:
Definition: The process of using a rotary cutting tool to separate individual PCBs from the panel by cutting through the breakaway tabs or perforations.

Pros: Low cost, simple, and suitable for low-volume production.

Cons: Inaccurate, time-consuming, and can cause mechanical stress or damage to the PCBs. Limited to straight cuts.

Technical information and limitations:
This process uses a rotary blade (pizza cutter) that has a diameter of about 100 mm and a thickness of up to 5 mm. The blade or cutter may have a motor or may be manually operated. Peak strain recorded 1,700με

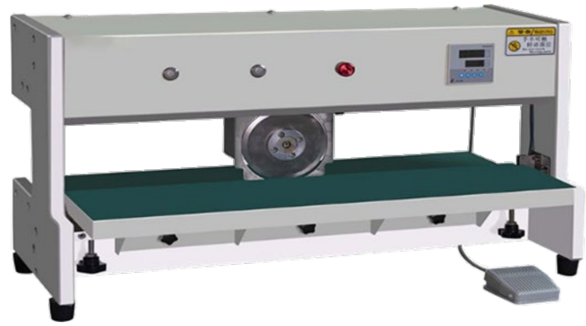
Figure 8: Powered rolling wheel

Punching/Die Cutting Method:
Definition: The process of using a special fixture to punch individual PCBs from the panel. The fixture has sharp blades on one part and supports on the other. Each board needs a distinct die, and dies must be often serviced to maintain sharpness.

Pros: High production rate, low cost per board.

Cons: High initial cost of fixtures and dies, frequent maintenance and sharpening, limited design flexibility, mechanical stress on boards and components.

Technical information and limitations:
This process uses a hydraulic or pneumatic press that can exert a force of up to 20 tons to punch out the boards. The blades and supports are made of hardened steel or carbide.

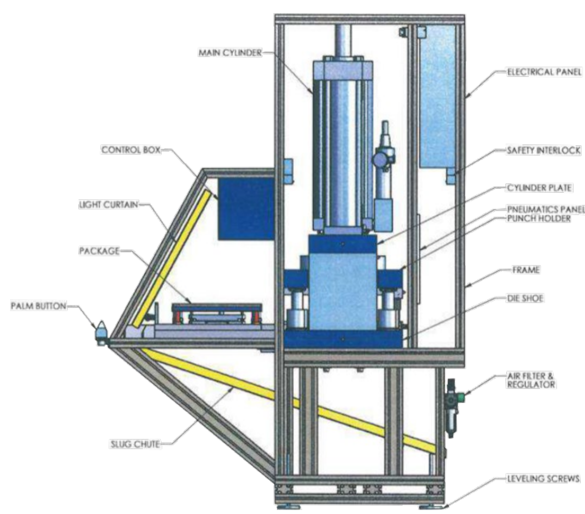

Figure 9: Pneumatic PCB Depaneler

Sawing:
Definition: Sawing is a process where a saw blade cuts the boards along tabs that connect them in a panel.

Pros: Fast cutting speed, suitable for medium to high-volume production. Suitable for aluminum PCB or thicker substrates.
Cons: Dust and debris, mechanical stress on boards and component, limited to straight line cuts.

Technical information and limitations:
This process typically uses a circular saw that has a diameter of 100 mm and a thickness up to 5 mm. The saw blade rotates up to 10,000 rpm and moves along a predefined path controlled by a computer program.

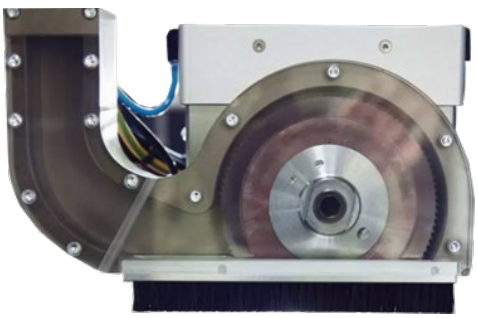

Figure 10: PCB Saw

Laser Depaneling Method:
Definition: The process of using a laser beam to vaporize or ablate the material along the separation lines to separate the PCBs from the panel.

Pros: High accuracy, speed, and precision, and suitable for various board types, particularly flexible PCB.

Cons: High cost, requires skilled operators and maintenance, and may produce harmful fumes and debris. Limited to thinner board sizes.

Technical information and limitations:
This process uses a laser beam or a focused light source that has a wavelength of about 10.6µm (Co2), 355 nm (UV), 1064 nm (IR), and the latest 532nm (Green) lasers that utilize a pulsed beam to minimize the heat affect zone (HAZ). The laser beam or typically has a power between 10 W and 40 W and moves the PCB along a predefined path. The process has typically been limited to flex or thinner boards, depending on the laser source and optics. The cutting width is typically less than 50 µm. Peak strain N/A

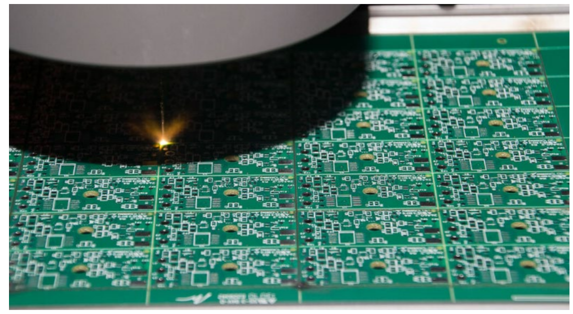

Figure 11: Laser Depanelization

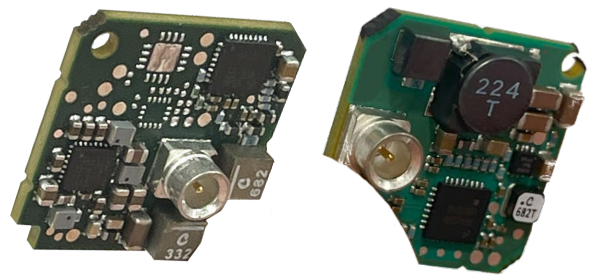

Figure 12: Result of 532nm green pulsed laser (left), Result of 10.6µm Co2 Continuous-wave laser (right)

Notice the increased carbonization with the use of the Co2 laser.

PCB Routing Method:
Definition: The process of using a CNC router to cut through the panel along the designated breakaway tabs or paths to separate the PCBs.

Pros: High accuracy, speed, and precision, and suitable for various board types and thicknesses. High design flexibility. Significantly reduced strain on board and components.

Cons: High initial cost, may produce dust and debris without the use of custom fixtures or dust collectors.

Technical information and limitations:
This process uses a fluted helical cutting bit. The bit spins up to 60,000 rpm and moves along a predefined path controlled by a computer program. Peak strain recorded 300µε

Figure 13: PCB Router

- **Latest trends and technologies:**

Automated depaneling: Automated depaneling is another growing trend in the industry, as it can significantly reduce the time and labor required for depaneling. Automated depaneling machines use robotics and advanced software to quickly and accurately separate the PCBs from the panel, without damaging the components or the board. They can also handle a wide range of PCB sizes and shapes however there is a lot of additional equipment and programming to fully automate the depaneling process.

Figure 14: Fully Automated PCB Depaneling Router

Conclusion:

While fully automated depanelers with robotic loaders sounds like an awesome solution it may be completely overkill for a project that would be acceptable with v-score and hand brake and for that reason you'll have to decide which process or combination of processes is right for each product. Thankfully there are many different options to choose from when it comes to depaneling and ultimately, you'll have to weigh the pros and cons of each method against the cost and see how much strain your components will tolerate… and how much stress you're willing to put up with!