LASER MICRO-PERFORATION *in food packaging: precision, shelf life and process efficiency*

ADVANCED MICRO-PERFORATION TECHNOLOGIES ENABLING CONTROLLED ATMOSPHERE, EXTENDED SHELF LIFE AND HIGHER PROCESS EFFICIENCY.

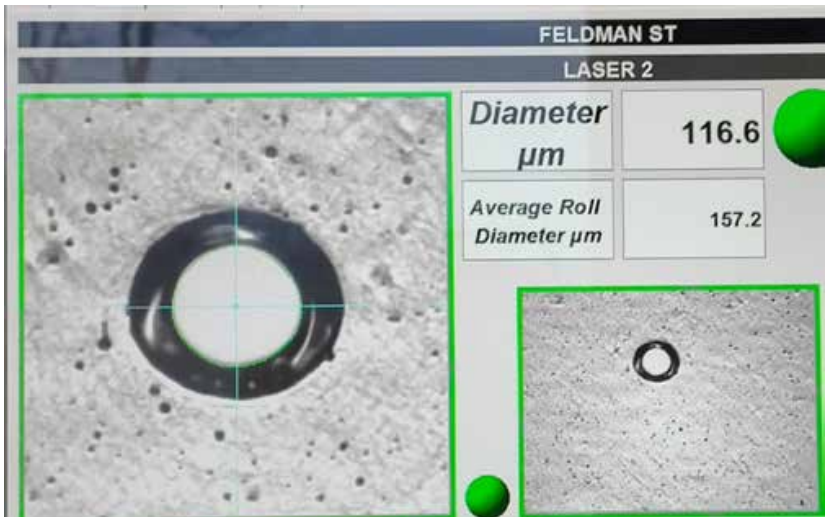
In food packaging, plastic film micro-perforation plays a crucial, yet often underestimated, role. Its function is simple but essential: allowing the product to "breathe" while maintaining a protective barrier against dust, insects and external contamination.

However, not all micro-perforation technologies deliver the same performance. The choice between cold needles, hot needles and laser systems depends on several variables, including film type, production speed and the specific requirements of the packaged food.

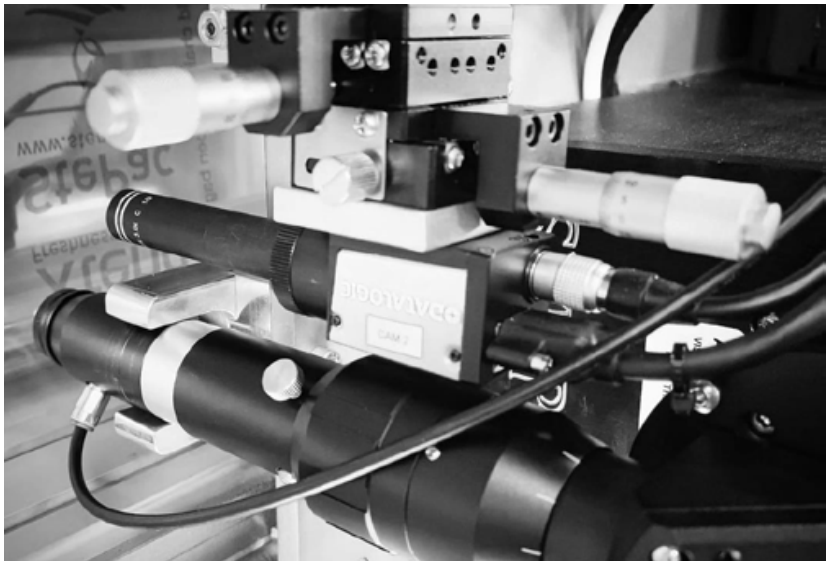
Many food products, such as fresh fruit and vegetables, bakery goods and certain dairy items, continue to respire after packaging, releasing moisture and gases like CO2. Without controlled ventilation, condensation builds up inside the package, accelerating spoilage and promoting microbial growth. Micro-perforation introduces calibrated openings that enable controlled gas exchange, creating what is known as Equilibrium Modified Atmosphere (EMA).

This balance is essential across multiple applications. Fresh-cut produce, for instance, is highly sensitive to excess humidity, which can compromise both shelf life and visual quality. Bakery products need to release residual moisture to maintain their crispness, while aged cheeses require controlled transpiration to preserve texture and flavour. In all these cases, the correct combination of hole diameter and density is critical: insufficient permeability leads to anaerobic conditions and off-odours, while excessive permeability causes dehydration and weight loss.

Cold needle micro-perforation remains the most widespread solution, thanks to its simplicity, cost-effectiveness and compatibility with heat-sensitive materials. It is particularly suitable for flexible films such as LDPE, HDPE, laminates and biodegradable substrates. Hot needle systems, on the other hand, address the limitations of cold perforation on oriented films. By locally melting the







polymer, they create stable holes with sealed edges, ensuring consistent performance in applications such as bakery packaging.

While both technologies are reliable and widely adopted, they present limitations in terms of flexibility, precision and process control, especially in high-performance or premium packaging applications. This is where laser micro-perforation represents a significant step forward.

Laser technology combines precision, flexibility and automation in a single system. By using high-energy light beams to vaporize the material, it creates extremely fine and uniform holes without any mechanical contact. This non-contact approach eliminates tool wear, reduces maintenance requirements and minimizes contamination risks.

One of the key advantages of laser systems is their micrometric precision. Hole diameters typically range from 80 to 250 microns, with extremely tight tolerances that ensure consistent and repeatable results. In addition, perforation patterns are fully programmable, allowing hole density and distribution to be adjusted across different areas of the film. This enables tailored gas exchange for specific products and packaging requirements.

Advanced laser systems also feature real-time monitoring and control, automatically measuring and adjusting hole dimensions during production. This ensures process stability without the need for continuous operator intervention. Moreover, laser technology is particularly effective on thin and multilayer films, where traditional methods may struggle to deliver consistent results.

The impact on food packaging performance is significant. Precise control of gas permeability allows accurate EMA conditions, extending product shelf life and reducing waste. The perforations are uniform and nearly invisible, preserving the visual integrity of the packaging. At the same time, the absence of mechanical adjustments makes it possible to switch quickly between different products or formats, increasing production flexibility.

From an operational standpoint, the benefits include reduced material waste, fewer defects and higher overall efficiency. Automated control systems ensure consistent output even at high production speeds, reducing dependency on manual intervention.

Selecting the right micro-perforation technology ultimately depends on the material, the product requirements and the production volumes. Cold needles remain a valid choice for simple and cost-sensitive applications, while hot needles are well suited for oriented films. Laser systems, however, offer clear advantages in applications where precision, flexibility and process control are critical.

As the food packaging industry continues to evolve towards longer shelf life, reduced waste and higher quality standards, micro-perforation is becoming a strategic process rather than a simple mechanical step. In this context, laser micro-perforation stands out as the most advanced solution, enabling converters and packaging professionals to improve product preservation while enhancing efficiency and competitiveness.

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