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A Guide to Manufacturing Microfluidic Device Key Components

Medical Materials & Technologies

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Introduction

Microfluidic devices can signal the difference between health and illness. They monitor blood glucose, genetic biomarkers, screen for cancer, and more. They can detect pathogens and genetic biomarkers. Accuracy and the right materials are paramount as you design and manufacture these critical tools.

Manufacturing microfluidic devices requires sophisticated techniques. These sensitive strips or discs transport, protect and detect important samples of blood or other fluids that give patients and their caregivers the crucial information they need. Microfluidic devices are usually small and have intricate channels and circuits which require a lot of attention and care to assemble and manufacture.

This paper will cover processing considerations and material properties of common microfluidic device components. The intention is to provide microfluidic device manufacturers insight into successful fabrication strategies when developing state-of-the-art products.

Microfluidic device tape components: What are their functions and properties?

It's important to understand the function of each component used to create microfluidic devices before we classify them.

Substrates & Backings

Functions

A substrate or backing is like the spine of the tape. It is the component that dictates the tape's mechanical characteristics. The backing type should be chosen based upon the desired performance of the tape, whether it needs to be thick and rigid, conformable, reflective, or in some instances, stretchy.

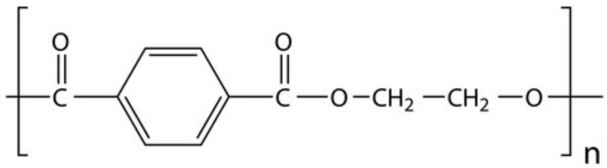
Surface modifications are sometimes added for microfluidic tapes to enable hydrophilic characteristics depending on its desired function. Additionally, surfaces can be treated to enhance adhesion or promote adhesive release.

Properties of different substrates

Included below is a short list of common substrates used in microfluidic devices:

- Biaxially oriented polypropylene (BOPP): offers good clarity, low autofluorescence with considerable strength and is easy to process in terms of coating, printing, and slitting. Special consideration should be given to avoid surface scratching during processing.
- Polyethylene terephthalate (PET): naturally clear with good strength. Low moisture transmission. Easy to add surface treatment.

Very easy to process, coat, slit etc. Good rigidity with lower susceptibility to plastic deformation compared to BOPP.



- Aluminum Foil: available in many forms of alloys and hardness tempers. Surface properties can be easily manipulated based off processing/milling conditions. Many aluminum configurations are malleable and can retain shape of the surface to which it is applied and offer enhanced thermal conductivity.

Adhesives

Functions

In the simplest of definitions, adhesives allow a tape to bond to a surface. In microfluidics, tapes are often bonded to plates for sealing sample-well boundaries. Tapes can also be bonded to other components to build a device (i.e. lab-on-a-chip, test strips). In these applications, adhesives are regularly in contact with samples and reagents, and as such must be chemically stable. Polymerase chain reaction (PCR) is used to sequence DNA. Devices may undergo temperature variation during storage and use ranging from below freezing to 98ºC. During processing, because of the significant repeated change in temperature, it is important that the adhesive not lose bond nor begin to break-down and potentially contaminate the reaction.

Properties of commonly used microfluidic adhesives

Silicone adhesives: offer very good adhesion to low surface energy (LSE) contact applications. Some variants have very low initial tack and increase bond when sufficient pressure is applied. This may be desirable when repositioning is needed (i.e. on a plate or well cover). Certain silicone-based formulations offer very good resistance to degradation during PCR processing. Silicones usually cost more than acrylate-based adhesive systems.

Acrylate adhesives: offer good bonding to a wide array of surfaces, with the ability to stay bonded for extended periods of time. They can be formulated to suit a range of adhesion and stiffness profiles needed to maintain critical channel structure and allow for good manufacturing processability. Acrylate adhesives may be lower cost than silicone adhesives.

Liners

Functions

Liners are the unsung heroes of a tape system. They often provide a clean, consistent surface on which to coat the adhesive (more on this in the lamination section below) and protect the adhesive surface from exposure and damage. Liners may be used as a processing aide (process liner) or may stay with the tape until its final usage at an end user (product liner). Due to the intricate and precise nature of coating and converting microfluidic devices, PET or BOPP (explained below) liners are often used to maintain tolerances and clean edge cuts.

Properties of different liner substrates

Just like a tape, liners come in numerous substrates based on the needs of the user.

- Paper is often used when a printed liner is needed or if the user needs a relatively inexpensive liner with substantial structure and protection. Paper liners used in the medical tape industry usually have at least one side coated with a poly-olefin layer to allow for a release coating to be applied without soaking into the paper. Surface modifications may include perforation for moisture management.

- BOPP is desirable for its consistency in thickness, strength, and optical qualities. It is generally more expensive than paper but less expensive than PET. Surface modification or priming are sometimes used with BOPP substrates to allow for anchoring of release chemistry (as described in the next section)

- PET is a commonly used polyester liner substrate in many industries. It offers very consistent, rigid properties with a high strength-to-thickness ratio. PET is desirable when coating thickness and precision die cutting are important to the processor or end user. PET is the most expensive option. Surface modification or priming may be employed with PET liners.

Liner release coatings

For a liner to work properly and release from the adhesive when peeled, it almost always has some type of coating applied to its surface. This coating is often called the release coating or chemistry, usually comprised of a cured silicone, fluorosilicone, or sometimes fluorocarbon variants. Acrylate adhesives are commonly paired with silicone release coatings. Fluorosilicone and fluorocarbon release coatings are used in conjunction with silicone adhesives, as any use of a pure silicone release chemistry would cause "block" or "lock up" with the adhesive and not perform correctly.

Single-coated liners

Sometimes called one-sided liners, this refers to the number of sides with release chemistry. Single-coated liners are primarily used for single-coated tapes, but sometimes can be used with another single-coated liner for double-coated tape and transfer tape constructions.

Double-coated liner

Sometimes called two-sided or tandem liners, this refers to a liner substrate with two sides of release coating. The release chemistry on either side of the liner is almost always different, to offer what's called a differential release gradient. This differential is extremely important for transfer adhesives as the discrepancy in bond allows for release from one side and anchoring to the other side during processing. More on that topic in the Transfer Adhesive section below. Double coated liners may

be also used with a single coated tape to protect a backside surface treatment of a substrate as well.

Tape types: Single coats, double coats, transfer tapes

Web processed films and laminates are often categorized by their function and appearance.

Single-coated Tapes

Single coated tapes offer an adhesive anchored to a substrate that provides strength, conformability, and in some cases a surface in which to adhere another component (tape stacking). In their finished construction single coated tapes can be found with or without a liner. If the construction does not include a liner, the backside of the substrate will have some type of surface treatment, coating or modification that will allow for release of the adhesive when unwinding. Single coated tapes cover a very large array of laminates in the market and are often further broken down into categories based off the specificity of the backing or adhesive (i.e. Non-woven tapes, silicone tapes, etc.)

Single-coated Tape

Double-coated tapes

A double-coated tape consists of a single substrate with adhesives coated on both sides. Depending on the intended use, the adhesives can be the same, can offer different-coating weights to achieve diverse levels of adhesion, or can be separate adhesive systems altogether. Double-coated tapes can be constructed with either two single-coated liners or with a one double-coated liner that provides release to both layers of adhesive.

Double-coated Tape

A spacer tape is a double-coated tape manufactured for microfluidic test strips. This tape has a precise overall thickness that provides gapping, channel height thickness, and structure to the test strip.

Transfer adhesives

Transfer adhesives are, in many ways, like double-coated tapes – the primary alteration being the absence of a substrate. The construction of a transfer adhesive must be either a two-side release coated liner or two single-sided liners. It is very important that the differential in release of the liners is sufficient. Generally, a release differential of 3x is considered ideal. A transfer adhesive with a differential of 2x may be enough but might require special care when unwinding the tape as to not cause "liner confusion". Liner confusion occurs when adhesive anchorage is similar between two release coatings – in this case the liner will begin to pick or split deeming it near impossible to use or process.

Manufacturing process overview

Now that the basic components of the device have been selected, it is time to manufacture. The manufacturing overview below follows the same seven primary, sequential, steps one would use to make a microfluidic device; starting with creating a substrate, modifying, coating, curing, inspecting, slitting, and, finally, assembling a finished medical device.

Polymer Extrusion of films

Polymer films are used regularly in microfluidic components as substrates and liners due to their high degree of dimensional controllability.

Process overview

Polymer extrusion is a complex science centered on the idea of heating input pellets or resin (feed) to a workable temperature, compressing a melt, and metering the melt at a desirable rate to a die to cast and cool a curtain at a consistent, desirable thickness.

Let's start with the extruder itself; at a high-level, it is a network of modular barrels encasing an extrusion screw, or two screws. Pellets are fed through a hopper into the extruder and heated to a nominal temperature, related to the melt temperature of the polymer. As the feed softens it is forced down the extruder barrel by the screw and begins to compress.[1] Pressure builds and what's called "the melt" begins to form.[1] The melt continues to move down the barrel to the final step of metering,[1] where temperature and flow are finely controlled to affect the flow rate of the melt from the extruder.

A note on single-screws and twin-screw designs: at a high-level, a twin-screw offers a more stable flow of material and ability to handle more moisture content in the melt, although having a higher overhead cost and more moving parts to service.

When the melt leaves the extruder, it travels via an insulated hose to a die, where the melt is channeled and metered further to spread into a curtain of desired width and thickness, usually through a drop die. The drop die should be set up over the casting surface or nip and use gravity in assisting the melt flow onto the casting surface. The curtain is cast either directly onto a cooled drum roller or onto a carrier (essentially acting as a release liner for extruded films), quenching the melt at a rate to match the chosen polymer(s) properties. Some techniques for ensuring the quenched melt stays on the cooling drum include nipping (using a release coated laminating nip), static pinning, and air pinning. Additionally, an air-knife (used for air-pinning) can aid in quenching a melt during the casting step. If using this cooling technique, the web should be closely monitored for air bubbles.

If the melt is cast at its desired end-product thickness, then it will pass through standard web handling and be wound as finished product. However, as biaxially oriented films are often used in microfluidic device constructions, the processing does not end here. Biaxial orientation implies the film is stretched in two ways, elongating the polymer chains and adding strength to a film. The film is stretched in both the machine direction (down-web) and cross direction (cross-web) via a length orienter and a tenter, respectively. The length orienter functions by heating the web quickly and immediately elongating via driven-roller speed differential. A tenter functions by grabbing the side of the web with clips on diverging tracks and passing through a series of heating oven zones.

After elongating and widening, the web will undergo an edge trim to remove the areas that were deformed by the clips in the tenter.

A note on fluorescence of plastic films

The florescence level of the extruded films often used in microfluidic devices and cover-tape applications can interfere with sample signal detection during testing. If the end-use product is sensitive to fluorescence interference it is recommended to evaluate the fluorescence of selected materials.

Aluminum foil rolling

Aluminum foil as a substrate routinely finds its way into microfluidic applications for its conformability, reflectivity, and ability to pierce, most predominately in cover-tapes and molecular diagnostic devices using PCR.

Process overview

Aluminum production is a vast industry and the scope of production from the mine to the mill includes many steps. The scope of this overview will focus solely on rolling aluminum coils at the mill. Coil stock input is generally received at a thicker gauge than can be used in microfluidic products and must be rolled to a thinner gauge. This rolling step also lets the processor fine-tune the desired surface finish of the output foil.

The coil stock input is fed into a work-roll nip that is usually supported with one or more backup rolls per work roll to exert the high forces necessary to deform the aluminum. There the coil may undergo several passes through work roll nips at incremental gapping to achieve a desired foil thickness. Different hot rolling or cold rolling methods can be employed to avoid or induce strain-hardening.[2] Many foils used in the microfluidic industry have some level of work hardening that gives the foil added rigidity, which is useful in some tape constructions.

In its final work-rolling step, the foil passes through a mill-roll nip that gives the foil a desired surface finish that is directly related to the finish of the mill roll. Industry standard defines the finish as "mill finish" – relatively rough, or "bright finish" – a mirror-like finish, with varying degrees in between. It is common for foils to be run through a mill roll nip as two webs back-to-back to increase throughput. This imparts one dull side to each of the foil webs where they are in contact though the nip. To achieve foil with consistent finish on both sides, it must be run through the mill nip as a single web.

Opposite strain-hardened foils are softened foils for cover tapes for microtiter plates. These often have a very ductile nature to allow for conformability and adhesion to sample well edges and allow needles to puncture the cover tape without tearing. Cover-tape foils are partially or fully annealed, a process that crystallizes the aluminum alloy's molecular structure.[3] The annealing process is completed either before or after rolling the aluminum and is done by heating the foil to an alloy-specific temperature for extended periods and cooling slowly.

A note on alloy

Special attention should be given to the alloys and compositions of the foil. A commonly found alloy is that of the 1XXX series. This series is a minimum of 99% aluminum. These alloys are resistant to corrosion and provide thermal and electric conductivity.[4] Other series of aluminum have other additives to impart specific properties and workability levels.

Hydrophilic surface modifications

There are various surface modification types and techniques used in microfluidics. The primary surface modification used for microfluidic device components is hydrophilic coatings.

Hydrophilic coatings

Hydrophilic films are found primarily in test strips and lab-on-a-chip products that require fluid transport on a very small level. A hydrophilic-coated film promotes fluid flow because of its modified surface energy.[5] For a substrate such as PET to increase hydrophilicity, it usually undergoes a specific treatment to increase the surface energy. Hydrophilic coating chemistries are often proprietary and can be surfactant-containing or surfactant-free.

Hydrophilic coatings are most often applied via the gravure method discussed in the coating section below. After coating, the web travels through an oven for drying and curing. The measure for hydrophilicity is called contact angle.

Adhesive coating/lamination

Precise and consistent adhesive coating is crucial to the function of microfluidic device components. Device end users rely on extremely controlled film and adhesive thicknesses to build sensitive products. Often this means regulating volumetric flow of fluids on a micro-liter level.

Solvent based

A solvent-based adhesive facilitates even application and simplicity in coating. The solvent portion of the solution is removed by drying the adhesive in large ovens. Solvent-based adhesives and coatings are widely used in the industry today, however, this technique may be disadvantaged in the future; primarily due to costly production lines (ovens, thermal oxidizers) and environmental regulations.

Solvent-based adhesives can be coated onto a moving web through many different die designs. The most common are slotted dies and rotogravure (gravure) cylinders. A slot die consists of a split manifold with specific geometries and adjustable zones that control internal die pressure and ultimately coating thickness. Die shims (implantable and removable gapping fixtures) used in slot dies facilitate specific coating widths and lanes explicit to each product made.

Another common coating method for solvent-based adhesives is roll-coating via gravure cylinder; most often employed for very thin and low viscosity coatings. This method consists of a cylinder with precisely machined cells that essentially pick up adhesive from an adhesive-solution bath in which the cylinder is partially submerged. As the cylinder rotates it passes under a doctor blade or other mechanism that skims off excess adhesive, thereby controlling coating thickness. As the cylinder continues its rotation the remaining adhesive in the cells gets applied to the moving web passing through a low-pressure nip.

Solvent-free adhesives

Solvent-free adhesives or hot melt adhesive inputs come in the form of pellets, resin, or blocks of different compounds. Rather than using a solution to achieve a working viscosity, as with the solvent-based method, the hot melt technique uses heat. The inputs are fed through an extruder where they are heated to specific working temperatures and then applied to the substrate or liner via a die. These adhesives require no drying and are often less expensive than solvent-based adhesives due to the lower amount of overhead required to process.

Hot melt adhesives are most commonly applied via drop die, like that used in extrusion, or a contact die. A contact die consists of a manifold with a gap that feeds adhesive to a segment of the die in physical contact with the web. This portion of the die imparts slight pressure to the web against a backup roll and leaves a thin, even coating. Some attributes of this coating technique are proprietary and manufacturer specific.

Direct adhesive coating

Direct coating is a method of applying an adhesive onto the tape component's substrate or backing. Because of the complex nature and sensitivity of many microfluidic substrate components this is not a very common practice. Direct coating implies that the backing would undergo the same, harsh environment necessary for adhesive drying/curing, as well as increasing chances of defect introduction into the backing. The primary benefit to applying a direct coat is improved adhesive anchoring to the component substrate.

Adhesive laminating

Adhesive is often applied to microfluidic device substrate by way of lamination instead of direct coating. In this method, adhesive is coated onto a release liner, goes through any necessary drying and/or curing, then laminated to the desired component substrate. This technique permits use of more complex component backings and significantly reduces risk of damage or contamination to the tape substrate. Another advantage is the ability to combine different transfer adhesive combinations with the component substrate. Common challenges of lamination include attaining sufficient bond to the tape backing and choosing a liner with proper release.

Lamination pressure: Lamination pressure is crucial when laminating two (or more) webs together. Pressure set-points depend mostly on the component backing and adhesive compositions. If the lamination pressure is too low, there will be insufficient anchorage of the adhesive to the backing. Too high of pressure could cause adhesive oozing or flow (especially with partially cured/ cross-linked adhesives) and can induce a cross-web curve. Additionally, excess pressure can cause a minor decrease in line speed on the leading edge of the laminator nip and impart scratches or stretch in the web.

Pressure uniformity: On top of choosing the correct setpoint for pressure, it is imperative that the pressure is applied uniformly in the cross-web direction. Inconsistent pressure can cause minute strain of the tape, inducing curl, or even cause slight adhesive ooze in one direction. Tramming the rollers usually remedies this issue, but in some cases it may be necessary to change out laminator rolls/drums or evaluate the drives for motor or bearing damage.

Roller release coatings and wraps: Release coating or wraps are used to reduce scratching or promote face side (adhesive side) release from rolls/idlers during web processing. These techniques are frequently used in web processing of microfluidic components as the substrate films and foils can be extremely prone to scratches or other induced blemishes. There are several options existing for this purpose, many commercially available, however some technology may be proprietary.

Roll formation: Once the tape construction has been laminated it reaches the winding step. Care should be taken to ensure the proper roll formation and wind orientation as to not scratch an unprotected sensitive surface. The benefit of liners in terms of protecting a surface, can often present a curse in terms of roll formation. For example, two sided liners are commonly used for purposes of protecting or releasing from the backside of a substrate. This, however, makes the roll prone to slippage and telescoping. Proper attention needs to be given to the roll when winding. If the roll begins to telescope, it is likely that the tension in the web is too high and should be lowered. Another technique to mitigate telescoping is enacting a tension taper, so as the roll winds and gets larger, the amount of tension decreases to counter the internally building pressure of the winding roll. Taper tension is referred to in units of %, as a proportion of the amount of tension decrease from its initial setpoint.

Curing

Curing controls: Dryness/extractables

The purpose of curing adhesives is to dry solvent and remove monomers in adhesives. The dryness of a solvent-based adhesive or coating is essential to its functionality. Dryness refers to the residual solvents that remain in a solvent-based adhesive after it has gone through a thermal oven. When set up properly, temperature and airflow-controlled zones in an oven allow for adequate drying of a coating at a given line speed. An extractables test can measure the quantity of solvents and other chemicals remaining in the coating after passing through a drying oven.

Curing methods

There are various ways to cure a coating or adhesive based on its chemical structure.

Thermal cure: Aside from using an oven to dry a solvent-based coating, ovens can also be used to cure an adhesive or coating. Increasing temperatures or dwell time in an oven can crosslink polymer chains in a coating, thus changing the tack or mechanical properties.

Ultraviolet (UV) cur: Ultraviolet lamps can be used to cure solvent-free adhesives or thin release coatings on liners. For curing release liners, passing through a UV lamp station decreases the amount of “free” chemistry (active release chemical or compound, i.e. Fluorosilicone) decreasing the amount of remaining extractables but increasing the release force of a liner.

Electron beam (E-beam): E-beam is used to cure or crosslink polymer chains, usually in adhesives, but sometimes for sterilization as well. Sometimes used with post-dried acrylate coatings, e-beam curing causes an adhesive to stiffen and increase in viscosity to meet desirable tack or mechanical properties.

Line speed/dwell time: Dwell time, in terms of curing an adhesive or coating, is essential to attaining desired residual solvents, tack and mechanical properties. During web processing, where a continuous line of material is moving, dwell time is inversely related to line speed. Dryness or cure level, however, is directly related to temperature or energy supplied to a web. As such, supplied energy and line speed then are the two primary control handles for drying and curing.

Steering, web handling, and vision systems

Tramming

Tramming, in terms of web processing, refers to the alignment of rollers and idlers in relation to each other. Another way to think of the tram of rollers is to imagine the three-dimensional parallelism between rollers in the x, y, and z directions. A small degree of misalignment can cause uneven tension in a web. When this occurs, different areas of the web see minute tension differences which can cause stretching, scratching, folds and wrinkles of the material passing over an untrammed roller. In microfluidic components, scratches and other defects can change light transmission or smoothness of a tape or film that can have profound effects in its finished device.

Bumpering

Bumpering is a technique applied in web processing to influence lateral (cross-web) tension on a moving web. Bumpering consists of wrapping a high friction tape around a roller at the edges of the web. Sometimes this is done in reaction to wrinkles observed in the machine direction, or it may be done strictly as a preventive measure. Bumpering is a relatively informal, yet effective, method for imparting lateral tension. Especially with the often highly sensitive backing used in microfluidic backing components, it is imperative to be mindful of the component substrate and consider if the bumper tape might cause unwanted scratches or induce excess static into the line.

Web guides/edge guides

Web guides, sometimes called line guides or edge guides, are commonly utilized steering systems for web processing and are valuable to precise coating and slitting of microfluidic device components. Web guides use light sensors to track either the edge of the moving web or a reference line that may be printed in the web (if there is a variable edge, sometimes when processing foams). These sensors are tied into the equipment logic controller and allow the machine to adjust in the cross direction to match any shift in the edge or reference line. Web guides are commonly used on both coating and slitting equipment as well as converting lines.

Vision systems

Vision systems enable defect detection and the possibility of roll mapping and/or defect marking. Vision system technologies are broad and have historically meant using a camera to detect defects (scratches, blemishes, contaminates) in a moving web based off a size or light contrast threshold. As technology advances, the use of infrared (IR) sensors has increased for less sensitive applications due to their lower cost. Many manufacturers want vision systems in production of microfluidic device components because it allows for 100% inspection of nonconforming early in the component creation. This decreases the number of defects and variability in the finished microfluidic device. Another benefit of a vision system is the ability to tie-in a roll map from, say, a coating process step into the ensuing slitting step. This can alert a “smart slitter” to mark the web next to a defect or alert operators to flag or altogether remove a defect, again limiting the chances of a defect reaching a final, highly sensitive microfluidic device.

Slitting

This section will focus on three primary methods of slitting for web processing of microfluidic components.

Burst slitting

In this method a stationary razor is setup at an angle to cut material. Good for thin films, this is a relatively inexpensive method that is easy to set up and adjust.[6]

Score slitting

Score slitting, sometimes called crush cutting, is a down-web cutting procedure in which a circular razor cuts through the tape construction up to a hardened backup roll.[6] In the simplest of terms, it employs the same cutting mechanics as a pizza cutter. This is the most common type of slitter and works for most microfluidic tapes.

Shear slitting

Shear slitting is utilized for sensitive materials that require fine edge finishes, or more often, for thicker materials, such as aluminum foils and thick polymer films. In these situations, a score slitter often does not impart a high enough pressure at the cutting location to separate the material, and rather will cause a deep indent in the product. In contrast, shear slitting makes use of two circular blades that work in tandem to cut the passing material.[6] The cutting mechanics force the material in different directions over a very small surface area, causing the material to separate, just like a pair of scissors. Shear slitting provides the finest edge quality of the three techniques but can be intricate to set up and costly as there are two cutting tools used for each cut, requiring more maintenance.[6]

Converting and Assembly

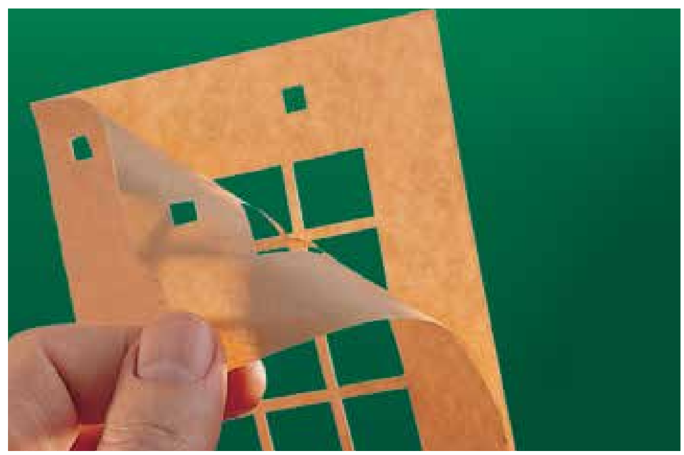
Converting and assembly of microfluidic components is, in a way a micro-summary of many elements discussed in this paper.

Lamination of other components

Microfluidic devices are often made by constructing or stacking layers of components, with different internal geometries and properties. For example, channels created by gapping between layers may allow for blood or fluid flow. In these applications registration between layers must be accurate and precise. Converting machines often have sensors that detect registration marks or "eye marks" that affirm laminates are aligned before laminating. Lamination of multiple components also requires edge guiding and proper laminator setup.

Cutting

Cutting microfluidic components is usually done via rotary dies or lasers.



Rotary die cutting: Rotary die cutting is a common method in microfluidic device converting. This technique consists of using a precision patterned hard-tool of the desired shape to cut a film or substrate. The patterned tool is cylindrical and rotates in index with the moving web to cut a flat design. The benefits of using a rotary die over laser cutting are its increased line speed potential, lower cost of entry, and high degree of durability. The drawbacks to hard-tooling are the cost of new dies, slower turnaround time for new tools and changes, and a

slightly lower cut accuracy than laser cutting, and cutting die maintenance requirements.[7]

Laser cutting and ablation: Laser cutting is also common in microfluidic device converting. This cutting method uses a focused laser to burn through a layer or layers of material following a computer or logic-controlled pattern. The timing and intensity of the laser is crucial to the efficacy of this cutting method. In microfluidic device converting, lasers facilitate very intricate cuts or can be used to "drill" holes in a component that would otherwise be difficult for a rotary die.

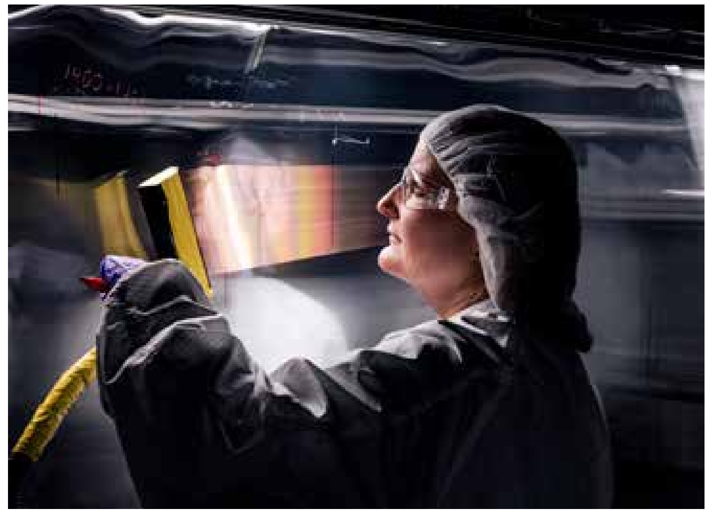
Lasers are often used in test strip converting to cut tiny conduits and vents that channel precise amounts of liquids or vapors. This example demonstrates a major benefit of laser cutting versus using a rotary die. Another benefit in terms of microfluidic device converting is a low cost to change geometries and iterate prototypes quickly, as it only requires a change in computer programming rather than hard tooling. The drawbacks of laser cutting are a higher cost barrier to entry for laser and computer equipment as well as a limit to line speed as lasers often require a degree of dwell time to cut material.[7]

**A note on laser cutting and ablation waste: Special precautions should be taken to manage and minimize char and ablated material during laser cutting as it is considered a contaminate.*

Through cuts and controlled depth cuts: Through cuts and controlled depth cuts are the two most common cuts used in microfluidic device converting. Through cuts separate material to match a specific design or pattern. As the name implies, this type of cut completely penetrates a component or stack of components to match an outline, usually the overall perimeter of the device component.

Controlled depth or "kiss" cuts separate a layer or layers of material to achieve a specific z-dimensional geometry in a component or stack. In laser cutting methodology, the depth of the cut is controlled by the laser intensity and exposure time, whereas in a rotary die method, this is controlled by precisely machined cutting surfaces at indexed depths on the tool.

Weed and slug handling: Rotary dies and lasers both require special handling of the trim or weed of a cut web. This needs to be either wound or pulled via vacuum away from the die-cut web. Slugs for round or encapsulated cuts need to be removed as well. These are often blown out with air-hoses/ air-knives. If using a physical means, such as rotating brushes or foam plugs, to remove slugs it's important to ensure the surface of the component is not scratched or otherwise damaged.



Conclusion

Microfluidic devices are extremely important to the medical industry for research and patient sample testing. The foundation for many microfluidic devices starts with tape constructions purposed to protect samples, transport fluids, and aid in sample detection. Understanding and choosing the right component materials and accompanying manufacturing methods is key when designing a microfluidic device.

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