Converting considerations for flexible materials

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The thin-film photovoltaic (TFPV) industry is beginning to scale up. Hundreds of millions of dollars are being invested in production facilities. Much attention is going to the front-end (the chemistry, physics and efficiencies of the films and the production of the films themselves) and to the back-end (integration into finished products and utility-scale installations, and retail economics), but sometimes less attention is paid to the steps in between, including the converting of the flexible materials.

This article will examine some of the more important considerations that go into these intermediate process steps, including technical and economic aspects, some of the hidden costs, and the pros and cons of outsourcing this important suite of manufacturing capabilities.

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'Converting' refers to the manipulation and finishing of flexible materials. It encompasses processes such as slitting, sheeting and traverse winding; coating, printing (including conductive printing), laminating, and assembly of multi-layer substrates; die-cutting, encapsulation, and similar processes. Other industries have failed to consider these aspects of the process until it was too late to design for optimal manufacturability and lowest cost. Avoiding this error will be especially important in industries such as TFPV, where the substrates are generally produced at fixed widths and require conversion before integration into final production.

The best place to start is 'with the end in mind.' TFPV companies should consider the entire range of end-products they plan to bring to market before designing their converting capabilities. They should build as much flexibility into converting capabilities as possible in order for this function not to be a bottleneck in either production efficiencies or in the ability to bring products with new configurations into the market.

So, for example, in choosing a method of sheeting, they may want to consider having both programmable blades in the machine direction and a programmable guillotine in the cross-machine direction. This combination will provide almost any size sheet. Similarly, those TFPV companies that are using glass as a carrier may find that this limits flexibility downstream and may want to consider a true roll-to-roll process.

In general, the thin-film products need to be kept clean and should be run in a cleanroom. Static needs to be minimized, because it will attract dust. Plastic cores should be made of materials that don't cause static, or coated with anti-stat coatings; rewinds with various cores 'clutching' at different rates are notorious sources of static.

Some films are sensitive to arcing caused by static electricity, and there are a number of methods to deal with that. Some are sensitive to humidity; they can literally grow in a humid environment.

Other considerations include the quality of slitting, especially the quality of slit edges. Slitter dust needs to be minimized by careful selection of blade geometries and depths, and sometimes by either contact- or non-contact web cleaning systems. Thin films are susceptible to dusting, especially hard-coated films, and they are also subject to some edge fracture. Dusting causes subsequent problems in downstream operations such as printing, coating and laminating, and fracture can sometimes be fatal to the performance of the films. In addition, belling (lipping at the edges of a slit roll, indicating uneven rewind tension, unsupported edges in the slitting process or uneven blade depth) can put a permanent 'set' into rolls that cannot be erased or easily dealt with. Rewind tensions need to be high enough to insure the integrity of the package, while low enough to not deform the materials. Metals can generally be rewound at higher tensions than films.

When the converting of TFPV requires coating, printing or laminating, it is important to recognize the differences in the requirements of these materials versus what might be expected from more common flexible substrates. The printing and coating that people are more familiar with are often trying to achieve an aesthetic objective that can be subjective. This is not the case when you are trying to accomplish functional electrical properties. The materials being printed or coated and the coatings being applied are often novel and unique and have been developed to produce specific effects.

Whenever possible, the chemistry being applied should be modified to promote its uniform metering and transfer throughout the metering and application process. Many coatings are developmental and have been formulated for electrical properties without regard to the rheology and surface energy needed for optimum transfer and leveling needed for printing or coating. Firms should select methods that don't compromise the sometimes delicate properties of the base substrate or the functional characteristics of the ink or coating. Printing and coating methods that achieve a degree of shear during the metering process will achieve a smoother and more uniform result, but one must be careful that this does not negatively

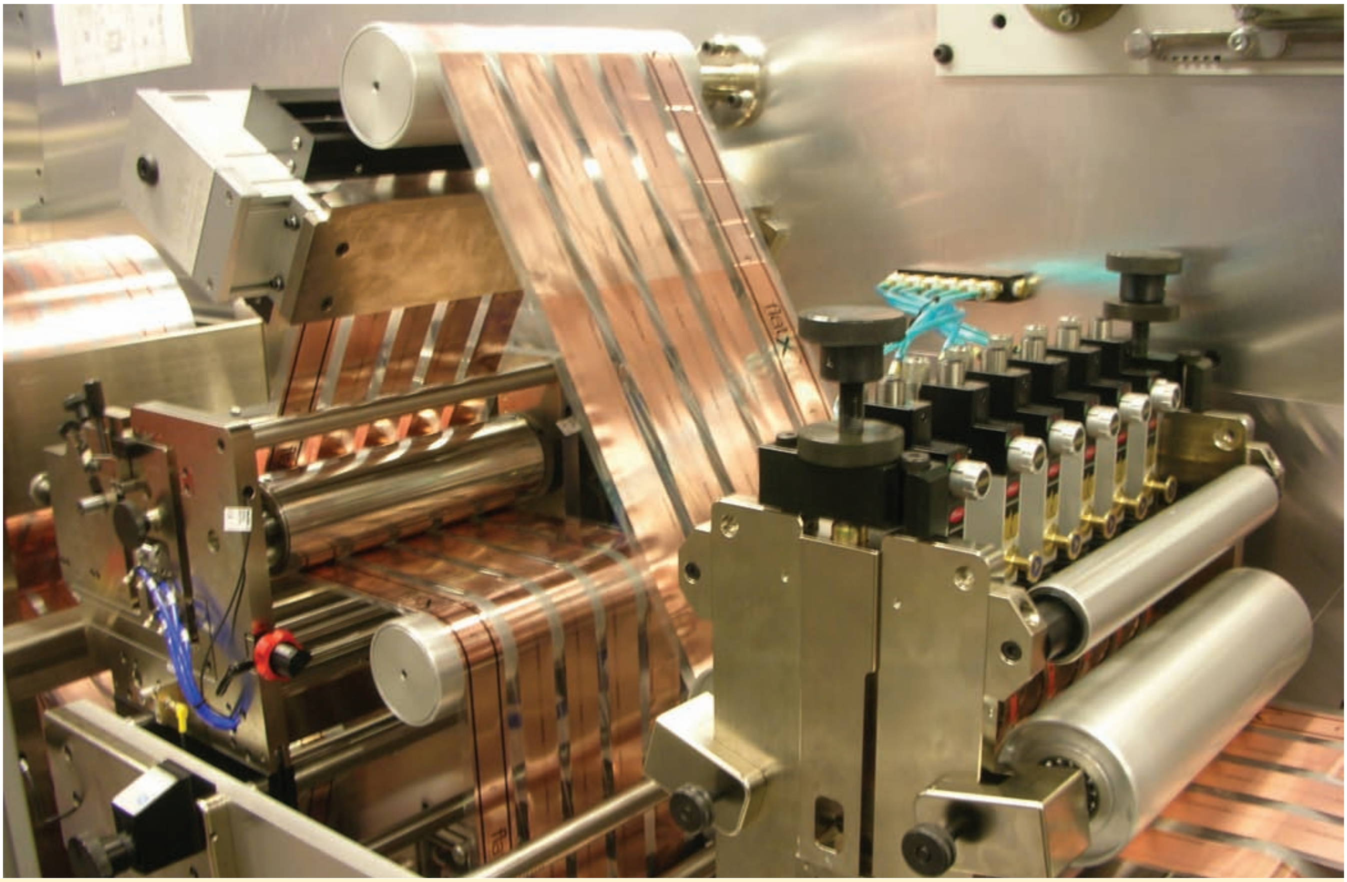

Figure 1. Laminating, zone-coating and slitting of multiple materials.

impact the performance of the coating or ink.

Surface preparation is equally important. Thorough web cleaning may be necessary, as well as surface energy modification by the use of corona- or plasma-treating to promote adhesion. It should be confirmed that any method chosen for improving the surface does not damage the functionality of the surface. This is also true for the method selected for drying or curing the coating or ink. Many coatings used to produce TFPV products are thermally sensitive, and care must be taken to not generate too much heat during this step. If contact pressure is a sensitivity for the materials being processed, a non-contact method should be considered, such as curtain coating or the use of application by ink jet. When laminating, avoid any excess pressure that might produce mechanical work to the coatings as they go through the laminating nip. If air entrainment is a concern, consider the use of smaller diameter nip rollers.

Materials slit to narrow widths can be 'spooled,' or wound transversely on a core many times wider than the slit width of the materials. This provides a more stable package and enables much longer lengths of material to be slit onto each package—sometimes 20-50 times longer than can be achieved with traditional pancake rolls. This in turn benefits the economics of downstream operations, since each roll changeover represents downtime and waste. One aspect to monitor in spooling is not introducing camber (curl) into the material. The spiral-winding methods can introduce camber, especially with metals and at the edges of the spools, but this can be controlled through careful design of the spool configurations, tensioning systems and winding patterns.

The spooling example above is a nice segue into discussing the economics of converting operations for two reasons.

First, it shows how both the incoming and finished configurations can affect converting costs. In general, converting is a service operation. Although a few converters will offer supply-chain management (purchasing of materials and vendor management) and a few will offer ancillary manufacturing services such as assembly, the economics of the manufacturing services, including converting, are generally driven by time rather than materials. Thus, longer incoming and outgoing lengths drive costs down, as does volume. Width doesn't matter as much, since width affects time only in a small way—but this can work to the advantage of a customer too, since adding width doesn't add much to costs. Spooling's major converting cost advantage over traditional 'pancake' winding is the much longer rewind lengths, which greatly reduce changeover time for the converter. There are many ways in all converting operations to design configurations to best advantage.

The second lesson spooling shows about the economics of converting is that the entire chain of events must be considered. Narrowly viewed, the economics can be deceiving; the direct converting costs often hide the value. For example, the direct costs of spooling can often be more than totally compensated for by the lowered downtime and waste associated with fewer changeovers in the next manufacturing steps.

Another very important economic aspect is waste. Materials are often so valuable that even a small percentage of waste can outstrip the entire converting cost. A great deal of attention needs to be paid to minimizing waste. Methods include proper configuration, converting techniques and machine design, and the use of low cost

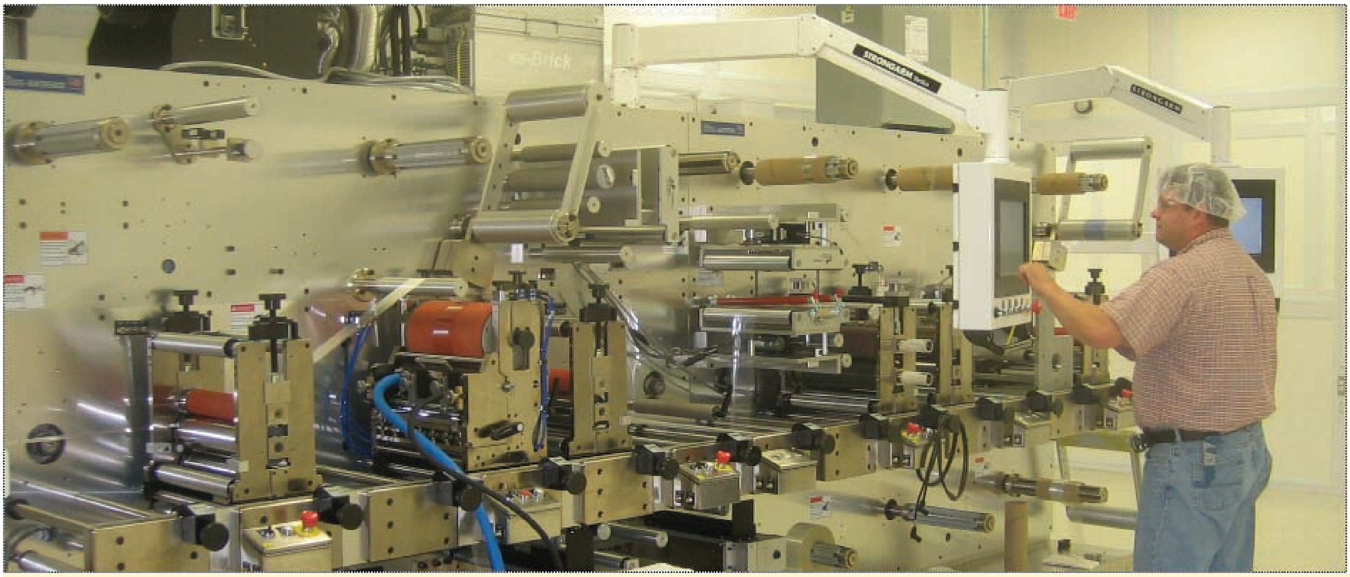

Figure 2. A configurable machine capable of performing multiple processes is any order.

leader and trailer materials for startup and shutdown.

Typically, in an outsource converting program, there will be five to ten opportunities through the whole chain of events to affect the cost, with the end result being that your outsource partner delivers demonstrable value over and above the simple cost.

TFPV companies in this market will need to decide how much, if any converting to perform themselves and how much to outsource. This is a question with strategic as well as tactical implications. A few of the more important factors are:

- Does the company have real expertise in thin-film converting?
- Does the company want to invest in the assets and devote the space?
- How does the company want to devote its time and talents?
- Can the assets be fully utilized at the volumes projected?
- Can the outsource partner really be considered a 'partner'? Will they protect important intellectual property? Will they be responsive to needs, and have they proven that they can and will make continuous improvements?

Each manufacturer of solar thin films may choose to answer the question of whether to outsource in a different way. Some companies will adopt a hybrid model; for example, keeping in-line converting processes in-house while outsourcing some of the more difficult processes, perhaps trials, and those where asset investments cannot be justified.

There are also a large number of considerations to review in choosing an outsource manufacturing partner. Perhaps the most important, as mentioned above, is whether they would really be a 'partner.' Good outsource manufacturing firms will assist TFPV firms in designing a product for manufacturability, which means they should be involved as early as possible. They will bring together available technologies with their own expertise and design a program that makes sense. They will procure materials and manage the vendors. They will demonstrate good listening skills. And they will have the people, technology, capital and MIS resources to pull it off, and to continuously improve the performance.

Of course, cost is a major consideration. However, TFPV companies are well advised to think in terms of 'value' rather than 'cost.' Narrowly viewed, internal direct costs almost always beat outsourced costs. But viewed on an end-to-end basis, a good outsource vendor will deliver more value than cost. For example, their direct cost of slitting may be higher, but if their waste factor is lower, the cost may well pay for itself. Playing 'bank' for their customer (by fronting the cash needed to pay for subtier vendors' materials) can free up needed cash. Simply eliminating various hassles such as managing vendors and expediting materials has value as well.

Other considerations in selecting an outsource converting vendor are:

- geographic reach, number of facilities
- ability to line up information systems with the customers'
- traceability of material
- registration to international quality standards (ISO 9001 being the minimum standard)
- ability to purchase materials to spec and to manage the subvendors
- ability to purchase outside services and to manage those sub-vendors

Finally, a most important consideration in choosing an outside converting partner is the extent in which the customer trusts that the converter will protect intellectual property. IP is often the most valuable asset that a TFPV owns. The converter should be able to demonstrate that they employ legal, physical and MIS protections that will safeguard this knowledge. It is not enough to simply sign a CDA.

Josh Chernin is the general manager of Web Industries' Boston facility. Web Industries is a leading provider of outsourced flexible material manufacturing services, with six plants in the United States. Services include slitting, sheeting, spooling, printing, coating, laminating and die cutting, as well as supply chain management and assembly. Josh can be reached at jchernin@webindustries.com.