Thin-Film and Printed Batteries: On-Board Solutions for Low-Power Electronics

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NanoMarkets, LC | PO Box 3840 | Glen Allen, VA 23058 | TEL: 804-270-7010 | FAX: 804-270-7017

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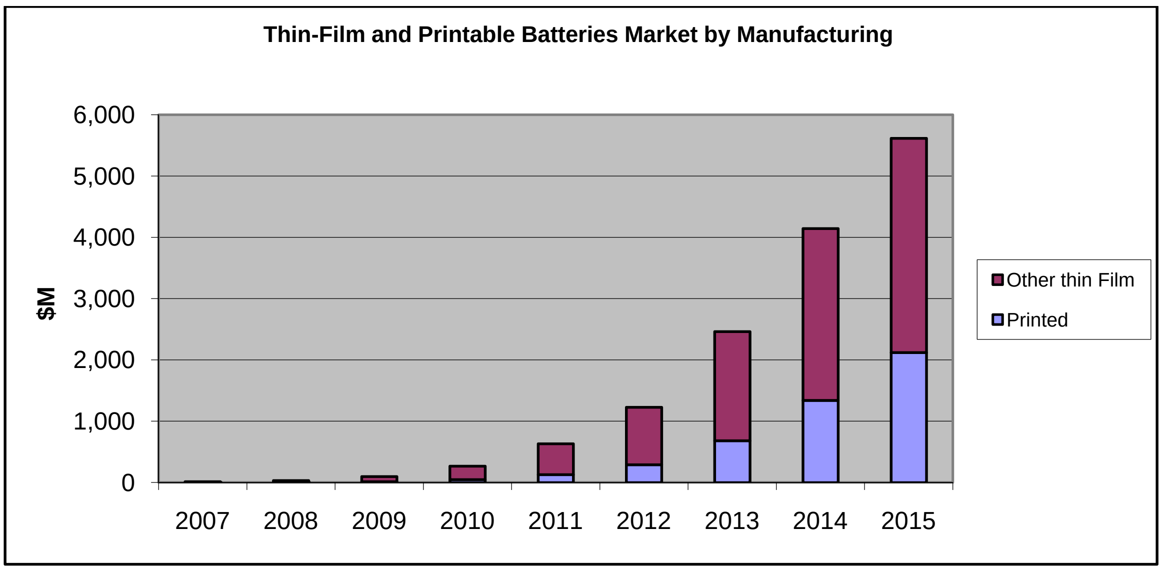
Thin-film and printed batteries are two related solid-state battery types that have smaller form factors than existing liquid-electrolyte based button batteries, are potentially low-cost, and can fit within existing manufacturing processes. While power densities are not as high as traditional battery types, which is why cell phones are not listed among target applications, NanoMarkets' analysts believe that the unique benefits of thin-film and printed batteries position them as energy sources for a variety of next-generation, low-power, ultra-small electronics in applications ranging from mundane, high-volume RFID product tracking, to mission-critical sensors that detect and protect soldiers from hazardous environmental agents.

Driven by these high-volume applications, NanoMarkets analysts predict that the thin-film and printable batteries market will climb from $13.9 million in 2007 to more than $5.6 billion by 2015. The NanoMarkets report, *Thin-Film and Printed Batteries Markets,* also analyzes the various technical and manufacturing approaches and remaining challenges, estimates the sizes and growth of major applications for these batteries, and outlines the major corporations developing thin-film and printed batteries.



Thin-film vs. Printed Batteries

Thin-film batteries are solid-state batteries, whose characteristic feature is, not surprisingly, that they are very thin. Printed batteries are at the moment characterized by printed electrodes. Most printed batteries use a liquid electrolyte applied after the electrodes are "printed" on the substrate. However, should the industry develop one of several solid-state electrolyte inks under development, these batteries could become entirely printed.

While most thin-film batteries are manufactured today using standard (and often expensive) semiconductor deposition and lithographic techniques, printed batteries could eventually be manufactured using far less expensive printing methods.

In other words the “thin-film” and “printed” battery categories seem destined to merge. For now, however, despite being similar in “thinness,” printed batteries are not normally thought of as thin-film batteries. In addition – and again for now – the value propositions of “thin film” and “printed” are a little different. Printing batteries is specifically aimed at reducing cost, because of the economies implicit in printing.

Printed batteries at least in theory can also be printed onto a flexible substrate making them easy to integrate into emerging flexible electronics products; notably flexible displays. Manufacturers of these batteries are therefore targeting their products specifically towards lower-power, disposable applications, while thin-film’s form factor—specifically its thinness—is usually the main selling point.

But these new kinds of batteries have plenty of challenges to overcome. For starters they face considerable price challenges; conventional button/coin batteries with which they compete are very low priced, because they are produced in volume. There are also several other new technologies that may be able to serve the same role as printed and thin-film batteries, but are not closely related to thin-film or printed batteries from a technological standpoint. These include, for example, energy harvesting and biobatteries.

Why Thin Is “In”

Despite their different manufacturing approaches, thin-film and printed batteries share several common benefits that are driving their development.

- The batteries are very thin with average thicknesses of less than 1 mm compared to several millimeters or more for button batteries, photovoltaics, and other energy harvesting techniques. The thickness of the active area for a thin-film battery is measured in microns.
- Thin-film and printed batteries have long shelf lives and can be reportedly recharged up to 45,000 times. This is partially offset by lower power densities and generation capabilities compared to traditional “thick” batteries.
- Long lives and robust rechargeabilty mean these batteries could work with competing energy sources rather than against them, such as storing electricity from energy harvesting devices (e.g., photovoltaics).
- Thin-film batteries using solid-state electrolytes have less potential to hurt the environment (think Sony’s Li-ion laptop battery troubles of 2006); while non-metal based liquid electrolytes used in today’s printed batteries are far less toxic than lithium, cadmium and similar wet electrolytes.
- These batteries can be fabricated in virtually any size or shape on a variety of substrates, including ceramics, semiconductors, and plastics.

Materials and Innovation

In terms of materials, a lot of the firms in this emerging battery business are sticking with the tried and true. Many of them are using thin-film versions of batteries with conventional Lithium Ion (Li-ion) chemistries; the same chemistries that can be found in batteries for cell phones and laptops. Among the thin-film battery makers adopting Li-ion include Cymbet, Excellatron, Front Edge Technology, Infinite Power Solutions (IPS), Oak Ridge Micro Energy (ORME) and Ultralife, each of which his profiled in the new NanoMarkets report. For printable batteries, Zinc chemistries are ubiquitous; Zinc Carbon, the newer Zinc Chloride and Zinc Manganese Dioxide all represent environmentally-friendly alternative electrolytes for printed thin-film batteries. However, these active materials are typically targeted towards primary, non-rechargeable thin-film batteries.

Conservatism is also noticeable in electrolytes. Thin-film batteries typically use a lithium phosphorous oxynitride polymer (LiPON) for the electrolyte. This was originally developed by Oak Ridge National Laboratory and was a breakthrough at the time, because it was the first electrolyte to bring the advantages of solid state chemistry at decent performance levels and with adequate electrochemical stability.

A few firms in the thin-film and printed battery space are seeking to distinguish themselves in the market, by innovating at the materials level. For example, in 2005, Solicore patented a solid-state electrolyte for its lithium polymer battery. Called the polymer matrix electrolyte (PME), the company claims that it gives its batteries unique abilities with regard to performance, form factor, safety and applications. Researchers at MIT have developed methacrylate-based solid polymer electrolytes that they say have liquid-like electrical conductivity with solid-like mechanical properties. The electrolyte is also mechanically flexible.

Also in the works, but certainly not in the market, are a range of revolutionary technologies that have the potential to revolutionize battery chemistries and (hopefully) their performance too. These include battery chemistries based on biomaterials (which use everything from carbohydrates to amino acids and fat,) carbon nanotubes, other nanomaterials, and radioisotopes. The report includes a summary of battery performance characteristics, battery size, and operating characteristics for each battery material based on prototype and commercial offerings from major suppliers in the thin-film and printed battery markets.

Applications and Markets

No one expects to see a “killer app” for printed and thin-film batteries discussed in this report. Instead, producers of such batteries note that there is a broad range of applications in which these batteries may play a role. If just one or two of these applications take off, then potential volume sales for thin-film/printable batteries could become very large.

While they are waiting, makers of these kind of batteries are seeking out niche applications—such as cosmetic patches—where there appears to be a unique need for the special features offered by this kind of battery. The advantage of this strategy is not only that it produces early revenues, but it enables the battery maker to take a hand in applications development, thereby promoting its batteries and squeezing some more value added out along the way.

The one factor that NanoMarkets expects to drive this market is form factor; thinness especially. In so many applications for printed and organic electronics, there appears to be the need for batteries that have sufficient power density, yet are packaged in a small format, with long periods between charges. With the emergence of different alternative chemistries for thin-film batteries, such requirements seem likely to be met soon. The safety and ease-of-disposal associated with solid-state batteries may also impress the market in certain circumstances.

About the Report

Thin-Film and Printed Battery Markets explores five general types of applications for these batteries that represent the highest potential market demand. These are: RFID and smart packaging, sensors, medical and cosmetic devices, smartcards and access cards and point-of-purchase displays. The report details the performance needs for each application, likely technical solutions for each application, market size and growth, as well as identifying thin-film battery suppliers that are positioning themselves for each market:

NanoMarkets' analysts predict that RFID will represent the largest potential market for thin-film batteries thanks to the need for low-cost active, or hybrid (semi-passive) RFID tags with longer ranges compared to non-powered passive RFID tags. Although their cost prohibits them from being used with low-cost commodity goods, such as food and other staples, the retail sector is expected to use powered RFID for higher-margin goods where security and loss is a greater issue.

Powered or semi-powered RFID is also a useful tracking method for goods that benefit from embedded sensors with the RFID tags to track equipment usage, for instance; and in asset management applications where longer ranges, RF interference and water absorption is likely, such as inside industrial settings or to monitor animals, which are mainly composed of water that absorbs the RF signal. With these drivers in mind, NanoMarkets analysts project that thin-film batteries for RFID and smart packaging applications will grow from 3% of the RFID market in 2007 to almost 18% by 2015 – the equivalent of $4.6 billion in battery sales.

In 2005 alone, the International Card Manufactures Association estimated that 2.6 billion smart cards were in use around the world, with an annual growth rate of 13.5%. While most smart cards are of the passive, contact variety, there is a growing need for 'smarter' cards that have the ability to generate one-time authentication for digital transactions and security through the use of a stored mathematic algorithm. There are several challenges for batteries in this application, however, the one that gets mentioned most frequently is the need to create battery technology that is capable of being laminated between plastic sheets without being destroyed. Conventional batteries, such as coin or button cells—even assuming that they were thin enough to be used—contain organic liquid electrolytes that would not survive such high-temperature lamination, thin-film batteries are robust against to high-temperature manufacturing processes.

Embedded sensors is the third largest market identified by NanoMarkets, although analysts believe it will eclipse the smartcard market in sales revenue by the end of the study's timeframe in 2015. This highly fragmented market includes sensors for remotely monitoring an aging population as well as a soldier's physical health, environmental dangers, and security, the form of bomb or hazardous substance detection. The ability to directly print or manufacture the battery along with the sensor electronics would allow manufacturers to share the cost of the manufacturing equipment among both the device and power supply, making thin-film batteries particularly attractive for sensor applications compared to traditional battery solutions. The longer lifetimes of thin-film batteries is also useful for sensor networks that may be sparsely serviced and hard to reach.

There are plenty of other potential applications for thin-film and printed batteries; even in some mainstream electronics. Embedded chips, such as battery back up power for computer memory chips, would also benefit from the ability to surface mount batteries right along with the PCB prior to high-temperature solder reflow.

Nonetheless, thin-film and printed batteries are not going to power your next PDA. However, they do have advantages in manufacturing, robustness, environmental issues, and form factor that could make them uniquely suited for several large-volume existing and emerging applications. What inroads these new battery designs will be able to make against tradition wet-electrolyte batteries is heavily dependent on cost, which is heavily dependent on manufacturing volume. NanoMarkets analysts expect that thin-film batteries will develop slowly over the next few years as design and manufacturing challenges related to electrolytes, manufacturing, and printing are overcome and refined, leading to significant growth as unit prices drop, volume rises, and momentum gains. But the long-term potential is quite impressive.

To obtain a copy of the NanoMarkets report, *Thin-Film and Printed Batteries Markets*, visit our website at www.nanomarkets.net or contact us at sales@nanomarkets.net or by calling our offices at (804) 270-7010.