NanoMarkets Report

Thin-Film and Printed Batteries Markets 2014-2021

Nano-667

Published December 2013

www.nanomarkets.net

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SUMMARY

NanoMarkets has provided coverage on the thin-film and printed batteries market for six years and has a deep understanding of what makes this market tick. During the period we have covered these power sources, some of the firms in this space have made slow but steady progress both technically and in terms of business development; a few of them are generating significant revenue. Other thin-film and printed battery firms have quit the market.

What have changed are the markets that are being addressed by these batteries. When the thin-film and printed battery business first appeared, the thought was that the main opportunity for them was RFID. But RFIDs have not taken off in the way that many people hoped. By contrast, these "thin" batteries have proved highly suited for powered smart cards, but for now this just a niche.

Now it seems that a new opportunity might be appearing in the form of the so-called "Internet-of-things," which promises ubiquitous sensors and other low-cost electronics. Such devices need to be powered and "thin" batteries may be just the power source that the Internet-of-Things needs. Has the thin-film and printed battery business suddenly found itself in the right place at the right time?

In this year's report, NanoMarkets analyzes these emerging opportunities. We also discuss the latest materials and design strategies being pursued by the thin-film and printed battery makers and assess how successful they are likely to be in the marketplace. As with all NanoMarkets reports, this report includes an eight-year forecast in volumes and value terms. We also discuss the funding of firms in this space and how that will shape the thin-film battery market.

This report will be important reading not just for firms in the battery industry, but for all firms interested in the new opportunities appearing in the Internet-of-Things, smart packaging and other related markets.

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Chapter One: Introduction

1.1 Background to this Report

To date, the history of thin-film and printed batteries has not been an entirely happy one. Both RFIDs and medical/cosmetic patches have failed to live up to the "killer app" expectations of the thin battery sector. And there are now perhaps 40 percent fewer firms making thin batteries than there was when NanoMarkets started covering this sector.

In this environment, one might be forgiven for condemning thin batteries as a technology in search of an application. And even if one considers smart cards, the one area where thin batteries have achieved some traction, it is hard to think of the battery firms creating large amounts of value. A CEO of a thin battery firm seeking that IPO down the road doesn't have much to hang his or her hat on.

But although still in the making, NanoMarkets points to wearable and flexible products as well as devices connected to the "Internet-of-Things" that potentially offer a large market for thin batteries going forward; big enough to make the whole thin battery opportunity much more worth pursuing than ever before.

If this proves to be the case, the disappointments around RFID, patches and the like can be forgotten. These new wearable and flexible and "IoT"-oriented products could well give the market for printed and thin-film batteries a new lease on life.

1.1.1 The Thin-Film/Printed Battery Sector is in a Validation Phase

The thin-film/printed battery industry has realized for quite some time that these batteries can never compete with conventional batteries in applications that do not have the constraints of size and shape or accessibility (where frequent replacing or recharging of batteries is not possible). Thin battery technology is meant to fill the gap created by conventional energy storage devices that are unable to keep pace with the demanding size and high density power requirements of some of today's highly advanced electronic devices.

With this situation in mind, thin-film/printed battery firms have spent the last few years pursuing various types of applications with the hope that something would stick. In some cases—and not always successfully—the battery firms have tried to develop their own applications. But much of the time, they have realized that partnering with OEMs to build an ecosystem of complementary vendors is essential to accelerate delivery of end products and create a steady market for thin batteries.

In addition, effort needs to be put into the simplification of the manufacturing process, reduction of costs, and thus the creation of the scale and quality that is required to drive this market. If the printed/thin-film battery sector is finally to succeed, we will have to see some significant financing in 2014, and perhaps some announcements of new manufacturing approaches.

An example here is Solicore's 2103 announcement that it has developed the world's first digitally printed thin-film lithium battery. This development aims to establish the necessary capacity to support the important markets, such as powered cards, medical patches, and powered RFIDs/sensors. It is also expected to cater to a variety of custom designs to meet the varying

needs of the marketplace.

Therefore, the current flavor in the thin-film and printed battery industry is a combination of application and business development through an ecosystem of vendors and investment in manufacturing facilities and technology to create the necessary framework to meet the demands of the market in the near future. (See Exhibit 1-1).

Exhibit 1-1: Focus Areas in the Thin-Film and Printed Battery Industry— Next Five Years

Focus Area	The Road Ahead	Target
Application development	More partnerships with application developers and device manufacturers	Well-established business ecosystems
Manufacturing infrastructure	Ramping up of manufacturing facilities	Moving past pilot facilities to meet market demands.
Marketing and sales	More battery firms are partnering with OEMs for the manufacturing, marketing, and sales distribution of batteries.	A well-established network for sales and distribution.

Source: NanoMarkets, LC

1.1.2 Smart Cards and Sensors: Where the Thin Battery Business is Now

RFIDs have been replaced in the affections of "thin" battery makers by powered smart cards, sensors, and portable electronics that will be part of the Internet-of-Things. All of these application areas will take a few years to grow to a level where they will be able to provide profitability for thin-film/printed electronics firms. However, the two application areas that seem to offer the best immediate-to-medium term opportunities for thin batteries are powered smart cards and sensors.

Powered smart cards: One-time password (OTP) generating powered smart cards may lose out to the OTP generation of mobile phones, which is a big risk for thin-film/printed battery makers. Everyone has a smart phone these days—or it seems that way—and OTP could be provided with an app at what is effectively zero cost.

If the thin-film battery firms that have focused on OTP cards ultimately lose this business, they will start scrambling for new card-related applications. One opportunity may be found in the biometric card. Thus for example in September 2013, two French companies—UINT, a French start-up firm and Mereal Biometrics—launched the first multi-application, powered smart card with an embedded fingerprint sensor. It has an internal contactless rechargeable source of power and uses components from Fingerprint Cards (Sweden).

Because they require the use of additional components, biometric cards are less vulnerable to replacement by smartphone apps than are OTP cards.

Sensors: Sensors could be powered by traditional means, but when sensors are distributed over a wide area, thin-film/printed batteries with long lifetimes/times between charges could become indispensable, and again, these capabilities are best provided by the batteries considered in this report.

In geographically remote locations, energy harvesting provides a solution to the problem of continuously powering the sensor nodes, including the replacement of the power source. While such energy harvesting could be considered a threat to thin batteries, complete reliance on this type of energy technology may not occur, because a sensor completely dependent on energy harvesting might give out at times when energy sources are not available.

However, if energy harvesting and thin battery technology was used in combination, such sensors would never need to be recharged. Moreover, such a combination would reduce the needed capacity of the battery, and thus reduce the overall cost.

On the other hand, energy harvesting devices add cost to the system. And in general, the thin-film/printed battery market should be wary, because the sensor industry is not very flexible in terms of adapting to new technologies. The industry must be convinced of the long-term cost benefit compared to the initial investment.

1.1.3 A New Generations of Applications and New Generations of Batteries

NanoMarkets believes that we are on the verge of important new developments that will take thin batteries in a new direction and expand their potential for revenue generation. The market that we are talking about here consists of the new generation of wearable and flexible gadgets, which we believe is the next big trend in electronics; and a trend that could give a huge boost to the prospects for thin batteries.

What we do know is that some of the emerging devices in this class will need batteries that are especially thin, flexible, lightweight, or created in non-standard shapes and sizes, which is where the batteries considered in this report come into the mix. The other factor that impresses us about this emerging sector is that the R&D that has been reported here so far includes some very big names, including Apple, LG, and Nokia.

Apple (U.S.): Apple's patent application published in July 2013 details the creation of a flexible battery shape, suggesting that the company is exploring solutions for future products that may take on a unique shape. The patent, which was filed in December of 2011, covers a flexible battery pack that consists of several different cells connected through a laminate layer designed to "allow the battery to be shaped to fit a form factor of the electronic device."

LG: In another interesting development, LG Chem (South Korea) announced in October 2013 that it has succeeded in producing batteries with different shapes. LG Chem's future batteries are categorized as stepped, curved, and cable batteries.

The company has already started mass-producing stepped and curved batteries, and has plans to produce cable batteries in upcoming years. Cable batteries will be applied to IT devices that are bendable, wearable, and even can be tied into a knot. In addition to flexibility, these batteries will be waterproof to enable use in wearable gadgets.

Nokia: Nokia (Finland) has also filed a patent in 2013 for a foldable battery that could enable the production of a new generation of paper-thin collapsible phones. It describes a battery pack made up of "foldable cells" that can curve and bend with the shape of a phone, as well as being capable of folding in on itself.

1.2 Objective and Scope of this Report

The main objective of this report is to elaborate on the trends outlined above and show how manufacturers of thin-film and printed batteries will make money over the next eight years. In addition to identifying the opportunities in this space, we quantify future revenues and assess corporate product/market strategies that are being used in the thin battery space.

NanoMarkets has been covering the thin-film and printed battery industry for the past seven years, and the product scope of this report is similar in many ways to our earlier reports in that it is focused on printed batteries (typically low-cost and of limited performance) and thin-film batteries (often quite high performance). But this time around, we have somewhat expanded coverage to include explicitly the new generation of flexible, multi-shaped batteries that are being sponsored by Nokia, LG, and Apple, as mentioned above.

The markets are similar to earlier reports, but we have deemphasized RFID and patches, which no longer seem of much interest to battery makers. Instead, we have provided extended coverage of biometric cards and various applications related to the Internet-of-Things. In addition to batteries and their applications, we have analyzed the future evolution of materials and battery chemistries used to produce thin-film and printed batteries.

This report—and the forecasts that we have included—are intended to be worldwide. We have attempted to cover as wide an area as possible in terms of the research that has gone into this report, both with respect to the applications and the national origins of the technologies being reviewed.

1.3 Methodology of this Report

This report follows the same methodology that was applied to previous NanoMarkets reports, i.e., the business prospects for thin batteries are assessed and predicted based on analysis of the functionality and adaptability of the features and capabilities that these batteries can offer in the real world, and the time frame in which they will be offered.

Both primary and secondary research were used in this report to determine where thin-film and printed battery technology is headed:

- Primary research included discussions with leading players in the thin battery arena, including manufacturers of devices powered by these batteries, as well as the battery makers themselves.
- Secondary research was based on the information available in this sector from various sources, such as the World Wide Web, commercial databases, trade press articles, government reports, SEC filings, and other corporate literature.
- Previous NanoMarkets reports that have covered similar or comparable markets.

In a few cases, where no suitable data was available, we have come up with plausible estimates based on broader statistical data from governments and trade associations.

1.3.1 Forecasting Methodology

The basic methodology that we use for forecasting in this report is similar to the methodology applied in most NanoMarkets reports. We estimate the size of the underlying addressable market for thin-film and printed batteries in each of the main application areas for these batteries. Then, we predict the penetration figures, which vary from one application to another.

Our estimates on penetration are calculated based on the historical trends observed for analogous technology introductions, such as the rapid growth of the traditional lithium-ion battery. The pricing estimates are then added to come up with revenue projections.

However, there is always uncertainty around the rate at which these applications will evolve from an idea to commercialization and launch of an actual product. Many of the applications for printed and thin-film batteries are very new and, therefore, the incubation period for these technologies to develop into viable products may vary from three to seven years depending on the application.

We have been careful not to become too optimistic about the progress that these thin batteries will make in the future. There are still many technological hurdles that must be overcome, and these issues are covered in the chapters to follow. We have thus kept these challenges in mind while making the penetration projections.

1.4 Economic Assumptions

The forecasts in this report do not directly depend on economic growth rates. However, assumptions about growth rates and economic conditions do have an impact on the way new technologies will be adopted, the availability of funding, etc.

Since the current economic environment is not very bright, the growth scenario assumed for the purpose of this report is not a rosy one. For example, in the U.S, the annual GDP growth rate is predicted to be approximately 2.0 percent for the next two years or more. The expectations for Europe are even lower.

In Asia, China is still anticipated to be at the forefront of world growth, but the numbers have declined compared to the past decade. An average growth rate of 4 percent to 7 percent is what seems to be the trend for the next few years. Japan, on the other hand, is predicted to experience a growth rate of just 1.5 percent to 2 percent in the next few years.

We may end on a positive note, though. Recessions come and go, and most of the industrialized regions can be expected to return to historically normal growth towards the end of the forecast period considered in this report.

1.5 Pricing Assumptions and Strategies

Pricing is a critical issue for thin batteries. It has been accepted that these batteries cannot compete with coin cell batteries around price points. Thin-film and printed batteries belong to the premium products club, and that position has not changed, even though their price points are significantly higher than those of coin batteries. In the long run, printed batteries may be able to compete with coin batteries if adequate market demand exists. But in the short term, all thin batteries compete on non-price factors, such as form factor, lifetimes, etc.

There are two general pricing strategies available for thin-film and printed battery manufacturers: long lifetimes or higher performance. In the first scenario, the initial cost of the battery is high, but the total cost over the life of the battery directly justifies the high initial cost. In the second scenario, the initial cost is high but can be justified by additional performance when compared to conventional batteries.

Another point to keep in mind is that the cost of these batteries is highly application-specific, and this consideration has been incorporated into our forecasting model. NanoMarkets believes that a thin/flexible battery can conveniently be priced at three times the level of conventional, bulky and rigid batteries in applications where flexibility is valued. An exception, of course, is the medical industry, where thin batteries can be much more expensive than conventional batteries.

Price declines are also important in the forecasts. NanoMarkets believes that the price decline scenario will not be rapid. The penetration of thin batteries into the market will not occur at dramatically high rates. Therefore, a rapid price decline will not be favorable for revenue generation, and there are chances that such declines will be resisted in the industry. A realistic scenario would be one in which price declines are significant but not revolutionary.

Therefore, in our forecasting we have reduced prices by 17 percent annually. This assumption may be overly simplified, but it does reflect a realistic view that the thin-film and printed batteries market will grow in volume, but that this growth will not result in drastic cost reductions in the forecasting period of this report. Another assumption in our forecasting model is that the price declines that we assume will translate across all sectors that we have covered in this report.

1.6 Plan of this Report

This report has been divided into seven chapters. In addition to this Chapter One, there is an Executive Summary, which summarizes the opportunities in this space

Chapter Two reviews the recent important trends in the technical advances in thin-film and printed batteries and includes an analysis of the opportunities created for substrate manufacturers.

Chapter Three is an analysis of the sensor market and how it is linked to the Internet-of-Things. It includes an eight-year forecast for the market for batteries in this segment.

Chapter Four explores the smart cards market for thin-film and printed batteries and also includes an eight-year forecast.

Chapter Five examines the opportunities for thin batteries in other applications, such as smart packaging and other disposables and once again provides an eight-year forecast for this market.

In Chapter Six we discuss other applications of these batteries, including medical implants, CPR devices, computer memory, and clocks. Special attention is also paid to the exciting new opportunities in the wearables and related sectors. Eight-year forecasts are included.

Chapter Seven provides a summary of the eight-year thin battery market forecasts both by application and by battery chemistry.