EDISON

Thin Film Electronics

Printing technology for disposable electronics

Initiation of coverage

Tech hardware & equipment

Thinfilm's printable, rewritable, non-volatile memory is a key component of printed electronics. Due to the low cost of production, printed electronics (PE) has the potential to add intelligence to high volume, disposable items. The PE market is predicated on achieving high volumes to make ubiquitous computing a reality, but is currently highly fragmented. As the only pure-play listed PE company, we believe Thinfilm is well placed to take a leadership role in integrating the industry. Thinfilm's relationships with global companies and licensing model provide scalable revenue opportunities and potential for significant share price upside.

Year end	Revenue (NOKm)	PBT* (NOKm)	EPS* (NOK)	DPS (NOK)	P/E (x)	Yield (%)
12/11	1.8	(35.7)	(0.13)	0	N/A	N/A
12/12	3.8	(42.0)	(0.13)	0	N/A	N/A
12/13e	12.5	(49.4)	(0.14)	0	N/A	N/A
12/14e	49.7	(43.3)	(0.12)	0	N/A	N/A
12/15e	253.1	1.1	0.00	0	825.6	N/A
12/16e	1,618.1	648.4	1.53	0	1.6	N/A

Note: *PBT and EPS are normalised, excluding amortisation of acquired intangibles, exceptional items and share-based payments.

Pioneering printable memory technology

Thinfilm's technology enables memory to be produced using standard industrial roll-to-roll printing techniques and organic materials. The low cost to produce printed electronics compared to well-established silicon-based electronics opens up a substantial opportunity to develop low-value, high-volume applications (eg brand protection, sensor tags) and to accelerate the "Internet of things". Thinfilm's technology can already be used to make passive array memory and further development is underway to expand the number of logic components that can be printed to make more complex electronic products. Thinfilm's strategy is to demonstrate what can be made by establishing in-house production capacity, before licensing the technology "copy-exact" to customers in target markets.

Commercial agreements prelude to production ramp

Thinfilm has signed several significant commercial contracts to develop products, including brand protection, smart labels and temperature sensor tags. We expect production to ramp from H213. Management expects to see the first licensing agreements in 2014, with 70% of volume from licensing partners by 2016. Key risks include scaling production, achieving targeted production yields, ability to access funds, and customer adoption and product roadmaps.

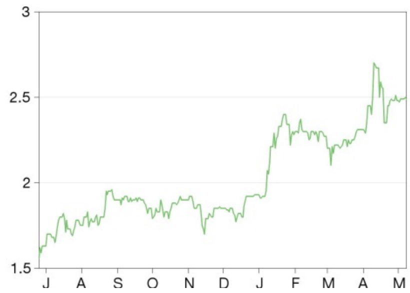
Valuation: Material upside if technology adopted

Based on management's assumptions for adoption, a WACC of 15% and long-term growth of 3%, our DCF values the company at NOK18.5/share. Varying the WACC and long-term growth rate produces a valuation range of NOK10.1-52.2/share; varying the licence fee or materials cost a range of NOK7.3-24.2/share. Using a slower adoption and licensing scenario, we calculate a value of NOK6.9/share.

26 June 2013

Price	**NOK2.46**
Market cap	**NOK900m ($153m)**
	NOK5.9/US$
Net cash (NOKm) at end-FY12	32.9
Shares in issue	366.0m
Free float	99%
Code	THIN
Primary exchange	Oslo
Secondary exchange	N/A

Share price performance



%	1m	3m	12m
Abs	(2.8)	10.2	45.9
Rel (local)	4.2	18.6	28.2
52-week high/low		NOK2.74	NOK1.56

Business description

Thin Film Electronics (Thinfilm) owns key patents for the printing of rewritable, non-volatile memory and licenses technology from others to develop complete printed systems.

Next events

Interim report – H113	15 August 2013
Interim report – Q312	7 November 2013

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Edison profile page

Thin Film Electronics is a research client of Edison Investment Research Limited

Investment summary

Company description: Printed memory in printed systems

Thin Film Electronics (Thinfilm) owns key patents for printing rewritable, non-volatile memory and licenses technology from others to develop complete printed systems. The printed systems are intended to provide low-level processing to a wide range of products and applications. It is initially targeting the high-volume, low-cost packaging market with brand protection products followed by sensor tags that monitor temperature. Longer term there is the potential to create a wide range of low-cost intelligent devices for a variety of applications. Thinfilm's strategy is to demonstrate what can be made by establishing in-house production capacity, before licensing the technology "copy exact" to customers in target markets. Thinfilm has signed several significant commercial contracts to develop products, including brand protection, smart labels and temperature sensor tags, with production expected to ramp from H213.

Financials: Adoption inflection in 2016

Our forecasts are based on the company's expectations for internal production and third-party licensing. We expect a low level of in-house production of brand protection tags from H213, with sensor tags starting to ship from H214. Thinfilm does not expect third-party licensing until 2014, with licensees producing 70% of volume by 2016. The ASP per tag rises over the forecast period to reflect the addition of functionality to tags and an increasing mix of higher-value tags. We assume that headcount increases from 23 at the end of FY12 to 175 by the end of 2016. For material costs, the company estimates that materials make up 80% of the cost of sales of each tag, and cost of sales will be c 50% per tag. The company also estimates that of the 5c licence fee per tag, it will need to pay up to 40% to third-party IP providers. The assumption that there is acceleration in adoption in 2016 results in significant revenue and profit generation.

Valuation: Material upside if technology adopted

As the company expects a significant acceleration in adoption of the technology and third-party licensing in 2016, multiples analysis is not appropriate. Based on management's assumptions for adoption, a WACC of 15% and long-term growth of 3%, our DCF values the company at NOK18.5/share. Varying the WACC (10-20%) and long-term growth (1-5%) results in a range of NOK10.1-52.2/share; varying the licence fee gives a valuation range of NOK7.3-24.2/share and valuing the materials cost a range of NOK16.1-19.8/share. Using a slower adoption and licensing scenario, we calculate a value of NOK6.9/share. In both cases, we assume the company raises money to fund the construction of production facilities.

Sensitivities: Technology, buyer power, reliance on suppliers

Technology remains to be developed for some of the key applications Thinfilm is targeting. Delays or problems with development could reduce profitability or threaten the business model. Funding will also be required to reach the targeted level of internal production. Thinfilm is reliant on other companies in the industry; particularly ink suppliers such as Solvay and Polyera. If these partnerships fall through, Thinfilm's business could be severely disrupted. Sales are closely linked to the success of its customers' products. The licensing model is very difficult to predict and will depend on the pace of adoption by third parties and the speed at which licensees can install and ramp up production. Thinfilm's technology is protected by patents, but this could result in expensive lawsuits in an effort to enforce those patents. It also faces competition on a number of fronts, from others in the printed electronics industry, to alternative solutions for target applications. Managing the expected rapid revenue growth and associated costs over the next four to five years will be important to ensure customer expectations are met.

Company description: Printed electronic systems

Thinfilm is developing printed electronics for high-volume, low-cost applications such as temperature sensor tags and dynamic price displays on consumer goods packaging. Its printed systems are based around its patented rewritable non-volatile memory, the only memory of its type available commercially. Its partnerships with other printed electronic firms and packaging manufacturers are key to the development of complete printed systems for its target applications.

Company background

Thin Film Electronics was originally created as a subsidiary of Opticom ASA, a Norwegian research and development company, to focus on the development of plastic memory. Opticom was acquired by FAST Search and Transfer in early-2006, at which point Thin Film Electronics was spun off. It listed on the Oslo stock exchange in 2008. The company is headquartered in Oslo, with R&D in Linkoping, Sweden, sales offices in San Francisco and Tokyo, and manufacturing in Pyongtaek, South Korea.

The company originally focused on the development of higher-density polymer-based memory and formed a joint venture with Intel from 1999 to 2004 when it demonstrated 0.5Gb of printed memory. It has since moved into the development of lower-density, high-volume printed memory, using some of the IP developed with Intel.

Company strategy – printed systems licensing

Thinfilm has developed a rewritable non-volatile memory that can be produced using standard printing techniques on a flexible substrate. The plan is to incorporate the memory with other electronic components to produce fully printable system solutions for a range of applications.

Initially, the company plans to manufacture products internally, but in the longer term will license out its processes and IP to third parties to produce in their own facilities. This strategy means the business model is very scalable and will be able to take advantage of the wide range of applications in which printed electronics could be used (explained in more detail from page 7).

As Thinfilm is still developing full system solutions, it has not yet signed any licence agreements, but has received technology access fees and government grants to fund the development of its memory and solutions.

Production plans

The company currently has a high-definition (HD) sheet-printing line (ie printed sheet by sheet) in operation in Linkoping and is in the process of installing an HD roll-to-roll printer (a continuous roll of substrate is fed through the machine while being printed) at the same facility. This capacity will be used for both development and commercial production and will have a capacity of c 50m units pa. Inktec, a production partner, separately provides production capacity for c 10m memory devices per month.

The company plans to build a full production facility – location and exact capacity have not yet been decided – to provide capacity for brand protection and sensor tag products. Management estimates it is likely to cost c $20m/NOK118m to build capacity of 500m units pa. Capacity for this technology can be built flexibly and can be located close to the end-customer without materially changing the cost of production. As a comparison, a traditional semiconductor fabrication plant would cost $5bn+ and would take weeks to process components compared to a printed electronics facility processing rolls at a rate of metres per minute. Once production has been optimised, the company plans to license the process to partners on a “copy exact” basis.

Technology and commercial roadmap

As the company is at an early stage of development, we believe that performance should be measured in terms of progress against key milestones. From a technology perspective, Thinfilm has set out the following development milestones over the next three years:

Exhibit 1: Technology milestones

Milestone	Products	Importance	Date Expected	Comments
Start production of passive array memory	Brand protection	Important	2013	This will initially be used for brand protection products, but is relevant for all Thinfilm products. Passive array memory will be produced at partners' **Inktec** facilities.
Pilot production of organic transistors	All	Important	2013	Printed transistors have already been demonstrated – this milestone is to implement the printing process on the pilot production line.
Improve TFTs for displays	Display	Important	Q214	Thinfilm partners **Acreo** and **Santa Anna** are developing these.
Logic for 7-segment display	Display	Less important	Q214	
Integration with battery including voltage/charge pump	Contactless tags	Very important	End-2014	Printed charge pumps are very important to increase the voltage from the battery to a level that is usable by the rest of the printed electronic devices, including the memory.
Rectifier diode	Contactless tags	Very important	End-2014	Rectifier diodes are important components of RF and NFC[1] tags.
96-bit passive array memory	All	Less important	End-2014	Scaling of memory allows more complicated applications. 96bits would make it possible to implement encrypted NFC.
Logic for communication protocols	Contactless tags	Very important	1) End-2014 2) End-2015/2016	A simple proprietary protocol over NFC is expected to be complete by the end of 2014. An NFC compatible protocol is expected to be completed in 2015/16.
Antenna	Contactless tags	Less important	End-2015/2016	Several existing printed technologies/antennas are available already.

Source: Thin Film Electronics

Assuming the technology milestones are met, we would expect to see the company working towards meeting the following commercial targets:

Exhibit 2: Commercial targets

Description	Date	Comment
Shipments of mass-produced passive array memory to toy customers.	2013	
Delivery of brand protection products.	2013	Contract announced March 2013.
Produce first samples of printed sensor product.	End-2013	
Pilot manufacturing of sensor product.	2014	
Delivery of smart labels to high-value label manufacturer.	Q114	Contract announced March 2013. The customer has not been disclosed but Thinfilm expects to receive technology access fees and will deliver the ordered devices in Q114.
Launch of Bemis product.	2014	This includes Thinfilm sensor tags.

Source: Thin Film Electronics

Management

Davor Sutija, CEO, served as senior vice president, product marketing at FAST before joining Thinfilm in 2010. FAST specialised in data search technologies and acquired Opticom, the original owner of Thin Film Electronics, in 2006. In 2008, FAST was acquired by Microsoft. Davor is a member of the board of the Organic Electronics Association and has a PhD in Chemical Engineering. Torgrim Takle, CFO, joined in March 2011 from McKinsey & Company. Other key members of the leadership team include Dr Christoper Karlsson, chief technology officer, previously deputy research director at the Swedish National Defence Research Establishment, and Jennifer Ernst, executive vice president, sales and business development, who was director of business development at PARC before joining Thinfilm.

[1] RF and NFC (near field communication) are short-range wireless communication technologies intended for low-cost, low-power items.

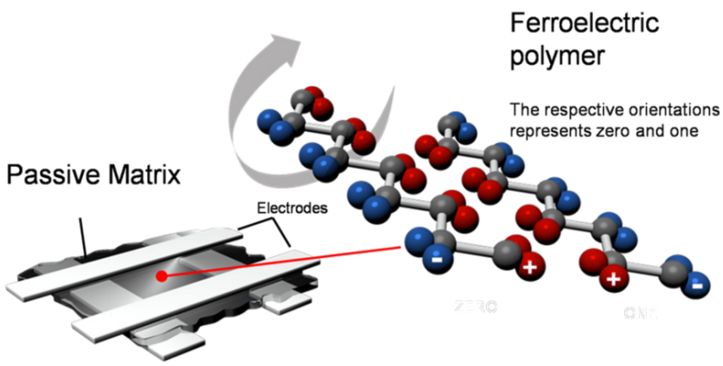
Printed electronics technology overview

The term ‘printed electronics’ refers to a range of techniques used to manufacture electronic circuits using traditional printing techniques. The benefits of printed electronics are lower cost and flexibility of form factor compared to traditional silicon-based electronics. Printing using high-volume printing machines significantly reduces the cost of production and enables printing on a variety of flexible substrates that can be incorporated into products of all shapes and sizes. It therefore opens up a whole new range of potential applications.

Inks are key enabling technology

The key technology that has enabled printed electronics to become a reality is inks that exhibit useful electronic properties such as conductivity, semi-conductivity, and, in the case of Thinfilm’s memory, ferroelectric properties. Ferroelectric polymers are organic compounds that can be polarised by an electric field. The polarisation is retained after power is removed, but can be reversed by applying the reverse electric field. The direction of polarisation will represent either a binary ‘1’ or ‘0’ and is thus used to store information.

Exhibit 3: Thinfilm memory design



Source: Thin Film Electronics

Organic versus inorganic

Printable inks can be either organic or inorganic. Generally, inorganic inks have higher performance and are currently less expensive, but organic inks have the potential to become cheaper in the longer term and easier to print. The best type of ink will vary depending on the application and may change over time.

Choice of printing technology influences throughput

The printing technology is important in determining the overall cost and performance of the resulting printed system. There are often trade-offs between printing resolution, speed and cost, so the choice of printing method will vary depending on the target application. Thinfilm uses a combination of gravure and screen-printing for the production of its memory. Gravure printing is one of the highest speed printing methods with a throughput of 50-100m^2/s, and rotary screen, although slightly slower, can still achieve throughputs of 1-60 m^2/s.

Developing the crucial building blocks

Once the ink and printing technology has been developed, the next important step is to construct electronic components. This process will vary significantly depending on the type of component, but it is a critical stage of the development process. Some of the fundamental components required for simple electronic circuitry are shown in Exhibit 4.

Exhibit 4: Key component status

Component	Description	Status
Memory	Memory is important in all electronic systems. It comes in many forms, but can generally be categorised according to whether it loses or retains data when power is removed (volatile/non-volatile respectively) and the combination of read and write access that it allows. Thinfilm's proprietary technology is for scalable, printable, non-volatile rewritable memory based on ferroelectric materials provided by **Solvay Specialty Chemicals**.	Thinfilm Passive Array Memory is expected to enter production in 2013.
Logic	The transistors that implement the logic circuitry are printed using P-type and N-type organic semi-conductor inks. **Polyera** provides the n-type semiconductor inks. The supplier of the P-type semiconductor ink has not been disclosed. The logic circuitry design for driving displays is being developed by **Acreo** and **Santa Anna**. Other logic circuitry is being developed by Thinfilm in partnership with **Xerox PARC**.	Using scalable methods, Thinfilm demonstrated fully printable, P-type transistors in January 2013. N-type transistors were also demonstrated, but were only partially printed.
Display	Thinfilm has entered into a sourcing contract with **Acreo** for delivery of low-cost electro-chromic displays.	Numerous display technologies are available and variety will be selected depending on the application.
Battery	Thinfilm has entered a Technology Evaluation Agreement with **Imprint Energy** for its printed batteries. Most of the specifications required have been met already. Most applications will require a battery to be included, apart from the brand protection memory and standalone passive array memory products.	A variety of batteries will also be required depending on application. Many are already in mass production so it is not expected to be a technical barrier.
Sensor	Various types of printable sensors are required for Thinfilm's targeted applications. The company demonstrated a fully printed temperature sensor system in December 2012, which was developed in partnership with **PST Sensors**.	Numerous other types of printable sensors are available and it is not deemed to be a technical barrier.
Antenna	Printed antennas are key for the implementation of printed NFC or RF circuits.	There are over 50 producers of printed antennas. Therefore, it is not deemed a technical barrier.

Source: Edison Investment Research

Thinfilm memory roadmap

Thinfilm memory is currently commercially available in sizes up to 20 bit, with plans to increase it to 96 bits within the next one to two years. The number of data points that can be stored with 20 bits is over 1m and doubles with each bit added. The initial brand protection products will be launched with fewer bits, as this is all that is required to provide the necessary functionality, resulting in lower production costs and selling prices. An example would be a min/max temperature sensor, where 12 bits would allow a minimum or maximum trigger temperature in the range of -2°C to 44°C, in one centigrade steps. Thinfilm plans to increase memory size to 96 bits by the end of 2014. We note that Thinfilm has been granted patents for 13 patent families relating to printed rewritable memory and has one pending for a patent family relating to printed strain-reducing protective coatings

Industry collaboration required to create complete solutions

As in traditional silicon-based electronics, printed electronics consist of a collection of components connected together to create a functional system. The IP for each type of printed component is currently spread out across the industry and therefore a high level of collaboration is required to develop complete systems. Thinfilm's IP relates to rewritable, non-volatile memory, which is a core component for many types of products and therefore puts it in a strong position in the industry. Thinfilm develops applications incorporating its memory by licensing IP for the other components from third parties. The key partners with which Thinfilm is working are shown in Exhibit 5.

Exhibit 5: Key technology partners

Name	Relationship	Description
Solvay specialty chemicals	Supplier	Manufactures the ferroelectric polymers, which are the key components of Thinfilm's memory.
Polyera	Supplier	Manufactures the n-type organic semiconductors required for printed logic. Thinfilm has a limited time exclusive supply agreement with Polyera.
Acreo	Supplier	Acreo and Santa Anna are working together to develop logic for driving dynamic displays. This work is part-funded by the EU's Eurostars Programme, which assists SMEs with R&D.
Santa Anna	Development partner	
Xerox – PARC	Development partner	PARC has granted Thinfilm an exclusive licence to all its IP around printed logic for use in systems containing rewritable printed memory. It also provides rapid-prototyping facilities for Thinfilm's use. PARC owns 1.7m (<1%) Thinfilm shares.
Topflight	Production partner	Converts products into labels.
Imprint Energy	Development partner/supplier	Thinfilm has entered into a technology evaluation agreement with Imprint Energy for printed batteries.
PST Sensors	Development partner/supplier	PST is collaborating with Thinfilm on the development of the temperature sensor tag.
Inktec	Development partner/ manufacturer	Inktec provides 10m units/month manufacturing capacity for Thinfilm Passive Array Memory.

Source: Thin Film Electronics

Applications

Printed electronics opens up a whole new range of applications that were previously impossible or uneconomic to make using traditional electronics. The printed electronics market in general is expected to grow from its current size of $2.8bn to $28.5bn in 2020[2] (including photo-voltaics, OLED displays and e-paper). The four key product groups that Thinfilm is focused on are brand protection, sensor tags, display tags and NFC tags. In addition, Thinfilm has signed agreements to develop toy-related applications and smart labels, demonstrating the wide range of applications for which printed electronics can be used.

Brand protection

Thinfilm's passive array memory can be printed onto product labels as an anti-counterfeiting measure. The global anti-counterfeiting market is worth $73bn and is expected to grow to approximately $85bn by 2015. Thinfilm's memory is an effective counterfeiting technology, because it is very difficult to copy and can be tailored to be unique for each company or product range. It provides a similar level of security to chemical tags and RFID tracking (c $1), but at a comparable price to holograms (c 3c). Both RFID and Thinfilm's technology require additional equipment to test the authenticity of products. RFID products need an RFID tag reader and Thinfilm's memory products require a handheld memory tester.

Customer signed up with production imminent

Thinfilm has already signed a contract with an undisclosed consumer goods company for brand protection tags. Mass production is expected to start this year (we believe they will be manufactured by Inktec) and it is expected to sell for $0.03-0.10 per tag depending on the number of bits per tag.

Sensor tags

Thinfilm is developing sensor tags for use on perishable and environmentally sensitive products to ensure they are kept in appropriate environmental conditions. The use of sensor tags based on silicon chips is increasing, but they are currently mainly used at a pallet level rather than item level, because of the high cost of traditional electronics. The simplest range of sensor tags is priced in the range of $5-15 and provides a range of sensor data that can be transmitted over a few metres to a receiver connected to a computer system that monitors the condition of each pallet. Thinfilm

[2] IDTechEx – Printed, Organic & Flexible electronics Forecasts, Players & Opportunities 2012 – 2020.

expects to sell sensors showing min/max temperature for c $0.40 and if average temperature, wireless read-out and timer functionality are added, the price could reach $0.50-1.00. A printed sensor tag that monitors temperature was demonstrated in December 2012, but certain key components and functionality need to be developed further before commercial release:

- Integration with battery, including voltage/charge pump.
- Improve functionality, eg measure max/min temperature (the demonstration product indicated whether a temperature had been exceeded, but did not record the minimum and maximum temperature).
- Improve temperature measurement accuracy and overall tag robustness.
- Add other sensor types – humidity, pressure, etc. and additional state machine logic.

Strategic partnership with Bemis – global leader in flexible packaging

Bemis and Thinfilm formed a strategic partnership in July 2012 to commercialise printed sensor tags. The exact application has not been disclosed, but could represent a significant opportunity for Thinfilm. Bemis produces c 200bn packages a year and generates revenues of $5.3bn, so capturing even a small percentage of these package sales would generate significant revenues. The company has indicated that it expects to start shipping wireless sensor tags to Bemis in 2014.

Dynamic display tag

Dynamic display tags have a range of potential applications, including product level pricing, temperature displays and freshness indicators. Thinfilm has experienced interest from a range of sources for this type of product. Supermarkets, for example, have expressed interest in product level pricing to reduce wastage and re-pricing costs. Dynamic shelf-level pricing is being used already in some supermarkets, but is too expensive to use at a product level. The company believes printed electronics could achieve a price point suitable for the supermarkets at both the shelf level and product level. The outstanding milestones required to achieve this are:

- Improve TFTs (Thinfilm's transistors) for display drive logic (expected Q214).
- Develop driver logic for 7-segment display (expected Q214).

Dynamic display tags are expected to sell for $0.40-0.70 compared to existing silicon-based electronic shelf labels priced at $3-4. This tag cost means that the target products will be the mid- to higher-value items (eg whole salmon) or products where additional electronic functionality will add value by increasing sales volumes (eg interactive games on cereal boxes).

Contactless tags

Existing static NFC tags are currently available for between $0.50-1.00 per tag and Thinfilm is targeting a market price of $0.30-0.50 for a wireless smart tag, which will incorporate proprietary NFC communications with additional sensors and intelligent logic. Standard NFC tags contain static memory and limited (if any) processing capability. IDTechEx estimates that 4bn RFID tags were sold in 2012, up 35% from 2.9bn in 2011, and forecasts this will increase to 16bn tags in 2022.

Some of the key technologies required to achieve this in a printed circuit are still in development and will vary depending on the application, but the company expects to complete the initial product offering (with proprietary protocols) by the end of 2014.

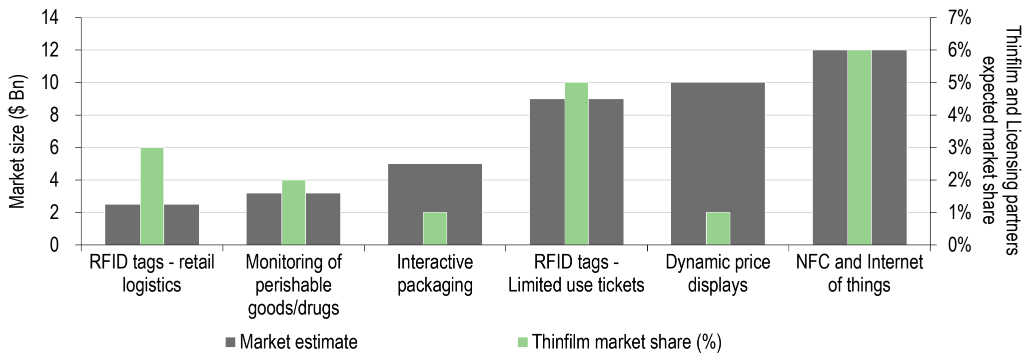
Other product and development agreements

In February 2011, Thinfilm demonstrated a children's game that used Thinfilm memory on printed cards to save character information and game status. It was developed in response to feedback from toy manufacturers that wanted a demonstration of concept and eventually led to Thinfilm signing a development agreement with Hasbro for toy-related applications. Thinfilm has delivered prototype memory products to another undisclosed customer for parts identification applications. In March 2013, Thinfilm announced it had signed an agreement with a high-value labels company for Smart Labels to be delivered in Q114.

Market potential

The opportunities for printed electronics cover a wide range of industries so the potential market size is huge. Exhibit 6 shows forecasts for the size of several markets that are most likely to adopt printed electronics. To put these in context, the number of disposable items sold in 2012 has been estimated at 5-10 trillion and the number of apparel items sold was 80bn. Even higher-cost semiconductor-based microcontrollers sold 15bn units last year. In relation to interactive packaging and retail logistics, Smithers Pira calculated the global consumer packaging market to be worth $58.3bn in 2011 and predicted it will grow to $71.3bn in 2016. McKinsey Global Institute predicts that the potential impact of the "Internet of things" will be $2.7tn by 2025. Although many other factors contribute to this figure and only a small proportion will be related to printed electronics, it puts the expected market value of $12bn for NFC and "Internet of things" in Exhibit 6 into context. In addition to the applications currently being targeted, it is likely that new markets will be created as the technology develops and consumers become aware of the ability to add intelligence to everyday items at low cost.

Exhibit 6: Expected market size in 2020 for potential applications of printed electronics



Source: Produced by Edison Investment Research, data from IDTechEx, Thin Film Electronics, Freedonia

Competitive environment in printed electronics

Many of the key players in the industry at the moment are research houses and relatively few are developing commercial solutions. The major electronics firms such as Samsung and Sony are developing printed electronics, but are more focused on the application of printed electronics to large-screen displays. Exhibit 7 shows a list of competitors in the printed electronics field.

Exhibit 7: Competitive landscape

Name	Comment
Kovio (private co)	Kovio produces a one-time programmable 2048-bit printed IC for NFC and ticketing applications. Products are already available. Kovio's technology is based on inorganic semiconductor inks and uses a deposition on steel substrate process, which is not as scalable as the techniques used by Thinfilm. This technology is therefore likely to be used more in high-performance applications rather than the very high-volume applications Thinfilm is targeting.
Paru (private co)	Paru Printed Electronics research institute, in combination with South Korea's Sunchon National University, developed 8-bit printed NFC cards, which cost less than 1c to produce. The tag does not contain rewriteable memory or internal logic and is not commercially available. The printed antenna and rectifier are the key components of the technology that could be useful to Thinfilm.
PragmaticIC (private co)	PragmaticIC has achieved very high transistor densities using higher-performance inorganic chemicals in an imprint printing process. Transistor sizes of the tens of nm have been achieved at frequencies up to 1GHz. This is at the higher-performance end of printed electronics and although the imprint printing process is not as scalable as gravure, high volumes can still be achieved, resulting in ICs that could potentially cost less than 1c per chip for simple applications when produced at volume. However, the slightly slower printing speed of imprint may mean this technique is not suitable for the high-volume package printing that Thinfilm is targeting. Similar to Thinfilm, it also develops complete products to customer specifications. It has already signed an agreement with Illinois Tool and Dyeworks and has delivered units to companies including Diageo and could be a key competitor to Thinfilm in some markets.
VTT (research)	VTT focuses on scalable technologies for printed electronics. The core components that it produces are printed transistors (both organic and inorganic), printed batteries and fully printed write-once-read-many (WORM) memory. WORM memory is useful for some applications, but rewritable enables more complicated and intelligent functions. The printed transistors and batteries will compete with Thinfilm's technology and that of its partners.
Holst (research)	Holst is an independent R&D centre focused on wireless sensor technologies and flexible electronics. It has produced a 1kb memory using a lithographic process. Lithographic processes are not as scalable as the gravure process used by Thinfilm. When Thinfilm was partnered with Intel, they jointly demonstrated a 0.5Gb process using a similar technique.
CEA (research)	In February 2013, CEA-Limited produced the first printed organic ADC (analogue to digital converter) on plastic foil. The ADC was produced using a sheet printing process, so although not as scalable as a gravure printing process it can still produce large volumes of devices.
PolyIC **(Private Co)**	PolyIC has released a printed NFC tag with incorporated printed electronics and display. It is a key competitor to Thinfilm, although it still uses Thinfilm for its rewritable memory.

Source: Edison Investment Research

Thinfilm well positioned to drive industry growth

The commercial success of the printed electronics industry is predicated on achieving high volumes of production at very low cost to extend the use of electronics into those very high-volume, low-cost applications that find silicon-based electronics to be too expensive. The industry is very fragmented and needs a well-capitalised player to take on the integrator role. As far as we are aware, Thinfilm is the only pure-play public company in this market and through its technology partnerships it has already made progress in bringing together key participants to develop complete solutions. We view the recent contracts signed with global packaging and toy manufacturers as evidence that Thinfilm is driving the commercialisation of the industry.

Sensitivities

Our forecasts and the share price are sensitive to the factors described below.

- **Execution risk:** The high rate of growth assumed in our forecasts is based on adoption of Thinfilm's technology and manufacturing processes by third parties. The process of transferring technology to licensees has yet to be tested, although Thinfilm's joint development work with Inktec may give some insight into potential challenges. Thinfilm will need to negotiate and sign licensing agreements in the next 12 months in order for licensees to build production capacity and ramp production to meet the volumes in our forecasts. The pace of adoption by third parties is difficult to predict and therefore a wide range of potential licensing revenues is possible in the short to medium term. It will also be important for costs to be managed as internal production is ramped up and partners start to manufacture under licence.
- **Technology development:** To design complete printed systems, there are some key components that still need to be developed. There is a risk that this development may be delayed or, in a worst-case scenario, the end product proves to be uneconomic in the targeted applications. Alternatively, competitors may develop solutions that make Thinfilm's technology less competitive or even redundant. Thinfilm's core memory technology and system integration skills should help mitigate this risk.

- **Access to funding:** To reach the level of internal production targeted over the next four years, the company will need to raise funds to invest in new production equipment.
- **Reliance on suppliers and partners:** Many different companies own different parts of the IP for printed electronics and key materials such as ink. For example, Thinfilm currently has limited time exclusivity with Polyera for its inks and while there are other suppliers of electronic inks, losing Polyera as a supplier would be disruptive to the business.
- **Dependence on technology roadmaps of customers:** As Thinfilm's products are integrated into its customers' products, it is dependent on the development and success of customers' products. Many of the customer relationships and agreements are confidential, so it is difficult to quantify the financial impact or assess the risks of each one.
- **IP protection:** Thinfilm's technology is protected by patents, but the company may become involved in litigation if its patents are infringed.
- **Competitive environment:** Thinfilm's technology faces competition on a number of fronts; from existing traditional electronics, printed electronics from other manufacturers and alternative methods for providing the same functionality (such as chemical temperature indicators in place of the sensor tag). However, Thinfilm's position in the printed electronics industry appears to be strong, as it is the only company able to produce scalable rewriteable, non-volatile memory, which is a key component of many electronic systems.

Valuation

The company's own projections for internal production and third-party licensing mean our forecasts for FY13-15 will not provide meaningful data for multiples analysis. The most useful method for valuing the business is a DCF analysis of adoption scenarios.

Base case valuation scenario

We use the company's assumptions for internal production and third-party licensing. The first four years use our forecasts, and out to 2020 we use company assumptions for volume, licensing and selling prices, and our cost and capex assumptions. From 2021, we assume moderating growth, with ongoing EBITDA margins of 48%.

Exhibit 8: Assumptions underlying base case valuation

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Units sold (m)	5	28	262	2,450	4,182	7,139	12,185	20,800	23,920	26,312
% produced by third parties	0%	0%	35%	70%	76%	83%	89%	95%	96%	97%
Revenue per in-house unit ($)	0.03	0.13	0.22	0.26	0.28	0.31	0.34	0.40	0.40	0.40
Gross licence fee/unit ($)		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
In-house production GM (estimated)	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Material cost total/cost of sales	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
Licence fee to third parties/unit ($)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Source: Edison Investment Research

Using a WACC of 15% and a long-term growth rate of 3% results in a valuation of NOK18.54 per share, substantially higher than the current share price. We note that to achieve these targets, we have assumed the company raises money at the beginning of 2014 and 2015 to fund the installation of internal production capacity, and have conservatively assumed it is raised at the current share price.

There are many assumptions that have been made in this valuation, and in the tables below we show the impact of varying different inputs.

Exhibit 9: Sensitivity to cost of capital and terminal growth rate

	Terminal growth rate				
WACC	**1%**	**2%**	**3%**	**4%**	**5%**
10.0%	34.04	36.88	40.52	45.38	52.18
12.5%	23.43	24.75	26.35	28.32	30.82
15.0%	17.05	17.74	**18.54**	19.49	20.63
17.5%	12.90	13.29	13.72	14.23	14.81
20.0%	10.05	10.28	10.53	10.82	11.15

Source: Edison Investment Research

Exhibit 10: Sensitivity to licence fee and material cost

	Sensitivity analysis			
Licence fee per tag ($)	0.03	0.04	0.05	0.06
Value per share (NOK)	7.26	12.90	**18.54**	24.18
Material cost/selling price	30%	40%	50%	60%
Value per share (NOK)	19.76	**18.54**	17.32	16.11

Source: Edison Investment Research

Slower adoption scenario

This scenario looks at the impact on valuation of a significantly slower adoption cycle. We forecast lower overall volumes than Thinfilm and assume third parties are slower to license the technology for their own manufacturing (see Exhibit 11). This scenario results in a higher level of internal production for Thinfilm, so again we factor in fund-raising to fund capex, assuming fund-raisings at the start of 2014 and 2016. In this scenario, we forecast that profitability is delayed until 2017 and operating costs rise more slowly to reflect the slower revenue growth. We use a long-term EBITDA margin of 40%. This values the company at NOK6.93, still substantially higher than the current share price.

Exhibit 11: Slower adoption assumptions

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Units sold (m)	5	28	100	200	500	1,000	2,000	3,000	4,000	5,000
% produced by third parties	0%	0%	0%	10%	20%	25%	30%	35%	40%	45%
Revenue per in-house unit ($)	0.03	0.13	0.15	0.20	0.25	0.28	0.29	0.30	0.30	0.30

Source: Edison Investment Research

Financials

P&L

Our forecasts are based on the company's expectations for internal production and third-party licensing. We expect a low level of in-house production of brand protection tags from H213, with sensor tags starting to ship from H214. Thinfilm does not expect third-party licensing revenues until 2015. In Exhibit 12, we show the key assumptions for internal production volumes, third-party licensing volumes and average selling price/licence fee per tag. The ASP per tag rises over the forecast period to reflect the addition of functionality to tags and an increasing mix of higher-value tags.

We note that the forecast volume production by licensees will require them to have production capacity in place in 2015, which would imply that they would need to start building out their facilities in 2014.

Exhibit 12: Revenue assumptions

	2013e	2014e	2015e	2016e
Volumes sold (m)	5.0	28.0	261.9	2,450.0
Internally produced	100%	100%	65%	30%
Via licensing partners	0%	0%	35%	70%
ASP per tag – internal production	0.03	0.13	0.22	0.26
Licence fee per tag	N/A	0.05	0.05	0.05

Source: Thin Film Electronics and Edison Investment Research

In Exhibit 13, we show our revenue and cost forecasts (Thinfilm does not report at the gross profit level). We assume headcount increases from 23 at the end of FY12 to 175 by the end of 2016. For material costs (included in the Premises, supplies line), the company estimates that materials make up 80% of the cost of sales of each tag, and cost of sales will be c 50% per tag. The company also estimates that of the 5c licence fee per tag, it will need to pay up to 40% of this to third-party IP providers.

Exhibit 13: Detailed profitability breakdown

NOK'000s	2012	2013e	2014e	2015e	2016e
Revenues					
Own production	-	885	20,650	220,888	1,112,888
Licensing	-	-	-	26,687	505,188
Other	3,773	11,574	29,012	5,503	-
Total	3,773	12,459	49,662	253,078	1,618,075
Revenue growth		230%	299%	410%	539%
Staff costs	19,774	32,627	46,591	89,492	173,121
Premises, supplies	4,895	5,739	14,183	105,545	660,260
Services	15,694	17,263	18,990	20,889	62,666
Sales & marketing	5,303	5,833	6,417	7,058	21,175
Other costs	(43)	63	179	818	6,574
EBITDA	(41,850)	(49,066)	(36,698)	29,275	694,279
EBITDA margin	-1,109.2%	-393.8%	-73.9%	11.6%	42.9%
Depreciation	(507)	(1,062)	(2,608)	(17,358)	(38,008)
Operating profit/(loss)	(42,357)	(50,128)	(39,306)	11,917	656,271
Operating margin	-1122.6%	-402.3%	-79.1%	4.7%	40.6%
Share-based payments	(4,369)	(5,120)	(5,120)	(5,120)	(5,120)
Reported operating profit/(loss)	(46,726)	(55,248)	(44,426)	6,797	651,151
Reported operating margin	-1238.4%	-443.4%	-89.5%	2.7%	40.2%

Source: Thin Film Electronics, Edison Investment Research

Tax: As Thinfilm is loss making, we estimate no tax is payable up to 2015. The company has substantial unrecognised tax losses that can be used to offset tax liabilities once it moves to profitability; we estimate these will be used up in 2016.

Grants: For its work with Santa Anna IT Research Institute and Acreo, Thinfilm was awarded a €0.8m grant by the Eurostars Programme. We assume this is recognised equally over the period Q412 to Q115. In Q213, Thinfilm was awarded a NOK7m grant by Innovation Norway's Industrial Research and Development Program for the development work it is undertaking with Bemis for sensor tags. This will be recognised over two years.

Cash flow and balance sheet

- **Capex:** We forecast capex of NOK11m in FY13 to equip the prototype facility in Linkoping. As at the end of Q113, NOK5m had been prepaid. The equipment is due for delivery in Q2 and Q313. The company will need to make a decision on whether to build a production facility by the beginning of 2014. We assume the company starts to make this investment from Q114, at a cost of $20m/NOK118m to build out capacity of 0.5bn units and then we forecast capex of NOK59m in FY15 and FY16 to build additional capacity to service the forecast internal production demand. We assume PPE is depreciated over five years.

- **Cash position:** As at the end of Q113, Thinfilm had net cash of NOK21.6m. The exercise of 12.1m warrants in early April generated a cash inflow of NOK26.8m. We forecast that Thinfilm will have a net cash position of NOK6.2m by the end of FY13 and will need to raise further finance in Q114, particularly if it decides to build out a production facility. We have represented the shortfall in funding as long-term debt on the balance sheet.

Exhibit 14: Financial summary

NOK'000s	2009	2010	2011	2012	2013e	2014e	2015e	2016e
Year end December	IFRS	IFRS	IFRS	IFRS	IFRS	IFRS	IFRS	IFRS
PROFIT & LOSS								
Revenue	4,457	63	1,763	3,774	12,459	49,662	253,078	1,618,075
EBITDA	(18,615)	(20,833)	(35,241)	(41,849)	(49,065)	(36,698)	29,275	694,279
Operating Profit (before amort. and except.)	(18,726)	(20,904)	(35,554)	(42,356)	(50,127)	(39,306)	11,917	656,271
Intangible Amortisation	0	0	0	0	0	0	0	0
Exceptionals	3,512	0	0	0	0	0	0	0
Share-based payments	(1,183)	(3,783)	(3,012)	(4,369)	(5,120)	(5,120)	(5,120)	(5,120)
Operating Profit	(16,397)	(24,687)	(38,566)	(46,725)	(55,247)	(44,426)	6,797	651,151
Net Interest	439	(207)	(125)	320	736	(3,971)	(10,808)	(7,856)
Profit Before Tax (norm)	(18,287)	(21,111)	(35,679)	(42,036)	(49,391)	(43,277)	1,109	648,415
Profit Before Tax (FRS 3)	(15,958)	(24,894)	(38,691)	(46,405)	(54,511)	(48,397)	(4,011)	643,295
Tax	0	0	0	0	0	0	0	(80,685)
Profit After Tax (norm)	(18,287)	(21,111)	(35,679)	(42,036)	(49,391)	(43,277)	1,109	567,730
Profit After Tax (FRS 3)	(15,958)	(24,894)	(38,691)	(46,405)	(54,511)	(48,397)	(4,011)	562,610
Average Number of Shares Outstanding (m)	90.6	206.6	284.6	330.1	359.9	366.0	366.0	366.0
EPS - normalised (NOK)	(0.20)	(0.10)	(0.13)	(0.13)	(0.14)	(0.12)	0.00	1.55
EPS - normalised and fully diluted (NOK)	(0.20)	(0.10)	(0.13)	(0.13)	(0.14)	(0.12)	0.00	1.53
EPS - (IFRS) (NOK)	(17.6)	(12.0)	(13.6)	(14.1)	(15.1)	(13.2)	(1.1)	153.7
Dividend per share (NOK)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EBITDA Margin (%)	N/A	N/A	N/A	N/A	N/A	N/A	11.6	42.9
Operating Margin (before GW and except.) (%)	N/A	N/A	N/A	N/A	N/A	N/A	4.7	40.6
BALANCE SHEET								
Fixed Assets	168	759	1,338	2,732	12,883	128,275	169,917	190,909
Intangible Assets	0	0	0	0	0	0	0	0
Tangible Assets	168	759	1,338	2,732	12,883	128,275	169,917	190,909
Investments	0	0	0	0	0	0	0	0
Current Assets	10,018	19,883	10,366	37,249	11,683	26,901	127,111	569,201
Stocks	0	0	0	0	354	11,210	70,800	189,169
Debtors	174	1,829	3,027	4,399	5,155	10,208	51,109	320,506
Cash	9,844	18,054	7,339	32,850	6,173	5,483	5,203	59,526
Other	0	0	0	0	0	0	0	0
Current Liabilities	(4,037)	(5,323)	(7,372)	(9,831)	(12,867)	(16,754)	(56,497)	(222,849)
Creditors	(4,037)	(5,323)	(7,372)	(9,831)	(12,867)	(16,754)	(56,497)	(222,849)
Short term borrowings	0	0	0	0	0	0	0	0
Long Term Liabilities	0	0	0	0	0	(170,000)	(271,000)	0
Long term borrowings	0	0	0	0	0	(170,000)	(271,000)	0
Other long term liabilities	0	0	0	0	0	0	0	0
Net Assets	6,149	15,319	4,332	30,150	11,699	(31,578)	(30,469)	537,261
CASH FLOW								
Operating Cash Flow	(19,598)	(21,202)	(34,390)	(40,762)	(47,140)	(48,719)	(31,472)	472,865
Net Interest	64	12	(42)	469	563	(3,971)	(10,808)	(7,856)
Tax	0	0	0	0	0	0	0	(80,685)
Capex	0	(650)	(879)	(1,924)	(11,058)	(118,000)	(59,000)	(59,000)
Acquisitions/disposals	3,905	0	0	0	0	0	0	0
Financing	16,184	30,051	24,597	67,727	30,958	0	0	0
Dividends	0	0	0	0	0	0	0	0
Net Cash Flow	555	8,211	(10,714)	25,510	(26,677)	(170,690)	(101,281)	325,324
Opening net debt/(cash)	(9,290)	(9,844)	(18,054)	(7,339)	(32,850)	(6,173)	164,517	265,797
HP finance leases initiated	0	0	0	0	0	0	0	0
Other	0	0	(1)	1	0	(0)	0	0
Closing net debt/(cash)	(9,845)	(18,055)	(7,339)	(32,850)	(6,173)	164,517	265,797	(59,526)

Source: Thin Film Electronics, Edison Investment Research

Contact details	Revenue by geography
Henrik Ibsens gate 100 PO Box 2911 Solli 0230 Oslo Norway +47 23 27 51 59 www.thinfilm.no	N/A

CAGR metrics		Profitability metrics		Balance sheet metrics		Sensitivities evaluation	
EPS 10-16e	N/A	ROCE 13e	N/A	Gearing 13e	N/A	Litigation/regulatory	○
EPS 12-16e	N/A	Avg ROCE 12-16e	N/A	Interest cover 13e	68.1	Pensions	○
EBITDA 10-16e	N/A	ROE 13e	137%	CA/CL 13e	0.9	Currency	◖
EBITDA 12-16e	N/A	Gross margin 13e	100%	Stock days 13e	10.4	Stock overhang	◖
Sales 10-16e	443%	Operating margin 13e	N/A	Debtor days 13e	151.0	Interest rates	○
Sales 12-16e	355%	Gr mgn / Op mgn YY	N/A	Creditor days YY	376.9	Oil/commodity prices	○

Management team

Non-Executive Chairman: Morten Opstad

Morten has served as chairman since October 2006. He is partner and chairman of Norwegian law firm Ræder DA. He also currently holds board positions at Idex ASA, Total Sports Online AS, Glommen Eiendom AS, Chaos AS and K-Konsult AS.

Chief Executive Officer: Dr Davor Sutija

Davor joined Thinfilm in January 2010 from FAST (a subsidiary of Microsoft). He was elected to the board of the Organic Electronics Association in 2012 and has a PhD in chemical engineering from the University of California.

Chief Financial Officer: Torgrim Takle

Torgrim joined Thinfilm in March 2011 from McKinsey & Company, where he managed corporate finance projects. He holds a Master of Science degree from the Norwegian University of Science and Technology's Institute of Industrial Economy and Technological Management.

Chief Technology Officer: Dr Christer Karlsson

Christer joined Thinfilm in 2000 and previously served as deputy research director at the Swedish National Defence Research Establishment. He holds a PhD from Linköping University.

Principal shareholders	(%)
Euroclear Bank S.A.	15.06
ASAH AS	7.79
HÅVI AS	4.77
Simpson Financial Ltd	4.68
AS Holding AS	4.03
Dukat AS	2.75
MP Pension PK	2.69

Companies named in this report

Bemis Company Inc (BMS), Hasbro Inc (HAS), Samsung (SMSN), Sony (SNE)