EDISON

Thin Film Electronics

Re-initiation of coverage

Energising innovation

Tech hardware & equipment

In January 2020, Thinfilm announced that it was pivoting its proven printed technology and roll-to-roll (R2R) production facility from NFC tags to the development of solid-state lithium micro-batteries. It is targeting markets where the high energy density, flexible form factor, enhanced cycling and improved safety features offered by its innovative technology should be able to command a premium compared with conventional batteries.

Year end	Revenue ($m)	EBITDA ($m)	PBT* ($m)	EPS* ($)	DPS ($)	P/E (x)
12/16**	3.8	(36.9)	(42.7)	(0.07)	0.00	N/A
12/17**	5.9	(50.9)	(54.5)	(0.06)	0.00	N/A
12/18**	3.4	(49.3)	(54.3)	(0.93)	0.00	N/A
12/19**	1.2	(30.6)	(35.9)	(0.61)	0.00	N/A

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

Addressing existing markets

Initially Thinfilm is targeting the medical wearables, hearables, connected sensor and sport and fitness wearables markets, which it estimates will collectively represent demand for over 1bn units by 2025. In contrast to the NFC market, where Thinfilm had to expend significant resources explaining potential applications for the technology to customers, the target markets for micro-batteries are already established. Moreover, the advantages offered by Thinfilm's battery technology, for example making continuous glucose monitoring patches more comfortable to wear, should help Thinfilm take market share. Management estimates that the company would break even on an output of 10m units a year, equivalent to only 1% of its collective target markets. It aims to reach this point by the end of CY22.

Fund-raising could extend cash runway into FY21

Thinfilm sold its remaining stock of antitheft tags in early H120 and is now back at a pre-revenue phase. Having developed the battery technology sufficiently to file patent applications regarding its stack and associated manufacturing processes, Thinfilm raised $3.4m (gross) during May and June and a further $6.7m (gross) between July and September. Management estimates that the cash raised by these programmes, including partial exercise of warrants, extends the company's cash runway through Q121, with further exercise of warrants issued as part of these programmes potentially extending the runway deeper into FY21. However, if the timing and quantity of warrant exercises are insufficient the company would need to pursue other sources of financing, which may be materially dilutive or not forthcoming. Thinfilm will not need cash to build a volume manufacturing facility as it already has one.

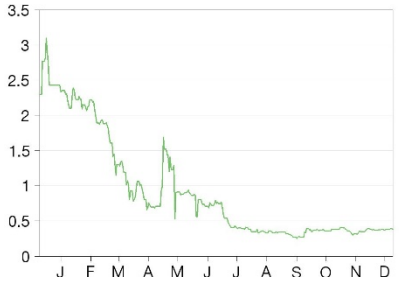
Valuation: Market of over 1bn units a year

Thinfilm is initially targeting the medical wearables, hearables, connected sensor and sport and fitness wearables markets. Our scenario analysis calculates that a 5–10% share of these markets represents annual revenues of $165–220m and EBITDA of $95.5–134m.

10 December 2020

Price	**NOK0.38**
Market cap	**NOK302m**
	US$0.11/NOK
Net debt ($m) at end September 2020 (excluding $1.6m restricted cash and $12.5m financial lease liabilities)	7.8
Shares in issue (to rise to 985.5m upon end December registration of warrants exercised 30 November 2020)	795.5m
Free float (excluding warrants exercised 30 November 2020)	55.8%
Code	THIN
Primary exchange	OSLO
Secondary exchange	OTCQB

Share price performance



%	1m	3m	12m
Abs	8.8	11.2	(65.4)
Rel	1.6	1.8	(64.6)

52-week high/low	NOK2.65	NOK0.25

Business description

Thin Film Electronics (Thinfilm) solid-state lithium battery technology combines advanced energy cell design with proprietary materials and manufacturing innovation to produce thin, flexible batteries that can power safer and more capable wearable devices and connected sensors.

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Investment summary

Company description: Pivot to solid-state lithium batteries

In January 2020 Thinfilm announced its new strategy of using its proven R2R assets and printed electronics IP to develop and manufacture miniature solid-state lithium batteries. Thinfilm's ability to manufacture electronic components on a flexible, ultra-thin steel substrate means that it can potentially offer micro-batteries that offer superior performance to conventional lithium-ion rechargeable batteries, thus commanding a premium price. Importantly, since Thinfilm's solid-state format is replacing conventional coin and button batteries in hearables as well as addressing emerging markets such as connected sensors and sports wearables, the demand is already there, so the company does not need to build up the market itself. In addition, since the average selling price (ASP) of a solid-state lithium battery is around 100 times greater than that for an NFC tag, break-even can be reached on substantially lower numbers of units.

Financials: Warrant exercises could extend runway into FY21

Total revenue and other income decreased by more than half year-on-year to $0.5m during the nine months ended September because of the absence of EU grants to top up the $0.5m from sales of the remaining stock of anti-theft tags. Following the restructuring initiatives that took place in Q319 and H120, operating losses narrowed by $21.6m to $8.6m. Thinfilm raised $3.4m (gross) during May and June through a private placing and subsequent offer. This fund-raising activity was followed between July and September by a private placement and subsequent offer collectively raising NOK60m ($6.7m) gross. Management estimates that the cash from these activities, including partial exercise of warrants, has extended the company's cash runway through Q121. Depending on the timing and quantity of further exercises of warrants, management estimates that it may be able to fund planned operations deeper into FY21. However, if the timing and quantity of warrant exercises are insufficient to meet the company's needs, the company would need to pursue other sources of financing, which may be materially dilutive or not forthcoming. We are not presenting estimates until the commercial development is more advanced.

Valuation: Addressing a market of over 1bn units a year

Management notes that the medical wearables, hearables, connected sensor and sport and fitness wearables markets are predicted to grow to over 1bn units per year by 2025. It estimates that it will be able to secure a price/unit in the lower single-digit dollars. Our scenario analysis calculates that a market share of 5–10% at $3/unit represents annual revenues of $165–220m and EBITDA of $95.5–134m. Management estimates that Thinfilm would break even with an output of around 10m units a year, equivalent to a 1% market share.

Sensitivities: Technical, commercial and financial

Since the existing R2R facility was used to manufacture several million anti-theft tags, we believe there is relatively little risk in migrating to volume production of batteries. Although Thinfilm has filed patents relating to its battery technology, we believe that an established lithium-ion battery manufacturer could theoretically develop its own variant, though it is likely that they may feel that the potential market size compared with the electric vehicle market does not justify the effort. The level of market penetration that Thinfilm will achieve is largely dependent on the success of sales and marketing programmes undertaken by its customers. While Thinfilm has already made samples of batteries using its steel substrate technology, it will need to carry out a substantial amount of research in the longer term to reach the energy density required for power tools or smartphones, which are not its core markets. Funding risks are discussed above.

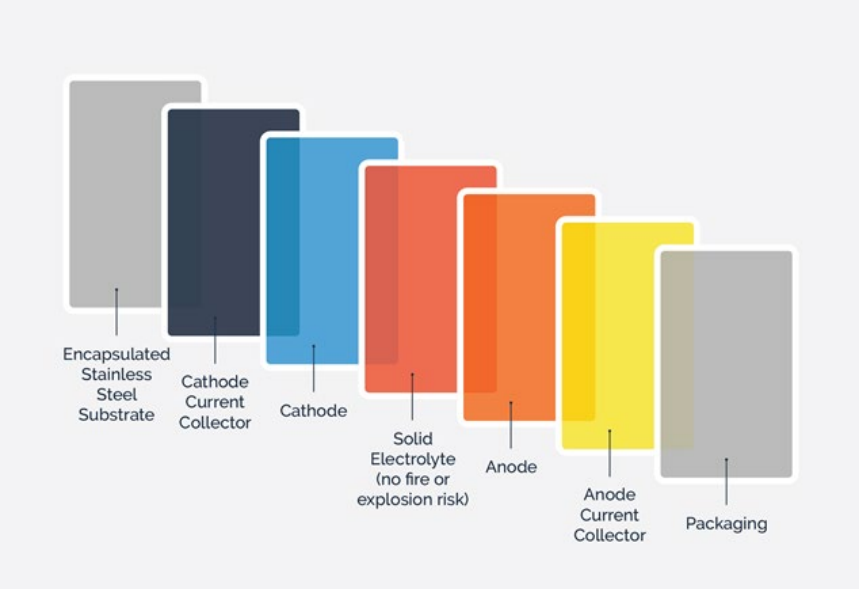
Company description: Differentiated micro-batteries

Thin Film Electronics started off 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. The company originally focused on the development of higher-density polymer-based memory and formed a joint venture with Intel from 1999 to 2004 during which it demonstrated 0.5Gb of ferroelectric polymer memory. It subsequently moved into the development of lower-density, high-volume printed memory, using some of the IP developed with Intel, integrating this memory with other electronic components to produce fully printable system solutions for a range of applications including near-field communication (NFC) and electronic article surveillance (EAS) tags. Following initial successes with global drinks giant Diageo, management decided in 2016 to expand capacity to c 1bn tags annually by installing an R2R production line in San Jose.

While initial uptake by customers was encouraging, Thinfilm was dependent on widespread adoption of NFC tags by brand owners for brand protection and marketing purposes. This did not happen, despite the manifold benefits of the new technology. Early in 2019 management decided to halt R2R production to save costs. By this stage the production line had output several million EAS tags and was preparing to commence R2R production of the more complex NFC tags.

In January 2020 management announced its new strategy, using the R2R assets and printed electronics IP to develop and manufacture miniature solid-state lithium batteries rather than NFC tags. Thinfilm's ability to print electronic components on a flexible steel substrate means that it can offer micro-batteries that offer superior performance to conventional lithium-ion rechargeable batteries, thus commanding a premium price. Importantly, since Thinfilm's solid-state format is proposed as a replacement for conventional coin and button batteries in hearing aids as well as addressing emerging markets such as connected sensors and sports wearables, the demand is already there, so the company does not need to build up the market itself. In addition, since the ASP for a solid-state lithium battery is around 100 times greater than that for an NFC tag, management estimates that it would be possible for Thinfilm to have a cash-generative, profitable business on around 10m units per year. This compares favourably with management's estimates of an addressable micro-batteries market of over 1bn units per year.

Exhibit 1: Structure of Thinfilm's solid-state lithium battery



Source: Thinfilm

The company's corporate headquarters are in Oslo, Norway, and its global headquarters are at its high-capacity flexible electronics manufacturing site in San Jose, California. It employs around 20 staff plus consultants. The company's shares were admitted to listing at the Oslo Axess in January 2008 and to the Oslo Børs in February 2015. Thinfilm's American depository receipts (ADRs) commenced trading in the US on the OTCQX market in March 2015. The US listing was transferred to the OTCQB Venture Market in June 2020.

Market overview

Advantages of solid-state battery technology

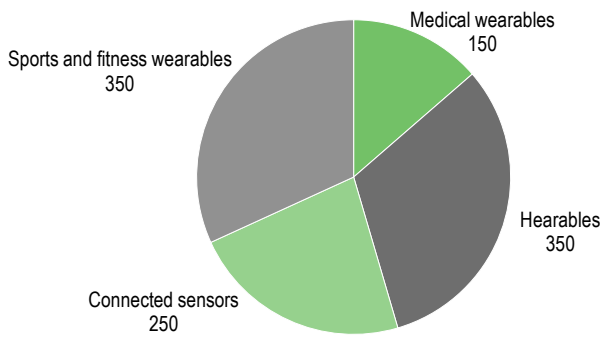
Of the many types of battery chemistry available, lithium-ion has become increasingly popular because of its relatively high energy density. This means that a conventional lithium-ion battery can store twice the energy of a nickel cadmium battery of the same size and weight. A solid-state lithium battery improves on a conventional lithium-ion battery by replacing the liquid or polymer gel electrolyte with a solid material, usually either a ceramic or a solid polymer, although sulphides and glass are also used. This solid electrolyte prevents the anode and cathode from touching and creating a short-circuit, eliminating the need for a dedicated separator as required in a battery with a liquid or gel electrolyte and thus reducing bulk and assembly complexity. Solid-state batteries can store around double the charge of their conventional counterparts, resulting in batteries that are smaller and lighter for the same amount of charge stored. Solid-state batteries also charge at twice the speed, retain the charge for longer and last for two to three times the number of charge/discharge cycles. The elimination of flammable liquid electrolytes makes batteries safer and reduces the amount of packaging or control circuitry required to reduce the risk of thermal runaway, further improving energy density. Since all the parts are solid, the resultant batteries can also be produced in unconventional formats such as wires or ribbons, which means that manufacturers can customise products, improving customer retention.

Addressing demonstratable needs in billion-unit end market

Near term

Management expects that its R2R manufacturing technique would enable it to offer solid-state lithium micro-batteries at a price that is similar to conventional lithium-ion batteries if required. However, it is focusing initially on those sectors where the high energy density and thin form factor enabled by the technology are most sought after and can command premium pricing, thus maximising the EBITDA potential of the existing manufacturing capacity.

Exhibit 2: Micro-batteries market in 2025 (in millions of units)



Source: Thinfilm estimates based on sources including IDTechEx

To start with Thinfilm is concentrating on the medical wearables and hearables markets, followed by the connected sensors and sports wearables markets, which are at an earlier stage of evolution. All four markets require micro-batteries capable of holding between a milliWatthour (mWh) and a Watthour (Wh) of energy and having a volumetric energy density of 600–1,000Wh /litre. This is achievable using Thinfilm's existing chemistry. Referencing research from IDTechEx, management notes that these markets are predicted to grow to over 1bn batteries per year by 2025. Following expressions of interest, management has recently expanded its target markets to include defence applications.

Hearables (addressable market of 350m units/year): This application includes hearing aids and wireless earbuds. Hearing aids are transitioning from non-rechargeable batteries to conventional lithium-ion batteries, which are rechargeable. However conventional rechargeable batteries only last through 300–400 charge/discharge cycles, which is around a year if the battery is recharged overnight while the wearer is asleep. In contrast, a solid-state lithium battery will last for over 1,000 charge/discharge cycles, or around three to four years. Once the rechargeable battery reaches its cycle limit, typically the user has to send the hearing aid to the supplier to have the battery replaced, the cost of which may be covered by the supplier as part of the service warranty. Using a solid-state micro-battery instead of a conventional lithium-ion battery would save on service costs, supporting payment of a premium for the solid-state option.

Medical wearables (addressable market of 150m units/year): this application includes continuous glucose monitors, cardiac monitors, temperature monitors, physiological monitors and motion sensors. Here patient comfort is a priority so replacing a coin (3.2 millimetres (mm) thick) or button (4.6mm thick) cell with a device that is not only half the volume but also available as a thin (0.05–0.5mm) patch that conforms to the shape of the body is a significant advantage. Eliminating concerns about a battery in close proximity to the body bursting into flames is also relevant. Moreover, substituting a conventional lithium-ion battery with a solid-state one means that the total cost of batteries over the lifetime of the wearable is likely reduced. In September 2020 Emergen Research predicted that the high incidence of diabetes, increasing geriatric population and technological advancements would result in the global continuous monitoring market system growing from $3.45bn in 2019 to $14.54bn in 2027, a CAGR of 19.6%. In August 2020 GlobalData published a report stating that the global wearable technology market was worth nearly $27bn in 2019. It predicted that the market was likely to grow to $64bn by 2024 despite the recessionary effect of the pandemic because the technology was being used to track disease contacts, predict symptoms and monitor patients.

Connected sensors (addressable market of 250m units/year): this application includes environmental sensors, smart commercial buildings and smart manufacturing. Here the goal is to integrate miniature batteries with energy harvesting devices, namely, small solar panels that top-up the charge during the day, or piezo-electric crystals so that a wireless sensor can be installed in a hard-to-reach area such as wind turbine blade and then left for several years without incurring the cost of a maintenance person replacing the battery. This approach requires a battery that can undergo multiple thousands of charge/discharge cycles before needing to be replaced, so a solid-state battery becomes a more cost-effective option than a conventional lithium-ion battery.

Sports and fitness wearables (addressable market of 350m units/year): this application includes small electronic devices for activity measurement and the emerging smart apparel/smart textiles market. Comfort is possibly even more important here than in the medical wearables markets, since wearing the monitor is discretionary.

Longer term

By 2023 Thinfilm intends to offer rechargeable batteries capable of holding a Watthour to a kiloWatthour of charge for devices such as power tools, mobile phones and smart watches where

the more rapid charging than is available from conventional lithium-ion batteries is highly desirable. This will require changes to Thinfilm's existing chemistry including enhancements to the electrolyte and adaptation to the anode chemistry to achieve the increase in volumetric energy density to over 1,000Wh/litre required, corresponding to Phase 3 of the company's technology roadmap (see Exhibit 7). Our valuation analysis (see below) excludes any revenues from the sales of these higher-capacity devices. Given the potential volumes involved relative to the capacity of the existing R2R facility, Thinfilm may decide to out-license the underlying technology at this point. Thinfilm does not intend to engage in the bulk storage market providing batteries for electric vehicles, domestic back-up storage or utility scale storage as this market is characterised by commodity pricing and is better addressed by companies investing in gigafactories, as discussed in our note on batteries for electric vehicles.

Competitive environment

Benefits of stainless steel substrate

Over the last decade Thinfilm has developed techniques for building high-performance electronics on very thin, flexible steel substrates, enabled by a proprietary barrier technology that makes steel a suitable substrate material for electronic devices. This process has been proven through the manufacture of millions of anti-theft tags. Thinfilm has taken the solid-state battery technology developed by Oak Ridge National Laboratory in the US during the 1990s, which is no longer under patent, and adapted it so that the layers forming the battery are printed on a very thin steel substrate. Compared to its earlier product lines such as NFC tags, Thinfilm's battery manufacturing process uses a subset of already proven manufacturing processes and installed equipment, thereby minimising the risk of new technology implementation.

Exhibit 3: Comparison of solid-state battery substrate types

Substrate	Silicon wafer	Flexible ceramic	Flex polyimide on Gen 8 glass	R2R steel
Company	Cymbet, Ilika	ITEN*	None*	Thinfilm
Energy density	Good	Good	Poor	Excellent – 30% higher than existing SSLB
Flexibility at 0.025mm	Poor	Good	Excellent	Excellent
Cost	Poor	Poor	Poor	Good
Substrate area	0.03m^2	20m^2	~ 3m^2	64m^2
Units per substrate (5cm^2)	50	36,000	5,400	108,000

Source: Thinfilm data. Note: *Probable.

Thinfilm manufactures the batteries on an ultra-thin film of stainless steel. Since steel is available as very thin foils, this results in a battery where the substrate takes up a smaller proportion of the total volume, immediately improving energy density. Manufacturing batteries with a thinner silicon substrate is more complicated because it requires additional processing steps to make the silicon substrate, which comes in a standard thickness, thinner. Having a steel support rather than part of a silicon wafer means that the battery is flexible and durable and can easily be made in unusual shapes such as rings. In contrast, silicon wafers are brittle and crack easily. Since steel is naturally air and water-tight the substrate is a good packaging material, preventing moisture or oxygen from reacting with the lithium metal forming the battery anode. This means fewer layers that only provide a packaging function are required, which also improves energy density. It is also relatively easy to stack cells made on a steel substrate.

Existing facility available for volume manufacture

Thinfilm already has a fully equipped and proven R2R production facility in which c $40m has been invested. It does not need any material capital expenditure to modify any of the existing tools for battery production. It does not need to raise finance to fund the capacity expansion required to move to volume production or alternatively to find a manufacturing partner that will take a share of

the profits. Management estimates that the R2R facility has the capacity to output around 50m milliamp-hour class micro-batteries per year, depending on the distribution of battery capacities. This position is in contrast with AIM-listed Ilika, which generated £0.4m revenues from sales of samples during FY20 (as well as £2.4m from grants) but only has the capacity at present to produce 1,500 batteries/year from its pilot line and will have to wait until capacity at its UK partner fabrication facility is commissioned towards the end of CY21 before it is able to supply 100,000 microamp-hour class devices a year.

Exhibit 4: Part of Thinfilm's R2R facility

Source: Thinfilm

Exhibit 5: Detail of R2R equipment

Source: Thinfilm

Cost benefit of roll-to-roll process

A continuous R2R process is much more cost-effective than processing batches of individual silicon wafers. We note that ceramic substrates are brittle and therefore unsuitable for use in R2R production processes.

Micro-battery competitors not addressing mWh category

Other companies developing solid-state batteries address applications that require either less power than Thinfilm's batteries can potentially provide or substantially more power so they are suitable for electric vehicles. A review of companies currently offering micro-batteries indicates that none of them have a product with as much capacity as the samples that Thinfilm has recently produced (<50 milliamp hours (mAh)). **Cymbet's** EnerChip is 0.05mAh. This is available as a bare die only as the company has discontinued sale of packaged devices. **FDK Corporation** announced in May 2019 that it was commencing sample shipments of its small solid-state battery for certain customers. While the product is targeted at IoT devices, wearables, chip-set reference clocks and industrial and automotive equipment used in harsh environments, its capacity is 0.5mAh. AIM-listed **Ilika**'s Stereax battery has a capacity of 0.05mAh and is also is available as a six-cell stack with a capacity of 0.3mAh. The company recommends combining the cells like Lego blocks if volume allows to reach the mAh level. **Iten** opened its manufacturing site in December 2018, with an initial production capacity of over 10m components each year and the potential to increase this fivefold. Its highest capacity off-the-shelf battery is 0.5mAh. **TDK Corporation**'s CeraCharge measures just 4.4mm by 3.0mm by 1.1mm, smaller than a dried lentil, and has a capacity of 0.1mAh. TDK announced output of 30,000 units a month in August 2018, claiming that it was 'The world's first instance of practical application for a solid-state battery that can be incorporated into electric circuits.'

Route to commercialisation

Thinfilm has already made significant progress on executing its revised strategy. Earlier this year it demonstrated that it could make solid-state lithium batteries using processes similar to those it has

already used for volume production of anti-shoplifting and NFC tags. Having done that, it has started to build up a customer-base and is preparing to ship samples to customers for evaluation. The next key milestone that investors should be looking for is whether any of these evaluations has been successful, leading to one or more customers deciding to develop products incorporating Thinfilm's batteries. Management expects that initial customers could make this decision towards the end of FY20.

Exhibit 6: Roadmap to profitability

Date	Milestone	Achieved
January 2020	Announcement of updated strategy focussing on solid-state lithium batteries	Yes
April 2020	Multiple battery-specific IP filings	Yes
June 2020	Successful deposition of critical layers of solid-state lithium battery stack	Yes
July 2020	Successful fabrication of functional batteries on stainless steel substrates at San Jose, manufacturing facility. Initial characterization testing demonstrates expected energy densities	Yes
October 2020	Successful creation of multi-cell batteries based on Thinfilm's proprietary stacking and encapsulation technology	Yes
End 2020	Customer design-ins	
2021	Phase 2 enhancements to technology (see Exhibit 7)	
End 2021	First revenue from solid-state lithium battery products	
2022	Phase 3 enhancements to technology (see Exhibit 7)	
End 2022	Cashflow break-even	
2023	Cash generation from delivery of over 10m units/year	

Source: Thinfilm data

Engaging with new customer base

Thinfilm is already engaged with more than two dozen potential customers. It is adopting a two-prong approach to market development. It is working directly with Tier One OEM customers in medical wearables, hearables, connected sensors and sports wearables markets. It is also partnering with companies that have expertise in wireless charging, energy harvesting and managing power consumption with the intention of helping them create a complete system for demonstrating to joint customers.

Improving technology

Management deliberately adopted a mature, well understood solid-state technology so that it can produce viable samples as quickly as possible and is targeting markets where customers are happy to pay a premium for higher energy densities. Thinfilm's initial samples have met or exceeded the company's expectations for energy density and initial products are expected to exhibit volumetric energy densities superior to typical rechargeable coin cells, enabling it to create batteries with the same capacity but that are 30–50% thinner. Its development programme through to 2023 aims to create batteries that have double to treble the energy density of a rechargeable coin battery. This will enable it to offer batteries that either have much higher capacity for the same battery volume, in effect extending times between charging for the same size battery, or provide equivalent energy storage capacity in a significantly smaller volume, thereby enabling form factor improvements in the end product.

Exhibit 7: Technology roadmap

Product	Timing	Volumetric energy density (Wh/l)	Capacity (mAh)	Comparative volumetric energy density	Development hurdles
Coin cell (third party)	Now	180–350	1–50	Reference level	Existing technology from in market
Thinfilm Phase 1	Sampling late 2020	400–500	1–50	30–50% higher than coin cell	Existing technology
Thinfilm Phase 2	2021	500–800	1–100	20–30% higher than Phase 1	Substrate thinning and cell stacking
Thinfilm Phase 3	2023	700–1000	1–200	50% higher than Phase 2	Packaging and cell chemistry improvements

Source: Thinfilm data

Optimising cash runway

Having decided to focus resources on developing a solid-state lithium battery that could be manufactured in volume using its existing R2R flexible electronics facility, Thinfilm quickly restructured its business operations to support this strategy. Management implemented major restructuring activities Q120. It made incremental reductions in headcount during Q220 in functions that were unrelated to the core battery activities, which were partially offset by hires in battery technology development, process integration, packaging development and equipment engineering.

Following the successful attainment of technical milestones, Thinfilm announced additional committed funding to facilitate the next phase of the company's technology development and commercialisation strategy. This is outlined in the Financials section.

Management

Kevin Barber joined Thinfilm as CEO in November 2018. He was previously senior vice president, general manager mobile division of Synaptics where he helped grow revenue fourfold to over $1bn annually. Prior to that he was CEO of ACCO Semiconductor, a venture capital-funded start-up. Before that he was senior vice president, general manager, mobile business at Skyworks Solutions where he led the strategy achieving top RF power amplifier market share in the high-growth mobile market. He has also served as senior vice president, operations at Conexant.

As part of the restructuring during H120, Mallorie Burak stepped down as CFO in May and Dave Williamson, the company's corporate controller, was appointed acting CFO.

Sensitivities

The key sensitivities as we see them are:

Technology risk: Thinfilm has already made development samples of micro-batteries using its stainless steel substrate technology. It has most of the expertise required in-house to complete Phase 2 of its technology roadmap as this is in effect an optimisation of the process already used to create sample batteries. However, Thinfilm will have to carry out a substantial amount of research to complete Phase 3 of its technology roadmap, which takes it into mid-market applications. It may consider licensing an anode technology if appropriate.

Scale-up risk: the existing R2R facility was used to manufacture several million anti-theft tags. These tags did not need as many processing steps as NFC tags. While NFC production did not progress from sheet-to-sheet to R2R production, each of the processes required to manufacture NFC tags was validated on the R2R equipment. Because manufacture of battery cells uses the same equipment and processes as tag manufacture, but actually requires significantly fewer steps, it is reasonable to assume that there is relatively little risk in migrating the battery technology from low volume sheet-to-sheet manufacture as at present to R2R production.

Commercial risk: because Thinfilm has not started to sell product in commercial volumes yet, there remains some risk that it will not be able to offer product at an appropriate price point. However, since Thinfilm has already run the R2R facility as a commercial operation, it should be able to calculate the cost of manufacturing batteries at volume fairly accurately. Moreover, as its solid state lithium batteries are proposed as a substitute for conventional lithium-ion batteries, particularly coin and button batteries, there is already a reference price point that potential customers can use when deciding whether the premium for the superior energy density, cycling and safety offered by Thinfilm's alternative is merited. Assuming that Thinfilm has already had

preliminary pricing discussions with potential customers, we believe the risk of not being able to manufacture the batteries at an acceptable price point is significantly reduced.

IP protection: Thinfilm has filed patents to protect core battery layer innovations as well as unique methods of cell packaging, including sealing, assembly, stacking and interconnection. This includes ensuring that the steel substrate, which is by nature highly conductive, is treated so that it does not short out the components deposited on it. It has also built-up considerable expertise in volume manufacturing of flexible electronics using R2R equipment. However, very large battery companies such as CATL and LG Electronics do have the in-house expertise to adapt the original solid-state technology from Oak Ridge National Laboratory to create their own battery stacks. We believe it would be possible for established battery companies to develop their own variants of Thinfilm's technology, copying the use of a steel substrate to get the energy density required to create cells with mAh scale capacity. Given the effort required though, we believe it is more likely that they would license the underlying technology or possibly even consider acquiring Thinfilm outright. However, at the moment these larger companies are focusing their development resources on much larger batteries for the electric vehicle market, where volumes are more suited to their business models.

Dependence on customers: The level of market penetration that Thinfilm will achieve is largely dependent on the success of sales and marketing programmes undertaken by its customers.

Funding: Management estimates that the cash from the private placement and subsequent subscription completed between July and September and warrant exercises has extended the company's cash runway through Q121. Depending on the timing and quantity of further warrant exercises (see Exhibit 9), management estimates that it may be able to fund planned operations deeper into FY21. However, if the timing and quantity of warrant exercises are insufficient to meet the company's needs, the company would need to pursue other sources of financing, which may be materially dilutive or not forthcoming.

Financials

Operating losses substantially reduced during FY20 so far

Exhibit 8: Nine months ended September 2020 (9M20) and September 2019 (9M19) profit and loss summary

Amounts in $k	9M20	Notes	9M19	Notes
Sales revenue	491	Sale of remaining EAS tags in finished goods inventory in January	696	Shipments of 5.3m EAS and 1.5m NFC tags
Other income	109	Sub-lease of second floor of San Jose facility	205	Sub-lease of second floor of San Jose facility
	(89)	Loss on disposal of fixed assets	314	Government grants
Total revenue & other income	**512**		**1,215**	
Payroll	(2,582)	Year-on-year reduction in headcount	(16,152)	
Services	(1,908	Expenditure on consultants and contractors lower because of reduced activity levels and cost saving initiatives	(3,756)	
Premises, supplies	(2,199)	Lower because of world-wide downsizing of operations during FY19	(4,655)	
Sales and marketing	(32)		(887)	
Other expenses	(2,182)	Includes cost of sales of EAS tags and higher insurance costs	(2,776)	
Share-based payments	(234)		(116)	
Depreciation and amortisation	(9)	Majority of fixed assets written off at end FY19	(3,140)	
Operating loss	(8,634)		(30,267)	
Net interest	(2,292)		(538)	
Warrants charge	(9,478)		-	
Loss before tax	(20,404)		(30,805)	

Source: Thinfilm data

Thinfilm derived $0.5m revenues during 9M20 from sales of the remaining stock of EAS tags. Total revenue and other income declined by more than half year-on-year to $0.5m because of the absence of EU grants. Following the restructuring initiatives that took place in Q319 and H120, payroll costs were $13.6m lower year-on-year in 9M20 and total operating costs were $19.2m lower. As a result, operating losses narrowed by $21.6m to $8.6m.

Cash benefits from oversubscribed fund-raising

Net debt increased by $1.8m during 9M20 to $7.8m at end September 2020 (excluding $1.6m restricted cash and $12.5m financial lease liabilities). Excluding restricted cash, gross cash at the end of September was $5.4m. Working capital increased by $0.5m as the company shipped EAS tags that had been paid for in December 2019. Interest paid was $2.3m. Investment in capital equipment was minimal and all R&D activity was expensed.

Having proven the technology sufficiently to file patent applications regarding the battery technology, Thinfilm raised $3.4m (net) through a private placing and subsequent offer, which was oversubscribed by over six times, at NOK 0.11/share during May and June, which was a significant discount to the market price. The terms of the offer included the issue of one Warrant A and one Warrant B for each of the 290.9m shares issued over this period (see Exhibit 9). The fund-raising programme during May and June was followed by another one between July and September. This consisted of a private placement raising NOK50m ($5.5m) and subsequent offer raising NOK10m ($1.1m), which was oversubscribed by nine times, resulting in the combined issue of 400.5m new shares at NOK0.15/share, also at a discount to the market price. Thinfilm has also raised an estimated NOK22.6m ($2.5m) through the exercise of warrants since the end of September. Management estimates that the cash from the private placement and subsequent subscription and warrant exercises has extended the company's cash runway through Q121. Depending on the timing and quantity of further warrant exercises (see Exhibit 9), management estimates that it may be able to fund planned operations deeper into FY21.

Exhibit 9: Potential financing from the exercise of warrants issued during FY20

Name	Number	Exercise date	Exercise price	Potential
Warrant A	290.9m	Expiring 31 December 2020	NOK0.11/share	< NOK32.0m
Warrant B	290.9m	Expiring 20 August 2021	NOK0.25/share	< NOK72.8m
Warrant C	400.5m	31 March 2021 to 30 June 2021	NOK0.25/share	< NOK100.1m

Source: Thinfilm data

Valuation: Addressing a market of over 1bn units/year

Since Thinfilm is still at the pre-revenue stage with regards to its solid-state battery technology and there are no consensus estimates, we prefer to present a scenario analysis rather than a formal valuation based on peer multiples.

Exhibit 10: Potential annual revenues from milliWatthour market ($m)

		Market share (%)				
		1%	3%	5%	7%	10%
Price/unit ($)	1	11	33	55	77	110
	2	22	66	110	154	220
	3	33	99	165	231	330
	4	44	132	220	308	440
	5	55	165	275	385	550

Source: Edison Investment Research

Referencing research from IDTechEx, and others, management notes that the medical wearables, hearables, connected sensor and sport and fitness wearables markets are predicted to grow to over 1bn units/year by 2025. As discussed above, these markets require batteries in the mWh–1Whr

capacity range. This capacity range is already covered by conventional lithium-ion batteries, though the relative size of lithium-ion batteries compared to solid-state batteries makes it likely that a material percentage of device manufactures will elect to pay a premium for the solid-state option. Thinfilm's management estimates that it will be able to secure a price/unit in the lower single-digit dollars. We note that Farnell sells 560mAh conventional lithium-ion rechargeable coin cells from Varta for £1.12–3.20 (ex-VAT) depending on the volume required. Our scenario analysis presents the annual revenues realisable from these markets for a range of unit prices and levels of market penetration.

The analysis shows that a 5–10% share of these markets represents annual revenues of $165–220m. Based on management guidance of c $20m fixed costs and 30% variable costs, this gives an EBITDA range of $95.5–134m. This calculation is consistent with management's observation that when the R2R factory in San Jose is fully utilised it should be able to output several hundred million mAh of batteries each year, potentially generating EBITDA of over $100m.

This analysis excludes any revenues from the sales of higher capacity devices for applications such as smartphones or power tools or for mWhr devices for defence applications. Given the potential volumes involved relative to the capacity of the existing R2R facility, Thinfilm may decide to out-license the underlying technology at this point.

Exhibit 11: Financial summary

US$m	2016	2017	2018	2019
Year end 31 December	IFRS	IFRS	IFRS	IFRS
PROFIT & LOSS				
Revenue	3.8	5.9	3.4	1.2
EBITDA	(36.9)	(50.9)	(49.3)	(30.6)
Operating Profit (before amort. and except.)	(39.9)	(54.8)	(53.3)	(34.5)
Intangible Amortisation	0.0	0.0	0.0	0.0
Exceptionals	(0.1)	(3.0)	(15.6)	(42.4)
Share-based payments	(1.4)	(2.2)	(1.8)	(0.2)
Operating Profit	(41.5)	(60.1)	(70.6)	(77.1)
Net Interest	(2.7)	0.4	(1.1)	(1.4)
Profit Before Tax (norm)	(42.7)	(54.5)	(54.3)	(35.9)
Profit Before Tax (FRS 3)	(44.2)	(59.7)	(71.7)	(78.5)
Tax	(0.3)	0.1	(0.0)	0.0
Profit After Tax (norm)	(43.0)	(54.3)	(54.4)	(35.9)
Profit After Tax (FRS 3)	(44.5)	(59.6)	(71.7)	(78.4)
Average Number of Shares Outstanding (m)	659.1	862.7	58.6	58.6
EPS - normalised ($)	(0.07)	(0.06)	(0.93)	(0.61)
EPS - (IFRS) ($)	(0.07)	(0.07)	(1.22)	(1.34)
Dividend per share ($)	0.00	0.00	0.00	0.00
EBITDA Margin (%)	N/A	N/A	N/A	N/A
Operating Margin (before GW and except.) (%)	N/A	N/A	N/A	N/A
BALANCE SHEET				
Fixed Assets	24.9	34.2	35.3	.6
Intangible Assets	3.1	2.2	2.4	0.0
Tangible Assets	9.2	20.5	22.5	0.0
Investments	12.6	11.5	10.4	.6
Current Assets	79.2	115.1	44.1	11.7
Stocks	1.1	0.7	2.6	0.0
Debtors	3.9	16.2	8.9	2.8
Cash	74.2	98.1	32.6	8.9
Other	0.0	0.0	0.0	0.0
Current Liabilities	(7.8)	(7.3)	(8.1)	(6.8)
Creditors	(7.8)	(7.3)	(8.1)	(5.5)
Short term borrowings	0.0	0.0	0.0	(1.4)
Long Term Liabilities	(12.9)	(12.1)	(11.5)	(25.1)
Long term borrowings	(12.6)	(12.1)	(11.5)	(25.1)
Other long term liabilities	(0.3)	0.0	0.0	0.0
Net Assets	83.5	129.9	59.7	(19.7)
CASH FLOW				
Operating Cash Flow	(37.4)	(52.3)	(52.3)	(29.1)
Net Interest	0.1	0.3	0.3	(1.4)
Tax	(0.1)	(0.0)	(0.1)	.0
Capex	(5.4)	(27.1)	(11.2)	(5.1)
Acquisitions/disposals	0.0	0.0	0.0	0.0
Financing	101.1	103.3	(0.0)	0.0
Dividend payments and Other items	(0.1)	.2	(1.6)	0.0
Net Cash Flow	58.3	24.4	(64.9)	(35.5)
Opening net debt/(cash)	(15.9)	(61.6)	(86.0)	(21.1)
Finance leases initiated	(12.6)	0.0	0.0	0.0
Other	0.0	0.0	0.0	(3.1)
Closing net debt/(cash)	(61.6)	(86.0)	(21.1)	17.6

Source: Thinfilm data

Contact details	Revenue by geography
2581 Junction Avenue San Jose, CA 95134 US +1 408 503 7300 www.thinfilmsystems.com	N/A

Management team

CEO: Kevin Barber	Acting CFO: Dave Williamson
Kevin Barber joined Thinfilm as CEO in November 2018. He was previously senior vice president, general manager mobile division of Synaptics where he helped grow revenue fourfold to over $1bn annually. Prior to that he was CEO of ACCO Semiconductor, a venture capital-funded start-up. Before that he was senior vice president, general manager, mobile business at Skyworks Solutions where he led the strategy achieving top radio frequency power amplifier market share in the high-growth mobile market. He has also served as senior vice president, operations at Conexant.	Dave Williamson joined Thinfilm in February 2020 and serves as acting chief financial officer. He is an experienced financial executive with years of vice president and senior controller experience at large public international companies in addition to successful venture-backed companies.
EVP Technology Development & Manufacturing: Dr Arvind Kamath	**Marketing: Matthew Bright**
Dr Kamath joined Thinfilm in January 2014 on the acquisition of Kovio, where he served as senior director, technology development. He was responsible for R2R scale-up at Thinfilm and led Kovio's development of a printed electronics based on silicon ink from feasibility to qualification and yield enhancement. Prior to Kovio he worked at LSI Logic in various managerial and specialist roles including process engineering, R&D operations, SRAM integration and yield enhancement.	Matthew joined Thinfilm in January 2014 on the acquisition of Kovio, where he had led technical marketing activities from 2010. Prior to Kovio he led marketing for the global wireless segment at Spansion and memory product launch activities at Advanced Micro Devices.

Principal shareholders	(%)
Alden	10.2
Tigerstaden	7.1
Middelborg Invest	6.9
Dukat	4.7
Forte Norge	2.6

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