

Supporting Information

Nanomanufacturing: A Perspective

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The text below captures the data sources and assumptions used in estimating the information presented in figures 2 and 4.

Figure 2

Assembling the data for (Fig. 2 in the main text requires piecing together information from many sources, together with some estimates. The data sources and assumption used are given below.

Flat glass

Annual production

9.2B m² in 2016 - <http://www.freedoniagroup.com/industry-study/2970/world-flat-glass.htm>

Construction (85 %), automotive (15 % to 20 %), solar (< 5%) -

<http://www.glassforeurope.com/en/industry/index.php>

Market value

\$78B in 2013 - <http://www.slideshare.net/MihirKumar2/flat-glass-industry-analysis-47205567>

Price

\$1 m⁻² to \$10 m⁻² – estimated from information available on commercial business to business websites.

Self-cleaning glass \$10 m⁻² to \$20 m⁻² <http://www.polyu.edu.hk/greencampus/en/news-and-communications/polyu-s-green-news/319-201504-nano-coating-curtain-walls.html>

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Flat Panel Displays

Annual Production

168.9 M m² <http://press.ihs.com/press-release/technology/flat-panel-display-area-demand-growing-rapidly-according-ihs>

Market value

Flat panel displays (all): \$97B in 2014 - <http://www.futuremarketinsights.com/reports/details/global-flat-panel-display-market>

Price

Estimated as \$1 000 from market size and annual production.

Touch Screens

Annual Production

168.9 M m² <http://press.ihs.com/press-release/technology/flat-panel-display-area-demand-growing-rapidly-according-ihs>

Smartbook touchscreens 2.2 M m² estimated to comprise 50 % of market

Market value

Estimated at between \$6B and \$20B from a large number of sources, including

<http://crystal-display.com/touchscreens/touchscreen-market-growing-10-times-faster-than-other-displays/>

Price

Price for notebook flat screen PC module \$40, ≈ \$500 m⁻²

<http://informationdisplay.org/IDArchive/2014/JulyAugust/DisplayMarketplaceNewTrends.aspx>

Conductive films

Indium Tin Oxide (ITO) films cost \$25 m⁻² in touchscreen displays – estimated from prices on commercial business to business websites.

PV

Annual Production

168.9 M m² <http://press.ihs.com/press-release/technology/flat-panel-display-area-demand-growing-rapidly-according-ihs>

Market value

\$90B

<https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&ved=0CDkQFjAEahUKewjB27rR9eXHAhUGkx4KHc1gDr0&url=https%3A%2F%2Fwww.fas.org%2Fsgp%2Fcrs%2Fmisc>

[%2FR42509.pdf&usg=AFQjCNFz8Xpukq9eg6eGuHX-t1MfLrkBeg&sig2=mvYYtOU_ExgLjF5rmVZUiQ&bvm=bv.102022582,d.dmo&cad=rja](#)

<http://www.nrel.gov/docs/fy14osti/62558.pdf>

Price

Module cost estimated from commercial business to business websites to derive $\$/\text{m}^2$

ICs

Annual production

Si wafers: 6.5 M m^2 <http://www.semi.org/node/54591>

Market value

\$335.8B in 2014

http://www.semiconductors.org/news/2015/02/02/global_sales_report_2014/global_semiconductor_industry_posts_record_sales_in_2014/

Price

Range estimated from fabrication costs for mature technology ($\$50000 \text{ m}^{-2}$) to price for leading-edge device (Intel Broadwell, 82mm^2 , 1.3B transistors, sale price $\$350$, $\$4.3\text{M m}^{-2}$)

HDD

Annual Production

<http://www.storagenewsletter.com/rubriques/market-reportsresearch/shipments-of-disk-drives-decline-5-in-2013/>

400M units

<http://www.forbes.com/sites/tomcoughlin/2015/01/29/hdd-annual-unit-shipments-increase-in-2014/>

560M units

Estimate of area produced per year based on number of units shipped. Assume 5, 100 mm diameter platters per drive. This yields $\approx 2 \times 10^7 \text{ m}^2$ of storage media produced annually.

https://en.wikipedia.org/wiki/Hard_disk_drive

Market value

\$32B

<https://technology.ihs.com/420442/hard-disk-drive-market-revenue-set-for-double-digit-decline-this-year>

Price

Estimated from prices quoted on commercial component supply websites and assuming a cost of $\$10$ per drive for the storage media.

Blu-ray

Annual Production

400M units, 120 mm in diameter. 4.5M m^2

<http://www.mwtnewsandviews.com/2011/06/report-charts-blu-rays-five-year.html>

Market value

\$3B

<http://www.mwtnewsandviews.com/2011/06/report-charts-blu-rays-five-year.html>

Price

\$7.5/disc estimated from commercial suppliers

Pregnancy Tests

Annual production

100M sold/year, Active area approx. 1cm^2 , $10\,000\text{ m}^2$

Market value

\$700M market, \approx \$15/pair <http://www.dcnx.com/application-detail/consumer-diagnostics>

\$500M, \$5/each <http://www.slideshare.net/technavio/global-pregnancy-detection-kit-market-20152019>

Price

$\$50\,000\text{ m}^{-2}$ Estimated from price per unit and active area

Figure 4

Throughputs and Cost

The data for Fig. 3 is estimated as follows from publicly available data and from private communications from industry experts.

193i photolithography - $\$141/\text{m}^2$. Throughput = 240 300mm wafers/hr = $4.7 \times 10^{-3}\text{ m}^2/\text{s}$

SEMATECH COO model of $\$10/\text{wafer}/\text{level}$.

Variable shaped-beam for mask making - $\$800,000/\text{m}^2$. Throughput = $25\text{ cm}^2/\text{hr} = 7 \times 10^{-7}\text{ m}^2 \cdot \text{s}^{-1}$

Operating costs of \approx $\$2,000/\text{hr}$

Focused ion beam for mask repair and circuit edit - $\$10^{11}\text{m}^{-2}$, $10^{-12}\text{ m}^2 \cdot \text{s}^{-1}$

Operating costs of \approx $\$600/\text{hr}$

Mask editing assumptions

Typical chrome thickness 100 nm

100 μm^2 milling area, time between 87 s to 164 s

Gives 0.6097 $\mu\text{m}^2\cdot\text{s}^{-1}$ to 1.149 $\mu\text{m}^2\cdot\text{s}^{-1}$

Nanoimprint

Hot embossing

Tool cost: \$3M

Tool throughput: 0.2 $\text{m}^2\cdot\text{s}^{-1}$

Mask cost: \$3000

Mask life: 100,000 m^2

Running cost estimate (includes labor and spare parts, etc.): \$0.3 m^{-2}

Tool CoO: \$0.13

Mask CoO: \$.03

Running \$.30

Total cost $\text{m}^{-2} \approx \$0.46 \text{m}^{-2}$

UV cure

Assume 100nm thick resist costing $\approx \$1000 \text{L}^{-1}$, the resist will cost about \$1 m^{-2} . Additional costs for coating unit and UV exposure unit will further increase the cost, leading to an estimate of $\approx \$5 \text{m}^{-2}$.