Potential Flexible Electronics Applications Using CNF as Substrate: Opportunities and Challenges

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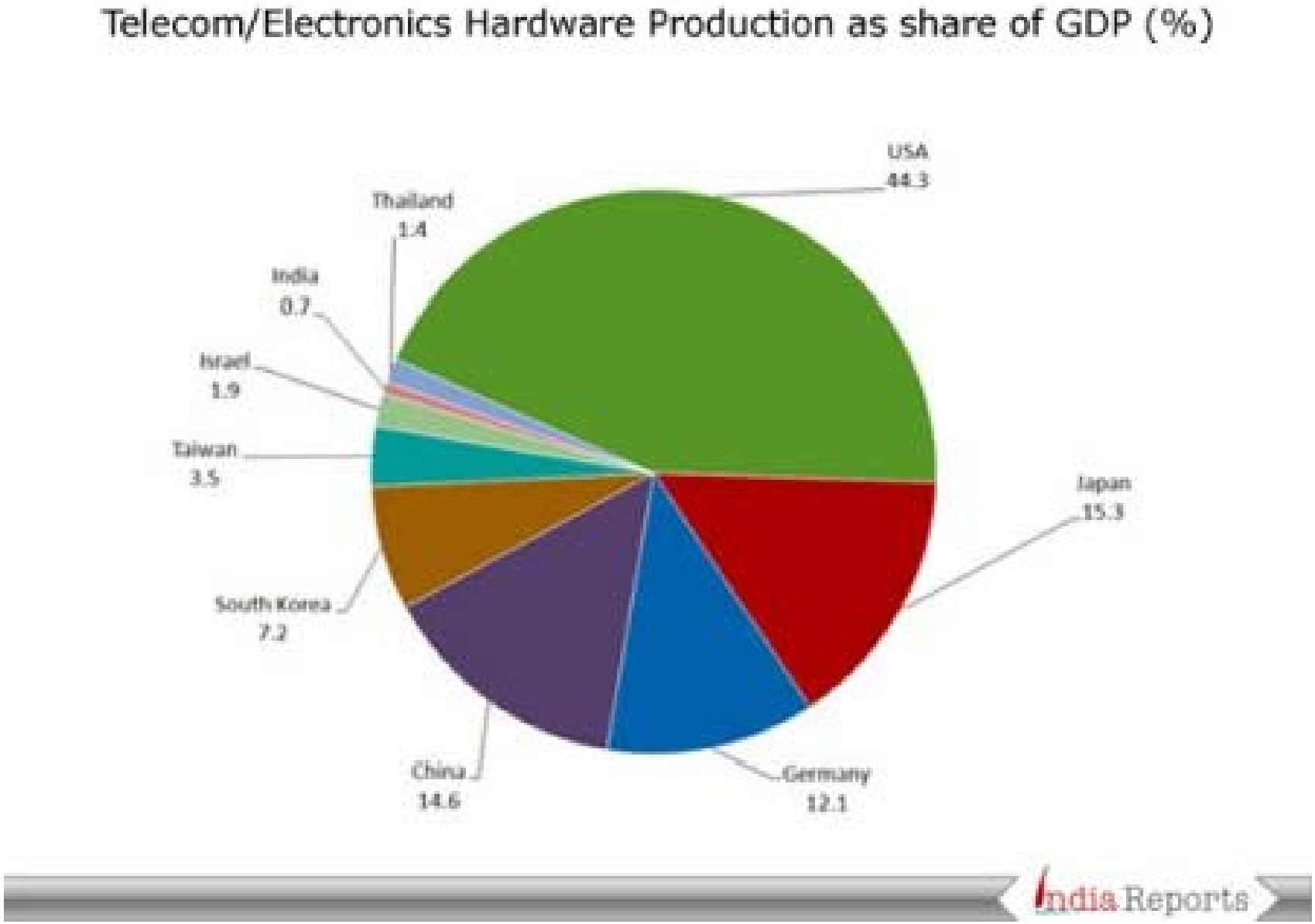
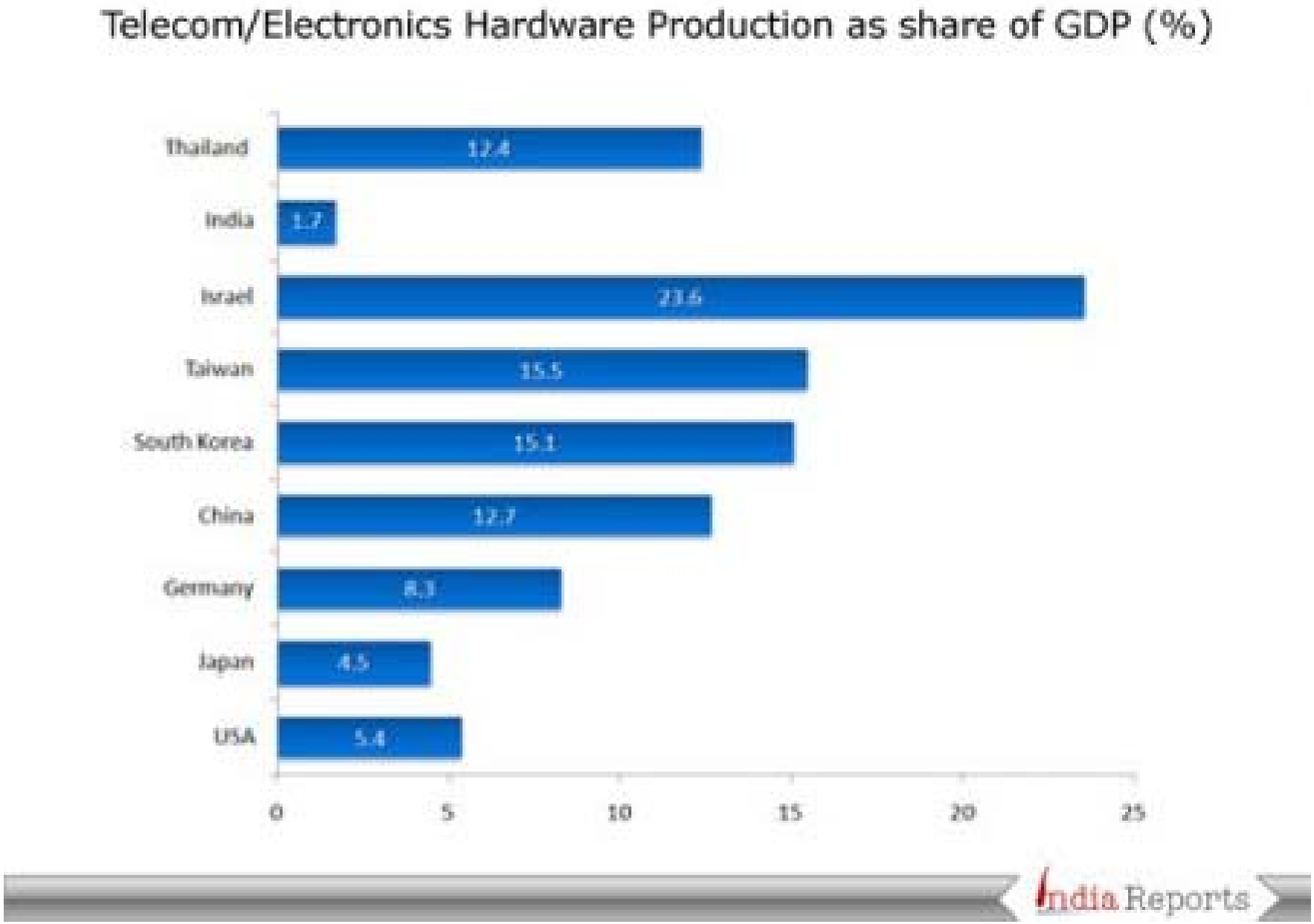
Outline

- Role of electronics in US and world economy (GDP).
- Electronic garbage.
- Electronics manufacturing and what is needed for an electronic chip.
- “Chip” can be made on foreign substrates, including on disposable CNF substrates, using single crystal nanomembranes.
- Challenges

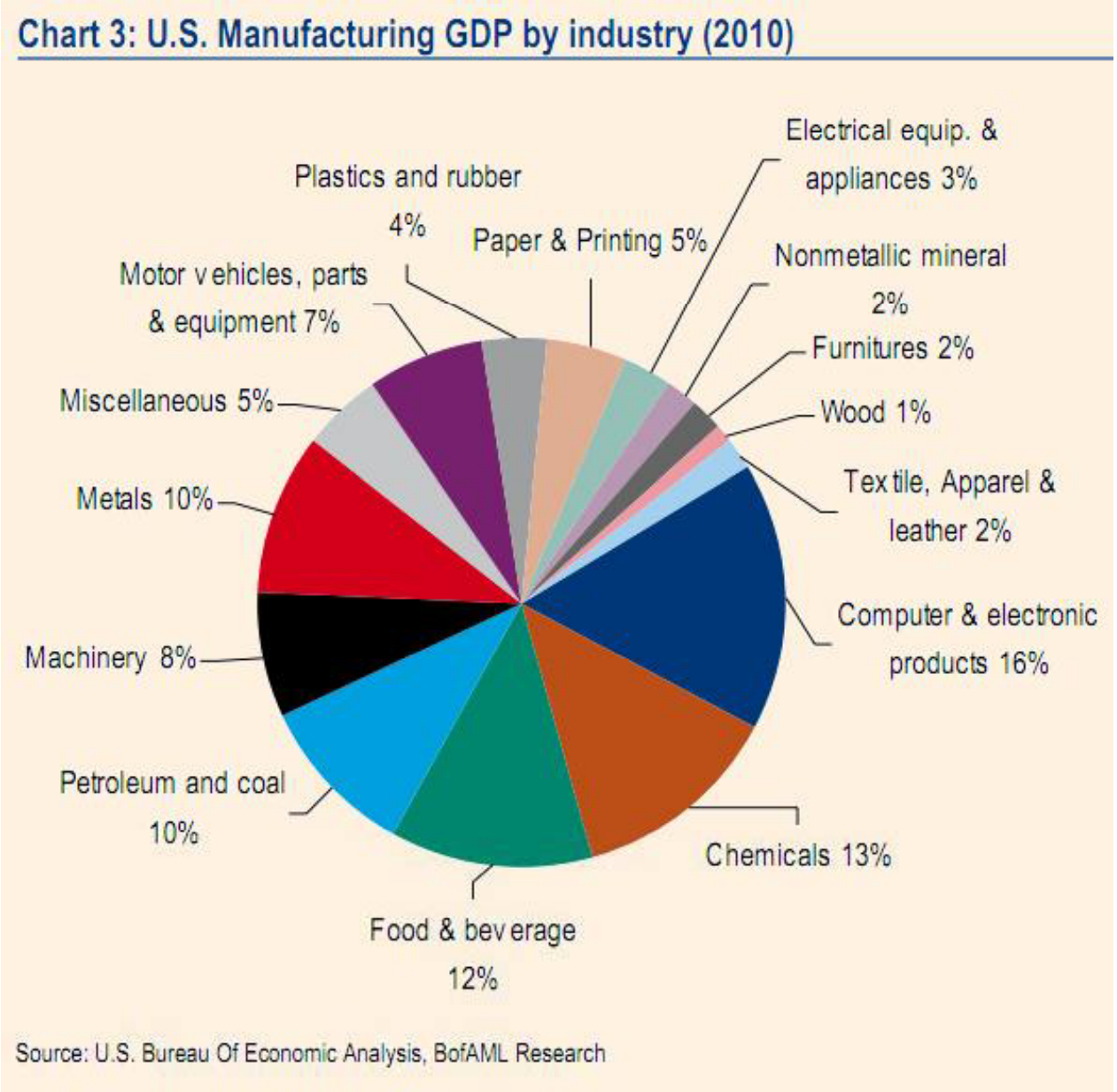
Electronics contribution to world and US economy



http://india-reports.in/shop/power-point-slide-on-telecom-electronics-hardware-production-as-share-of-gdp-for-select-countries-including-india/



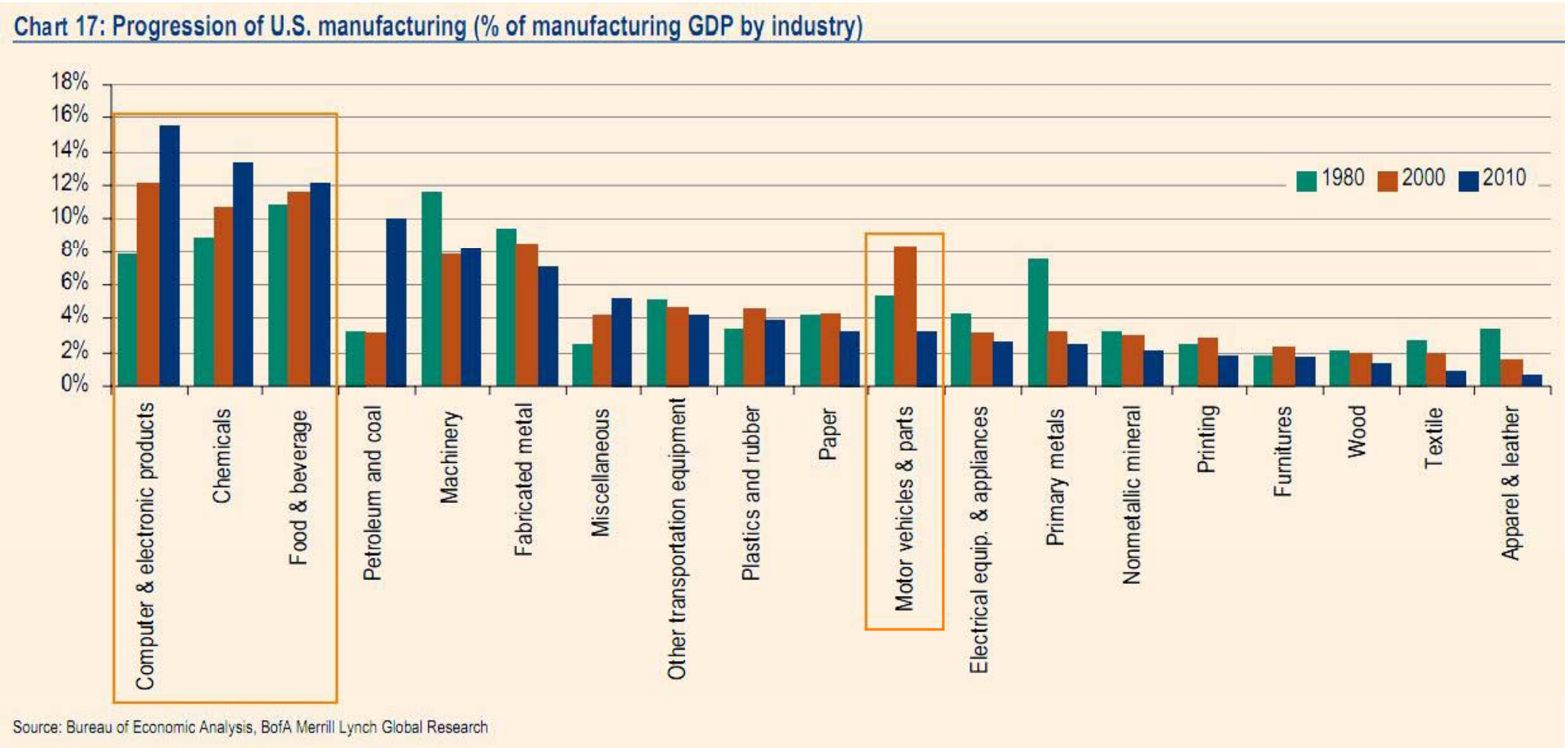
http://india-reports.in/shop/power-point-slide-on-telecom-electronics-hardware-production-as-share-of-gdp-for-select-countries-including-india/



Electronics help on

- GDP growth
- Job opportunity
- Life quality
- …

<Financial Times, http://ftalphaville.ft.com/blog/2012/04/04/947201/the-return-of-the-us-manufacturer/>



<Financial Times, http://ftalphaville.ft.com/blog/2012/04/04/947201/the-return-of-the-us-manufacturer/>

Electronic garbage

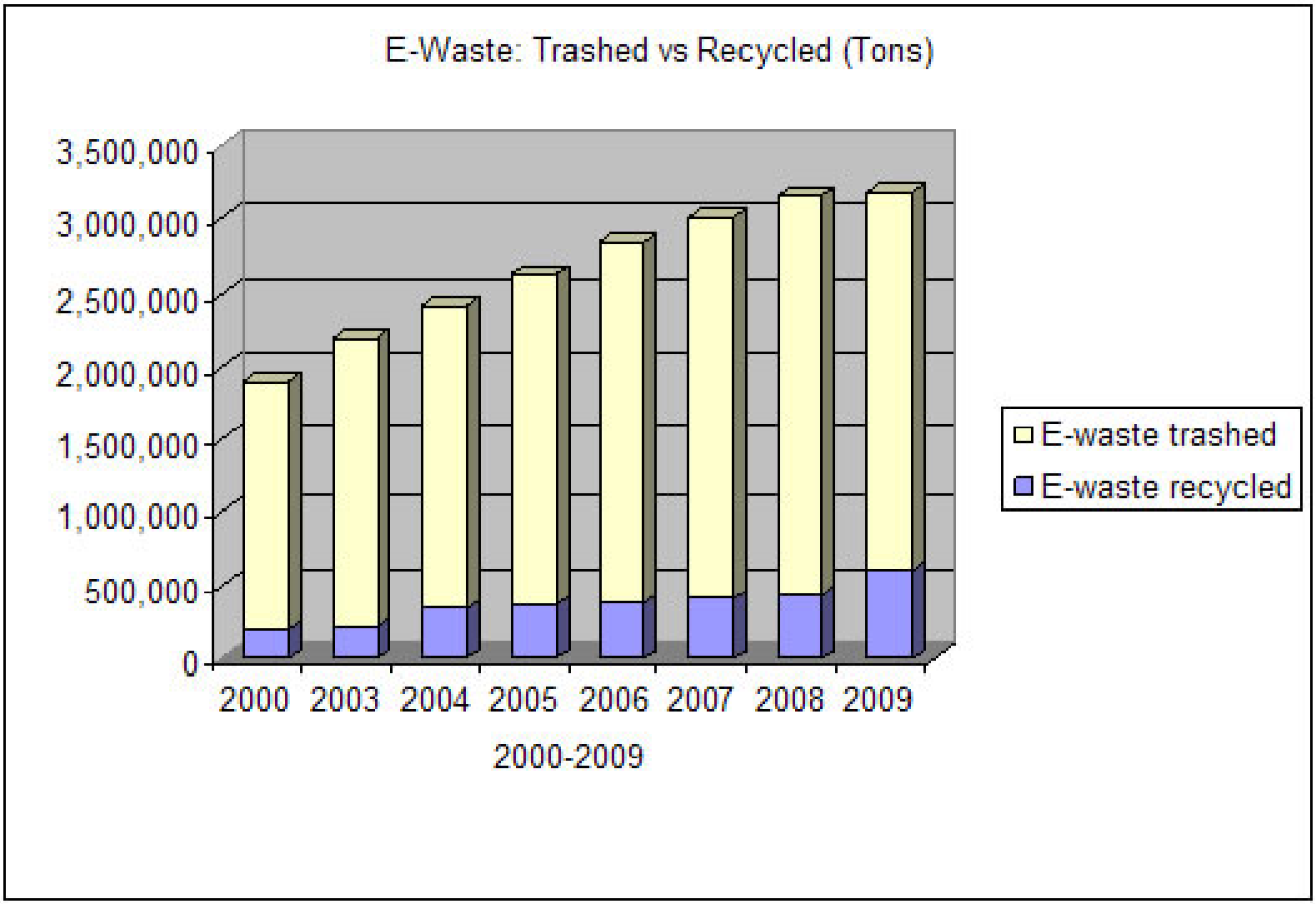
http://urbanmedialabwaste.files.wordpress.com/2011/04/e-waste.jpg

http://www.scientificamerican.com/blog/post.cfm?id=major-us-recycler-vows-to-stop-ship-2008-09-23

http://urbanmedialabwaste.wordpress.com/author/cindypound/

426 000 Discarded Cellphones/day in US
September 2007, *IEEE Spectrum*

Histogram of electronic products collected for recycling or disposed from 2000 to 2009



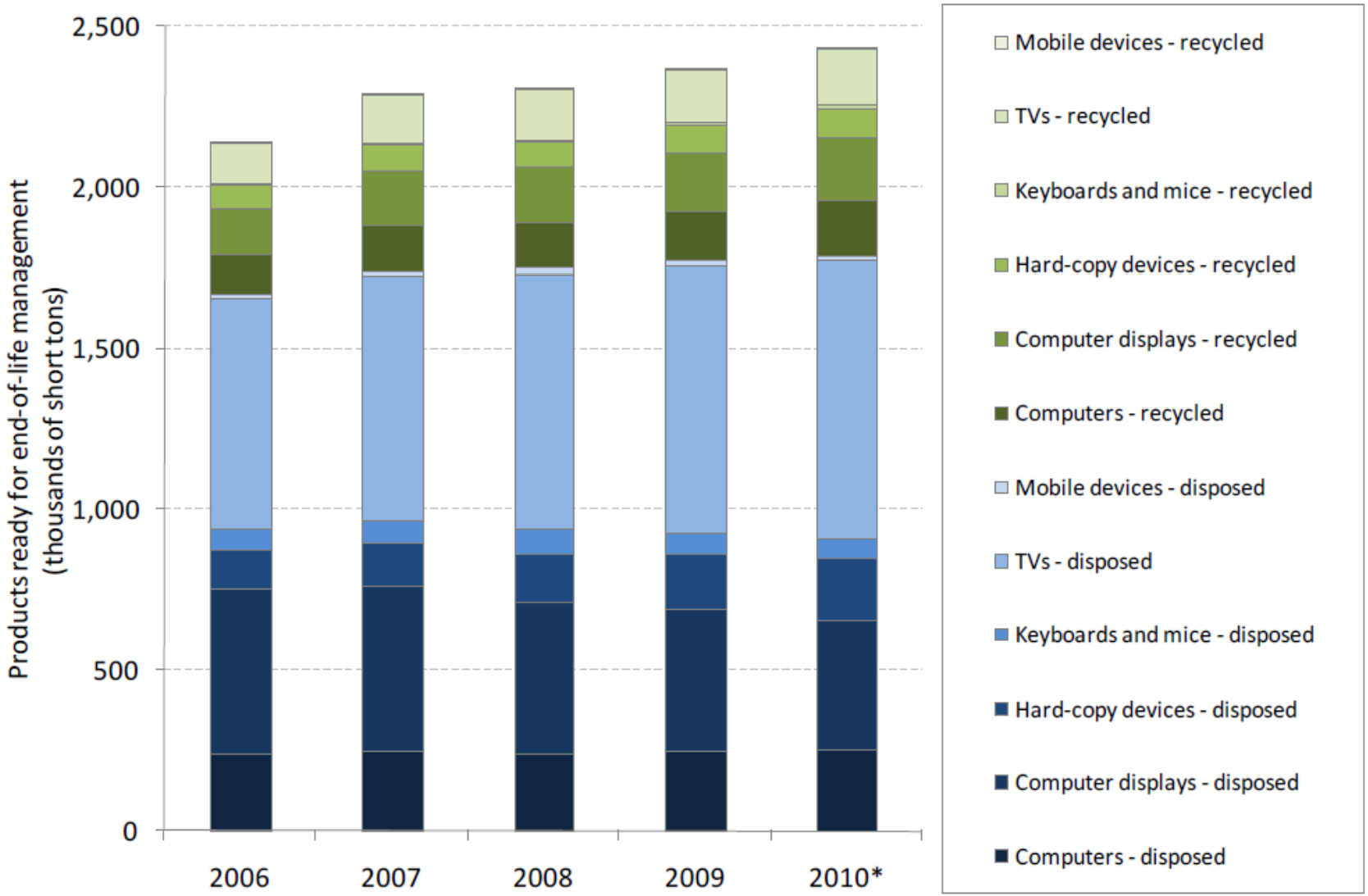
In 2009, as in previous years, the vast majority (82.3%) of e-waste discarded in the U.S. is still ending up in our landfills and incinerators, with only 17.7 percent going to recyclers

http://www.electronicstakeback.com/2011/01/26/epas-new-figures-show-most-e-waste-still-getting-trashed/

Table of electronic products collected for recycling or disposed in2010

E-Waste by the Ton in 2010 – Was it Trashed or Recycled (According to the EPA)				
Products	**Total disposed****	**Trashed**	**Recycled**	**Recycling Rate**
	tons	tons	tons	%
Computers	423,000	255,000	168,000	40%
Monitors	595,000	401,000	194,000	33%
Hard copy devices	290,000	193,000	97,000	33%
Keyboards and Mice	67,800	61,400	6,460	10%
Televisions	1,040	864,000	181,000	17%
Mobile devices	19,500	17,200	2,240	11%
TV peripherals*	Not included	Not included	Not included	Not included
Total (in tons)	2,440,000	1,790,000	649,000	27%

Quantity of electronic products collected for recycling or disposed, by type and by year.



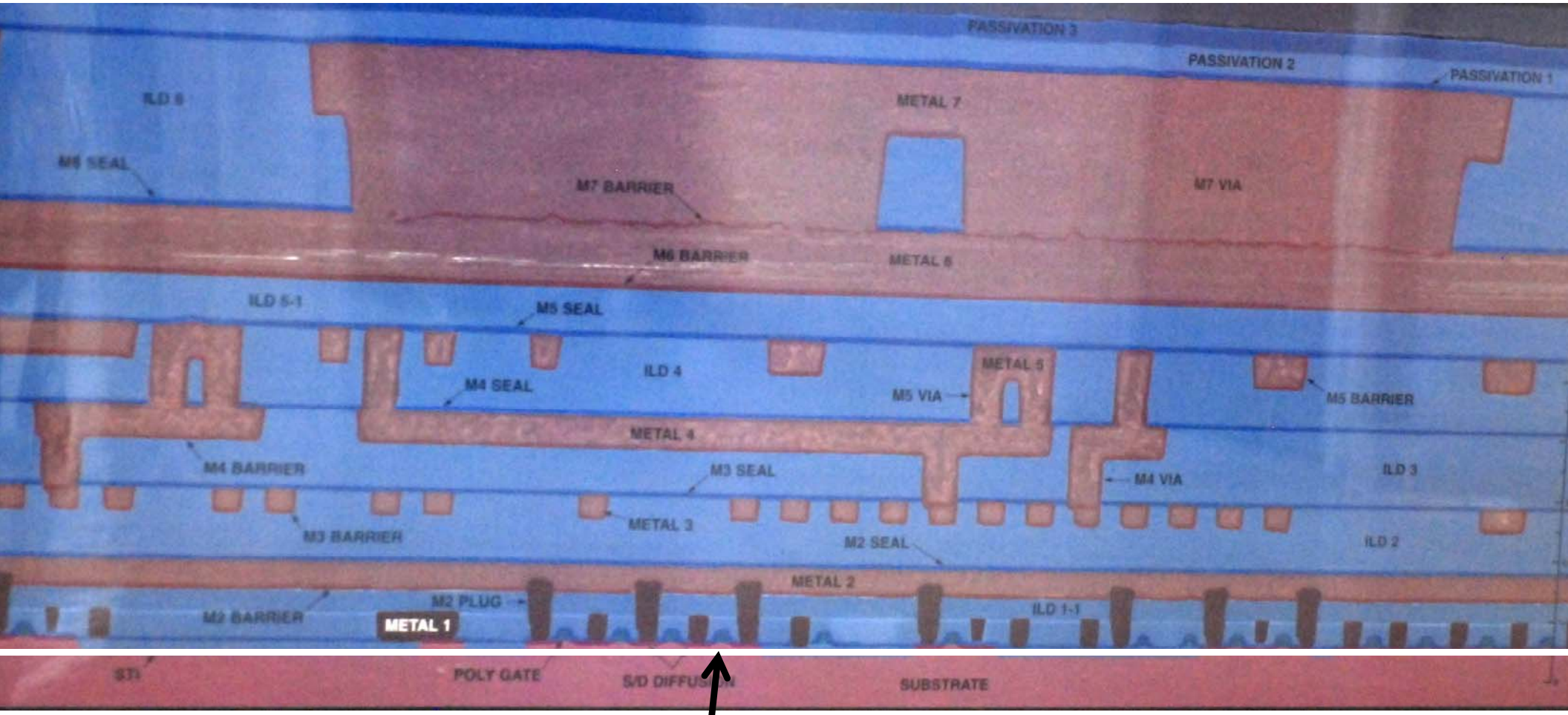
U.S. Environmental Protection Agency Office of Resource Conservation and Recovery
Electronics Waste Management in the United States Through 2009

http://www.epa.gov/osw/conserve/materials/ecycling/docs/fullbaselinereport2011.pdf

Electronics product manufacturing cycle

Electronic chip manufacturing (as an example)

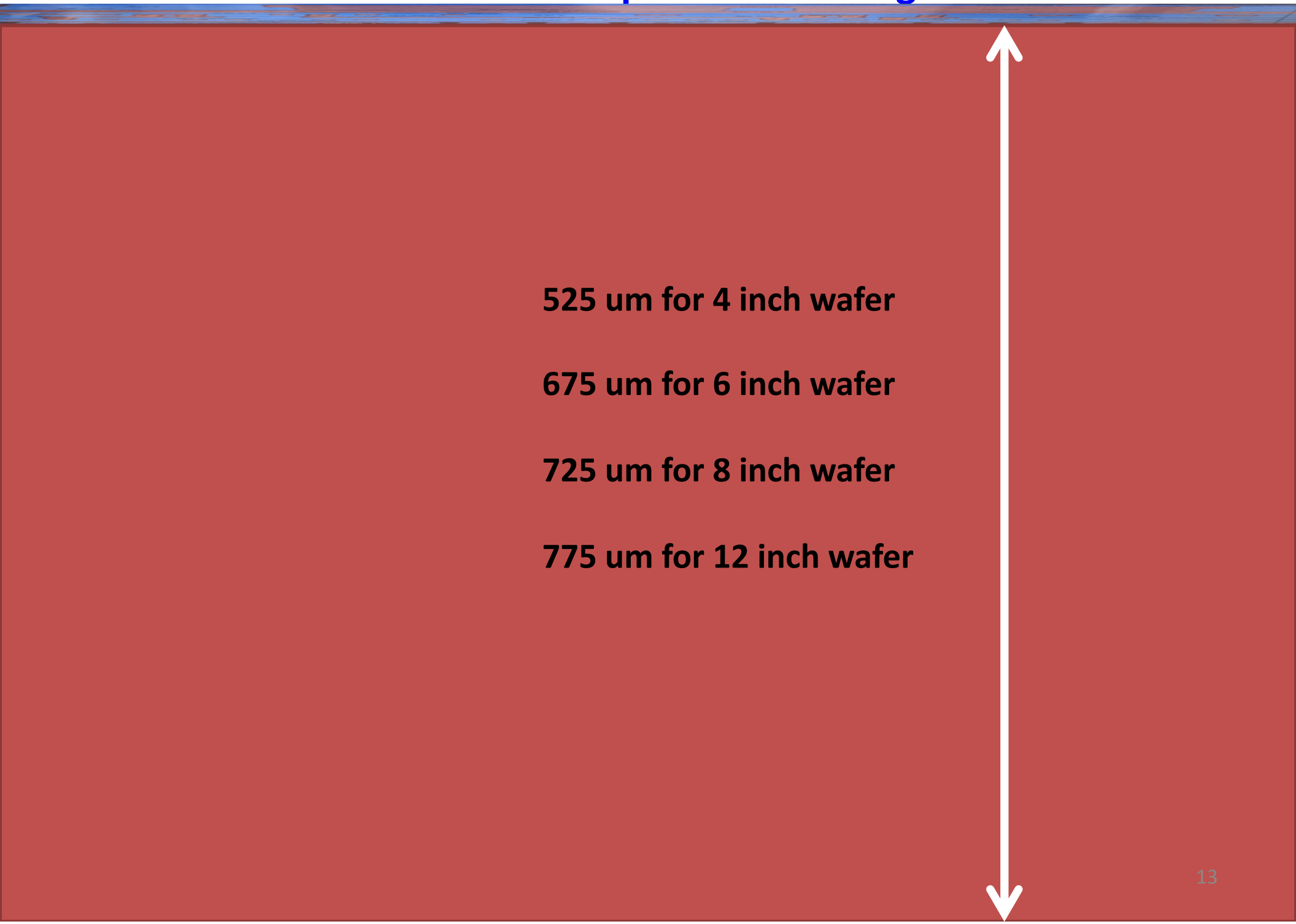
Cross section of a fabricated chip



Device layer thickness <0.3 um

Expensive resources, such as precious and rare earth metals are used.

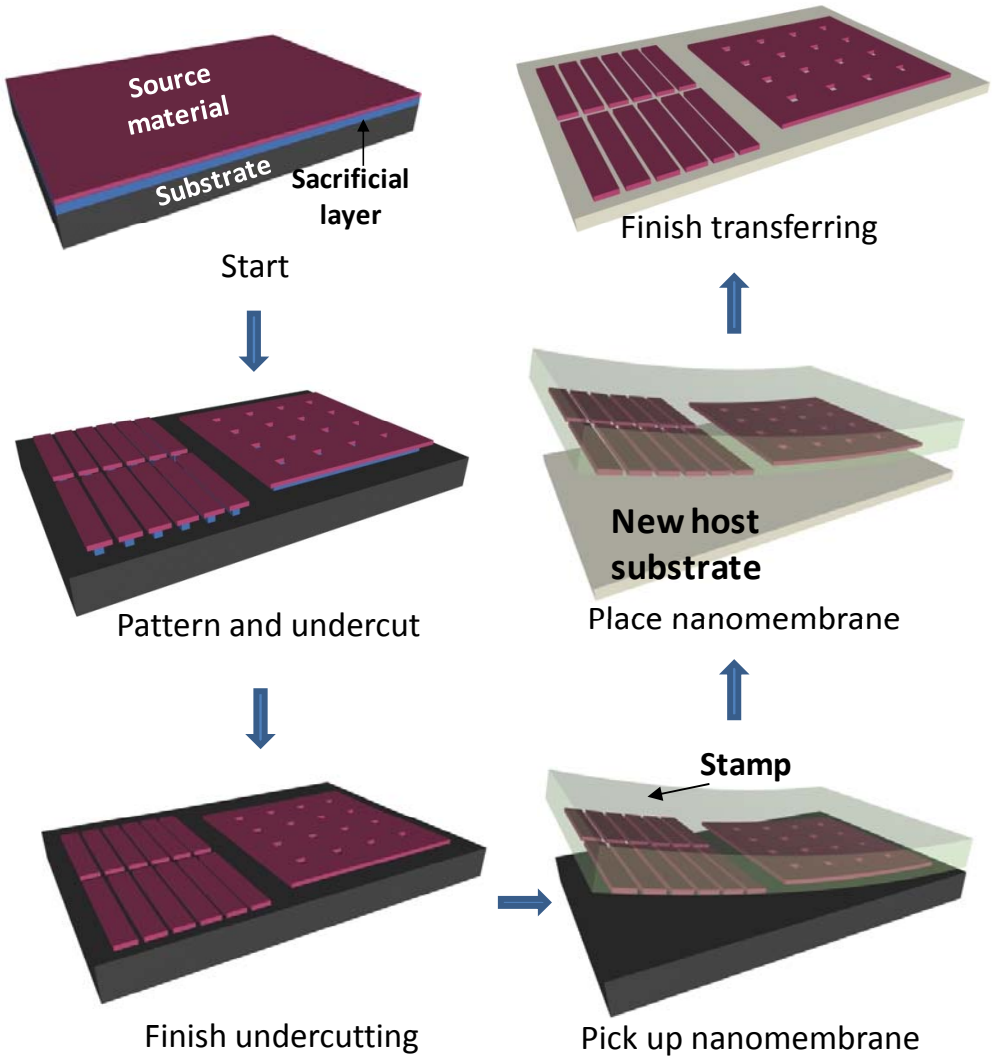
Electronic chip manufacturing



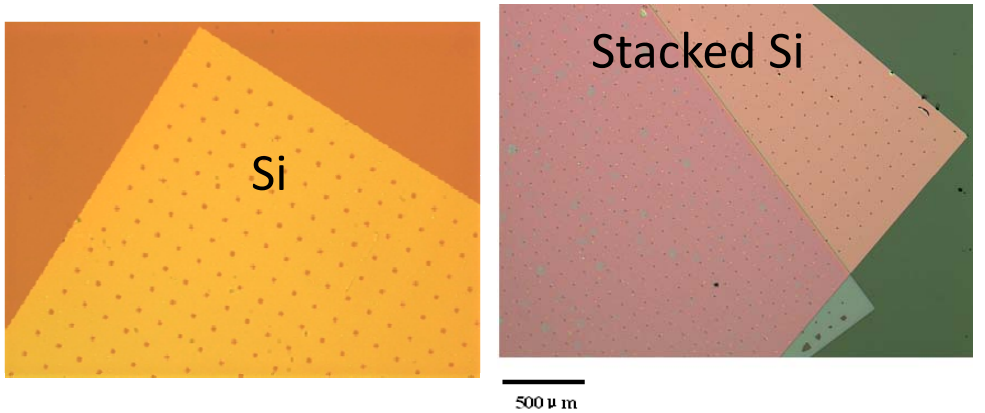
“Chips” on foreign substrates

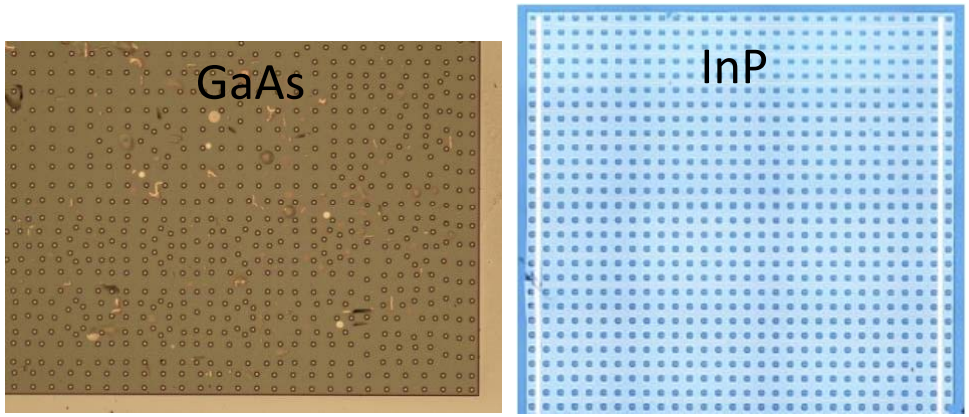
(Flexible electronics research at UW-Madison)

Typical process for releasing and transferring single-crystal semiconductors



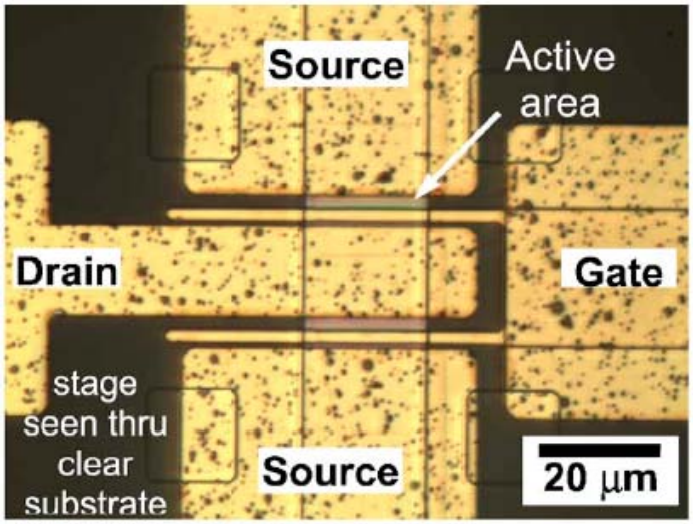
Various examples of transferred single crystal semiconductors

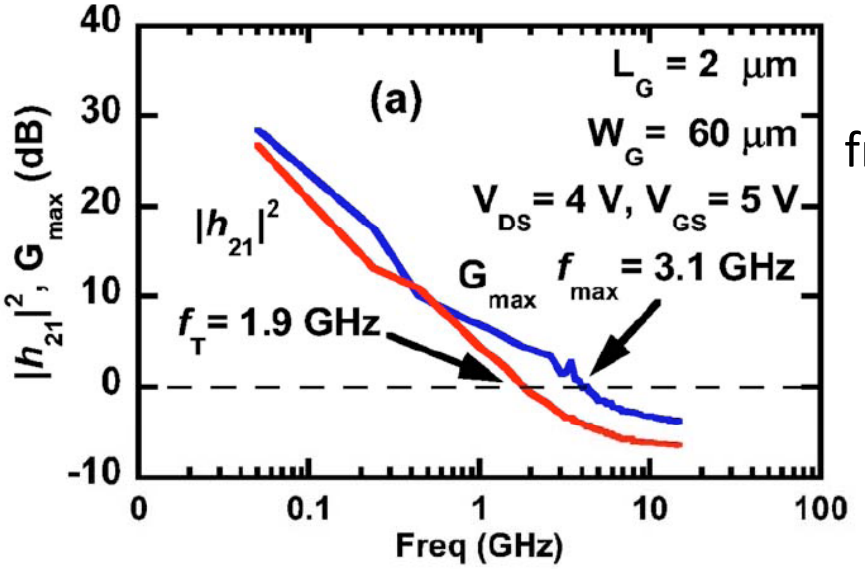




K. Zhang, et al, *J. Phys. D: Appl. Phys.* **45** (2012) 143001.

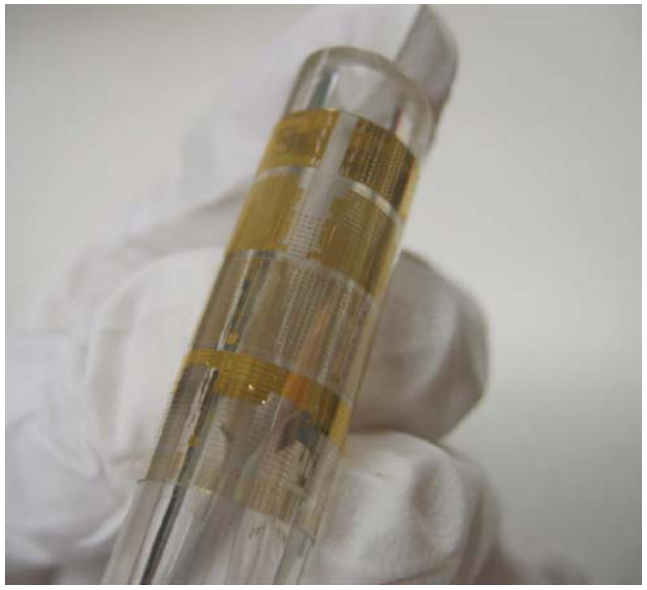
(Flexible) "Chips" on foreign substrates

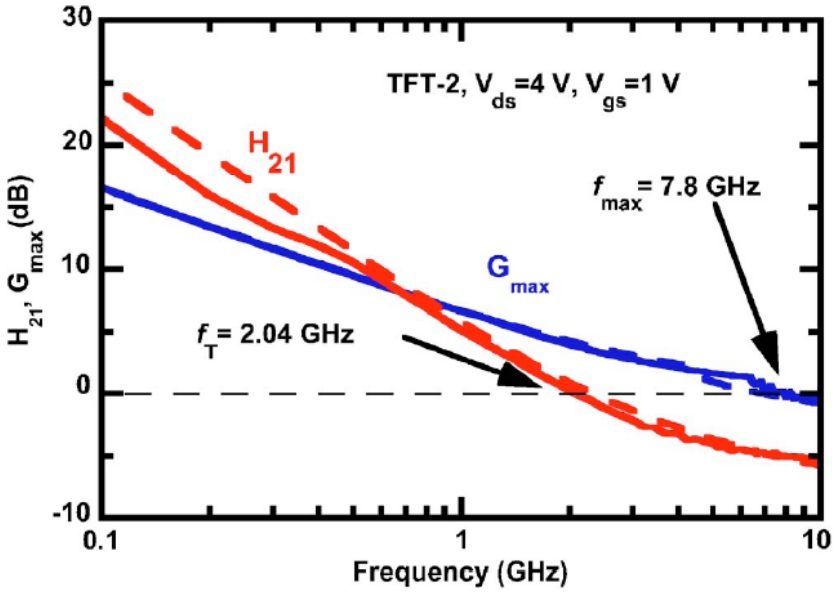




World's first radio-frequency (RF) flexible thin-film transistor (TFT)

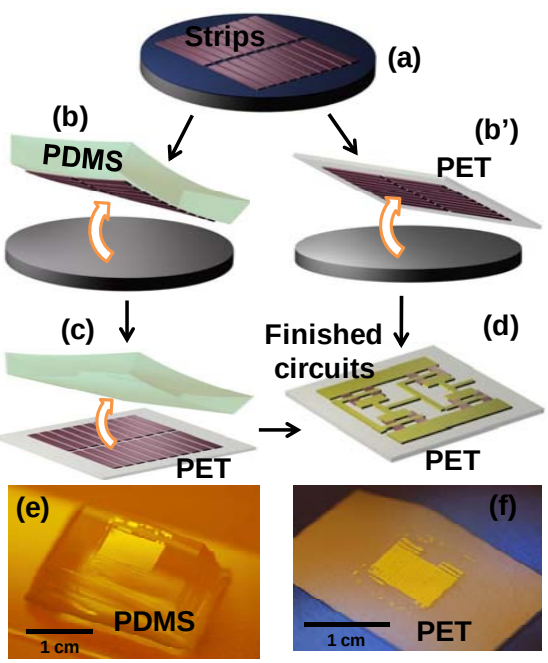
Yuan and Ma, APL 89, 212105, (2006).

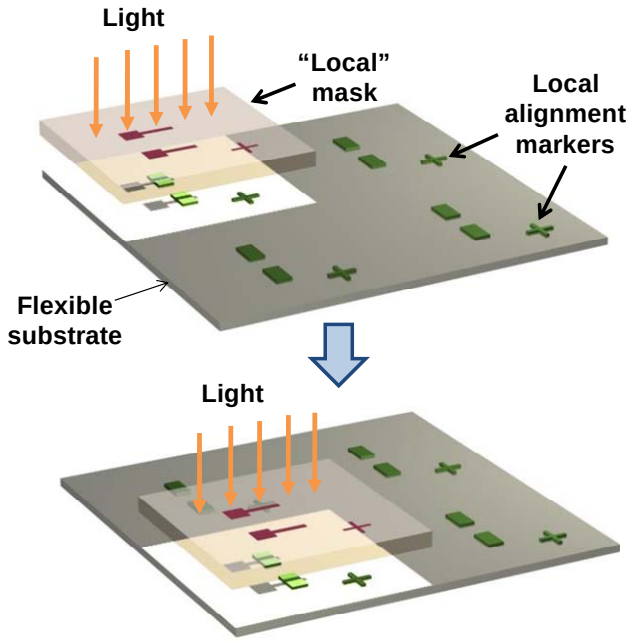


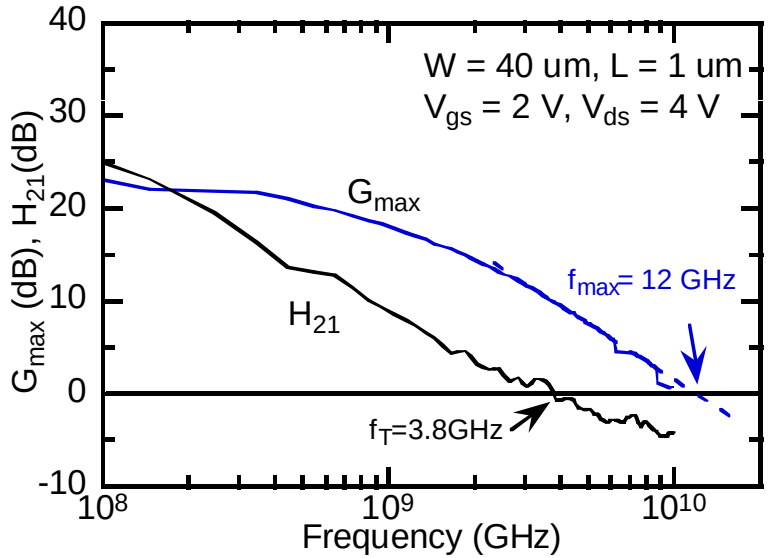


H.-C. Yuan, Z. Ma, *et al.*, *J. Appl. Phys.* 102, 034501 (2007).

Very fast flexible “Chips” on foreign substrates



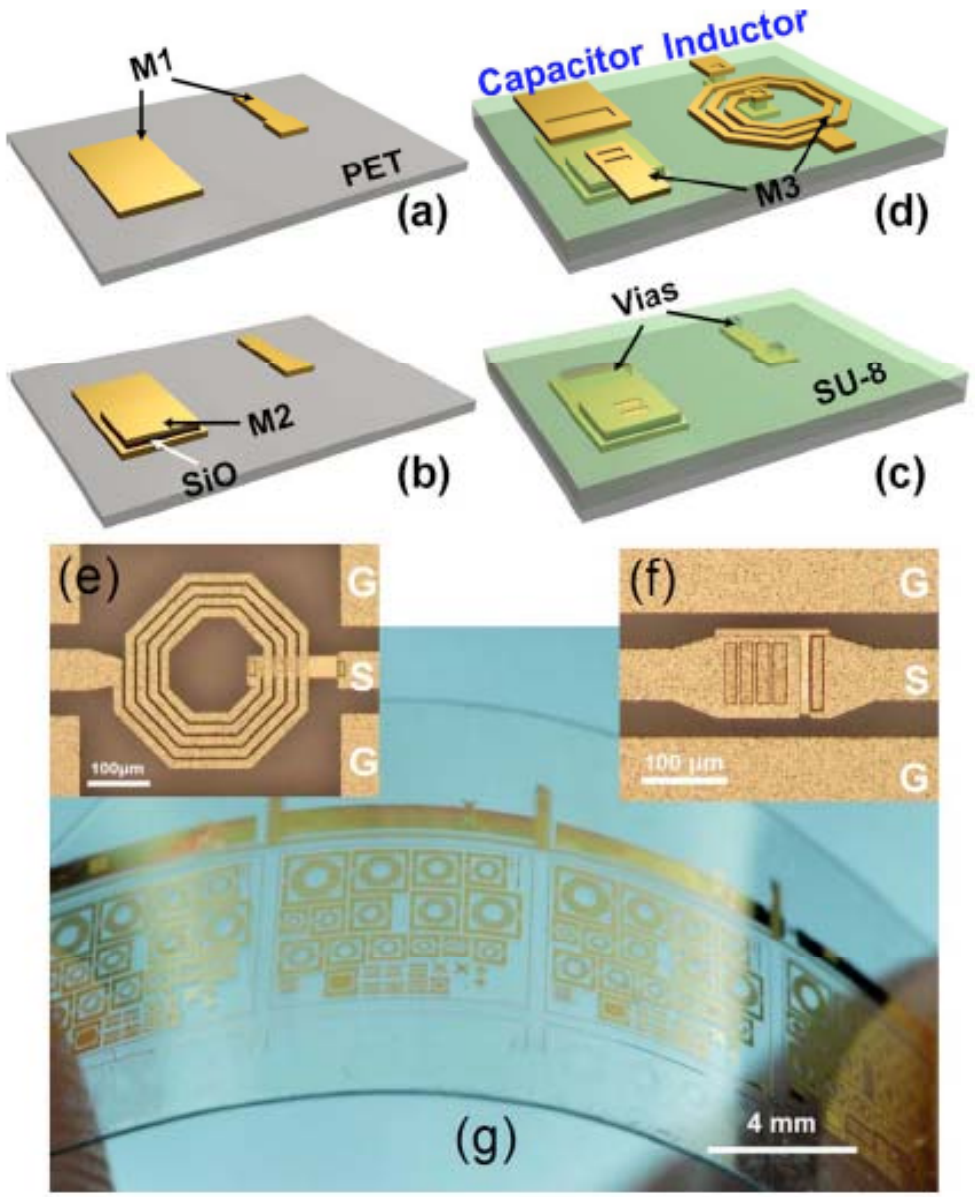


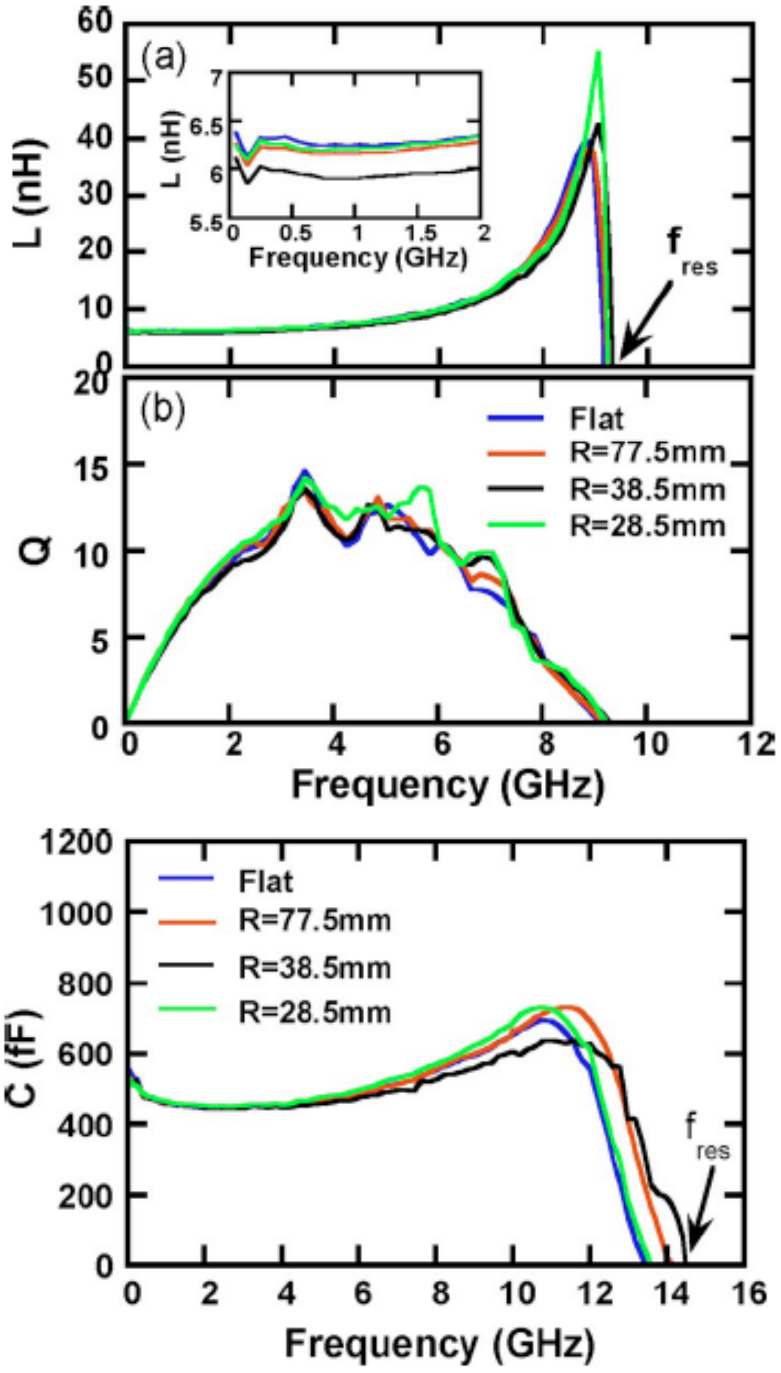


L. Sun, et al, *Small* **6**(22), 2010.

Higher frequency/speed is readily feasible.

Radio frequency passives on foreign substrates

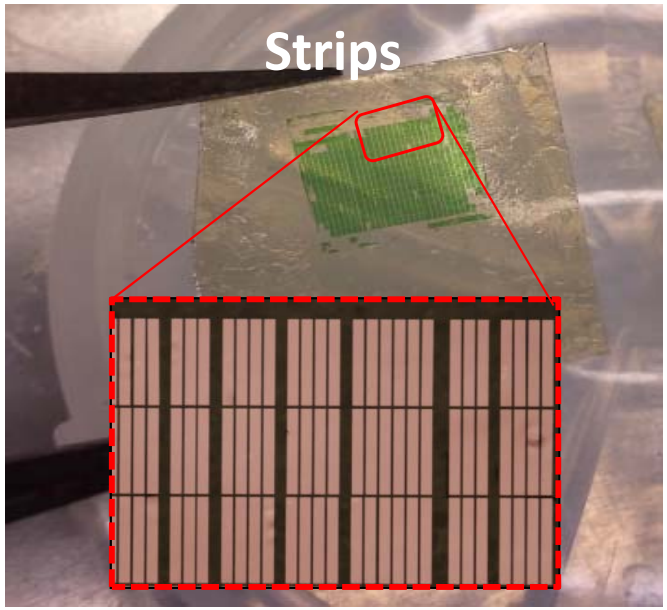


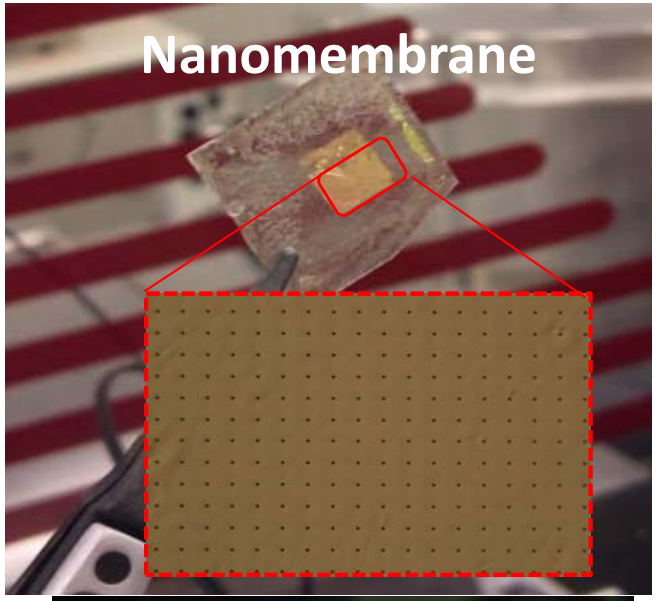


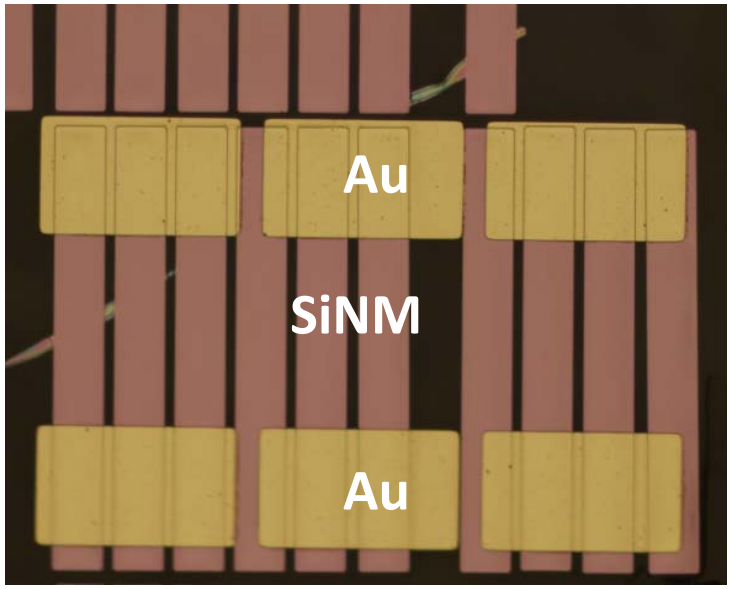
L. Sun, et al., APL (96) 013509, (2010)

Toward low-cost and disposable electronics --"transistors" on CNF substrates

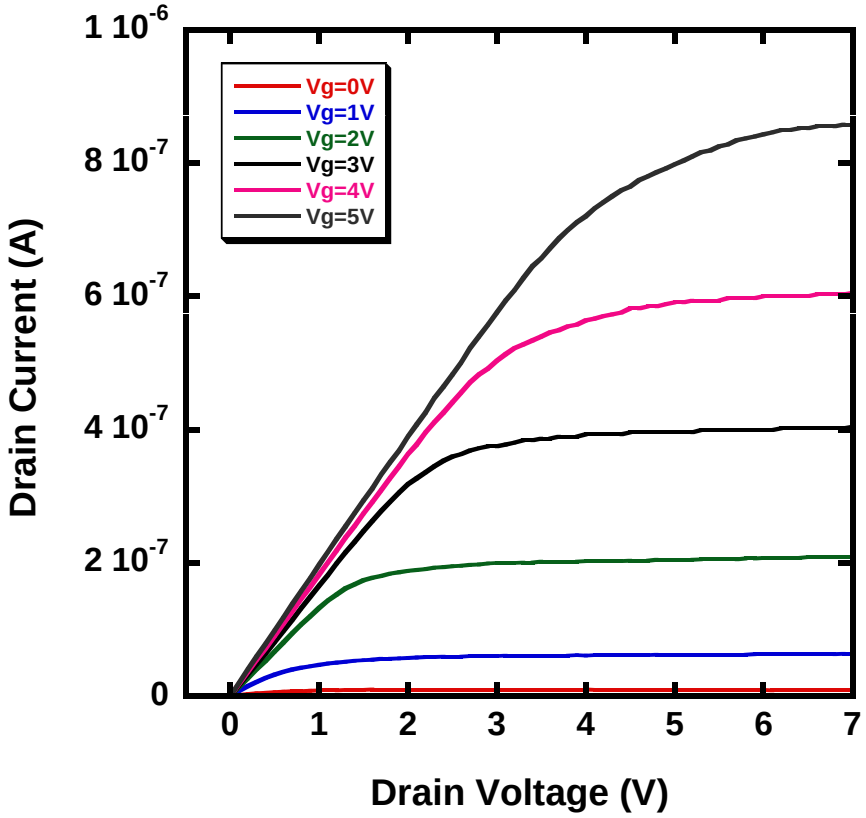
(Flexible electronics research between UW-Madison and FPL)

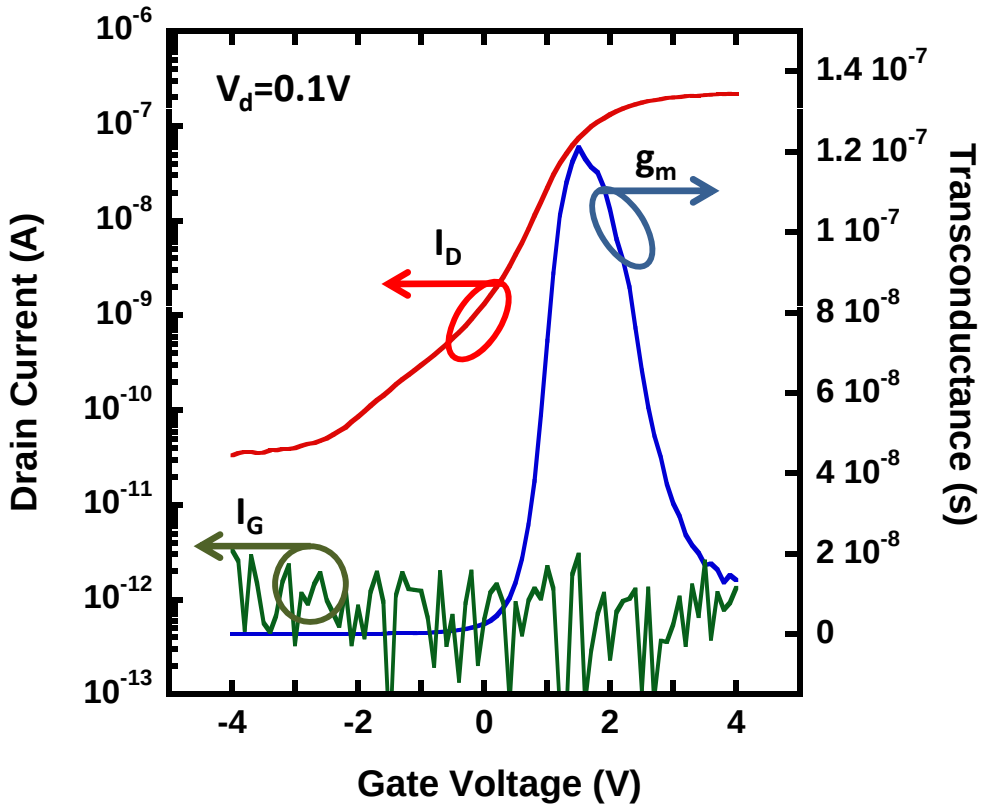






Working flexible transistors demonstrated on CNF films





R. Sabo, et al., *Proceedings of 2012 TAPPI International Conference on Nanotechnology for Renewable Materials,* Montreal, Canada, June 4-7, 2012.

Challenges

- Requirements for CNF substrate properties
  - Surface smoothness
  - Mechanical strength
  - RF properties
  - Dielectric properties
  - Thermal properties
  - Processing and metrology compatibility with semiconductor infrastructure
  - Reliability
  - Moisture barrier/Encapsulation