Nano-Scale Heat Transfer Properties

MAE 284

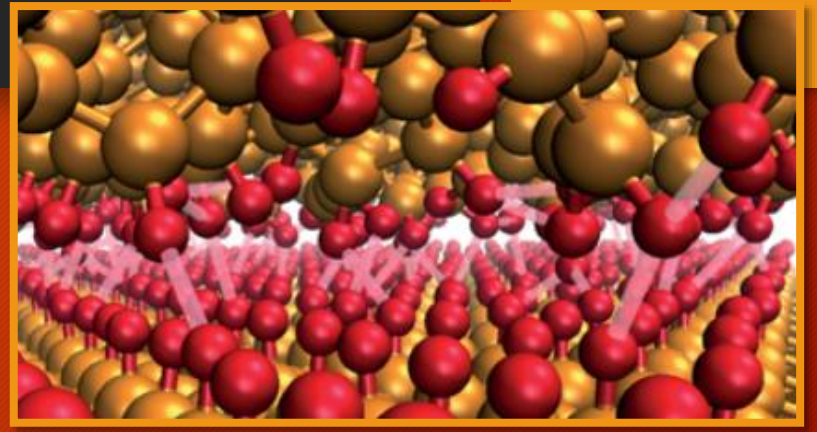
Wilson Lam

Graduate Class

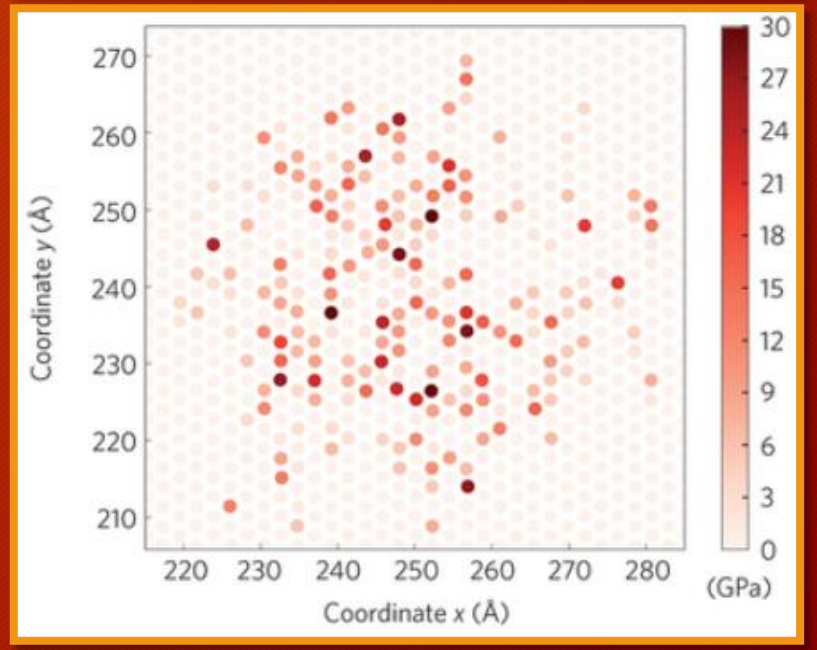
January 20, 2014

Nano-Scale Heat Transfer Outlines

- The size effects on the phonon and electron transport change the heat transferring significantly when compare to macroscales.
  - Surface contact at nanoscale becomes 1-dimensional channels (atomic-level contact points).
- Size effects:
  - Cause by particle and wave properties of phonons
  - This cause Fourier Law to fail by classical and quantum size effects.
- This size effect on nanostructures and potentials of highly efficient thermoelectric (TE)
  - Nanostructures: Thin fims, Superlattices, and Nanowires



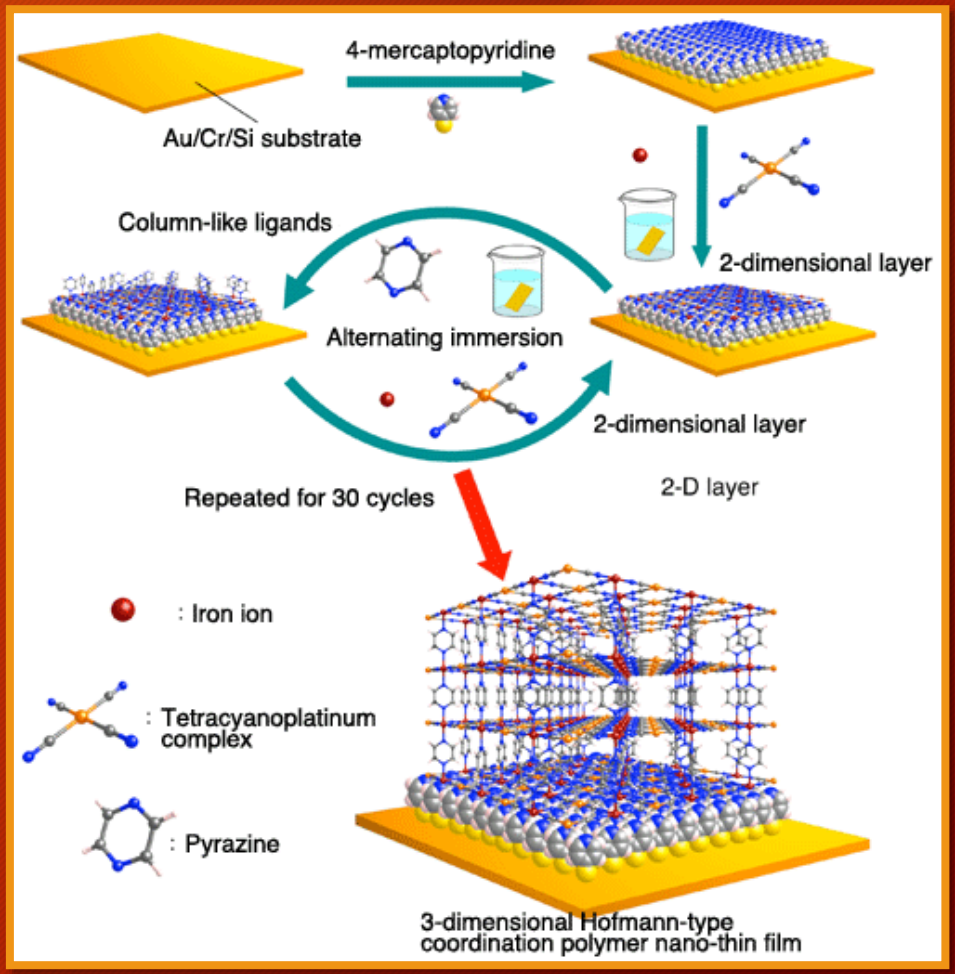
[1]



[1]

Thin films

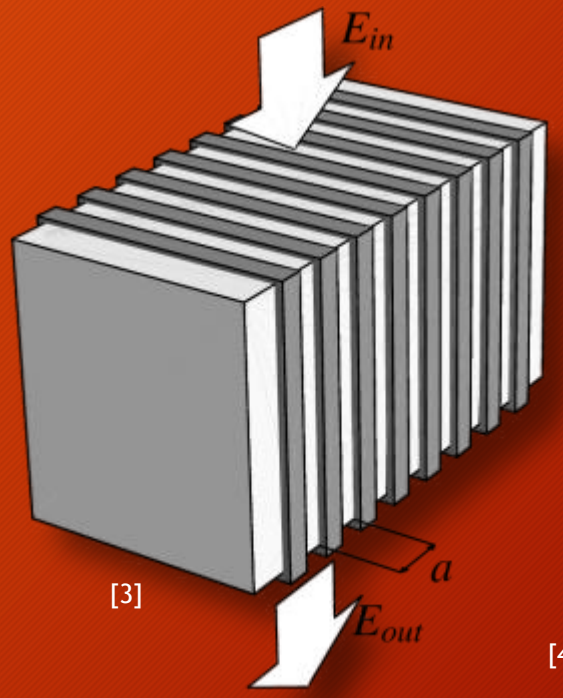
- Thin films heterostructures that have many materials layers may interferes with heat transfer
  - mean free path and film thickness will determine whether the phonons be scattered more frequently or not
- The interface of thin films may have a specular effect in which it will reflect the phonons wave back trapping the heat in the interface.



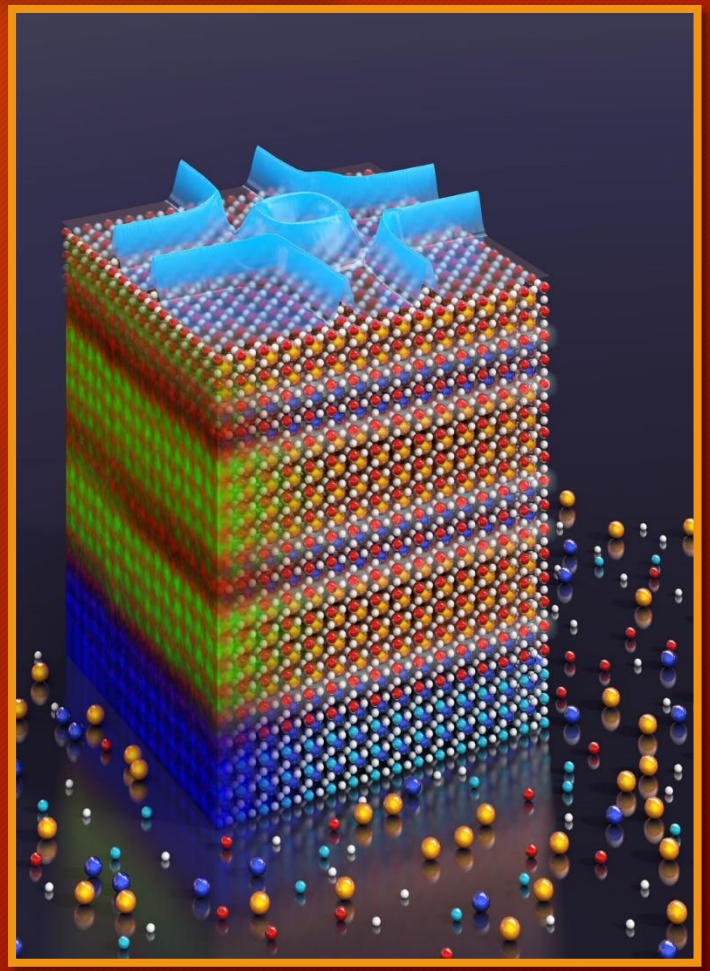
[2]

Superlattices

- Superlattices impacts on device temperature rise.
  - Multilayer thin films of superlattices create additional thermal resistance.
  - Increased boundary scattering of heat.
- Phonons properties in superlattices
  - Lower thermal conductivities
  - Phonons wavelength is schatter in the lattice leading to higher temperature.



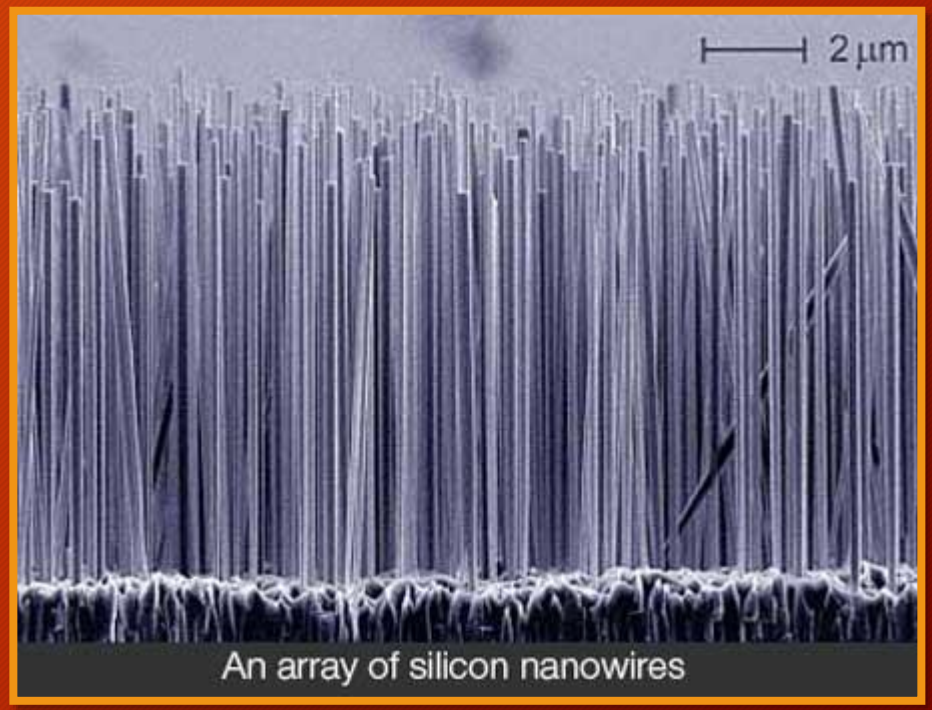
[3]



[4]

Nanowires

- Nanowires are nanostructures with diameter of nanometer to tens of nanometers
  - Nanowires may be insulating, semiconducting, and metallic.
  - Possibilities of making more powerful solar cells.
- Interest in nanowires heat transfer is in the axial direction
  - During experimental conditions thermal conductivity for nanowires can be higher than diamond.

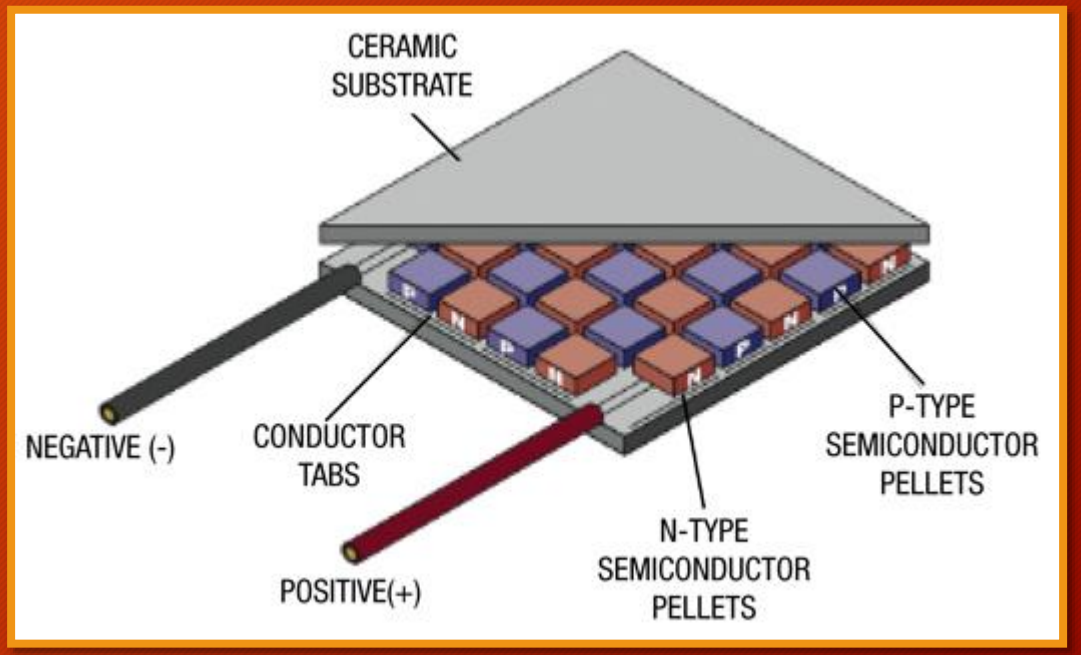


An array of silicon nanowires

[5]

Thermoelectrics (TE)

- Govern by the Thermoelectric Effect:
  - Seebeck effect
    - converts temperature to current
  - Peltier effect
    - current to temperature
  - Thomson effect
    - cooling and heating of current carrying conductor that has a temperature gradient
- This technology is relatively new and hold potential to future developments.



[6]

References

I. Chen, G., X. Chen and R. Yang. "Nanoscale heat transfer and thermal-electric energy conversion." *J. Phys. IV France 125*. 2005. 499-504.

II. Chen, Gang. "Nanoscale Heat Transfer and NanostructuredThermoelectrics." *IEEE TRANSACTIONS ON COMPONENTS AND PACKAGING TECHNOLOGIES* 29 (2006). Research Paper.

III. Patch, Kimberly. "Chips turn more heat to power." *Technology Research News*. Technology Research News. Boston, 27 November 2001. 16 January 2014. <http://www.trnmag.com/Stories/2001/121901/Chips_turn_more_heat_to_power_121901.html>.

IV. Skatssoon, Judy. "World's Strongest Nanowire." *News in Science*. ABC Science Online. 19 December 2006. electronic document. 15 January 2014. <http://www.abc.net.au/science/news/stories/2006/1813845.htm>.

V. Stober, Dan. "Nanowire battery can hold 10 times the charge of existing lithium-ion battery." *Stanford News*. Stanford: Stanford Report, 18 December 2007. Electronic Document. 15 January 2014. <http://news.stanford.edu/news/2008/january9/nanowire-010908.html>.

Image Obtain from the following sites:

1. Mo, Yifei and Izabela Szlufarska. "Nanoscale heat transfer: Single hot contacts." *Nature Materials*. Nature Publishing Group. 2013. 19 January 2014. <http://www.nature.com/nmat/journal/v12/n1/fig_tab/nmat3506_F2.html>.
2. http://www.spring8.or.jp/en/news_publications/press_release/2012/120719/
3. http://cc.oulu.fi/~tf/tiedostot/pub/Isohatala/
4. http://phys.org/news/2012-09-interfaces-key-metal-oxide-superlattices.html
5. http://consciouslifenews.com/nanowires-make-powerful-solar-cells/
6. http://www.digikey.com/us/en/techzone/energy-harvesting/resources/articles/thermoelectric-energy-harvesting.html