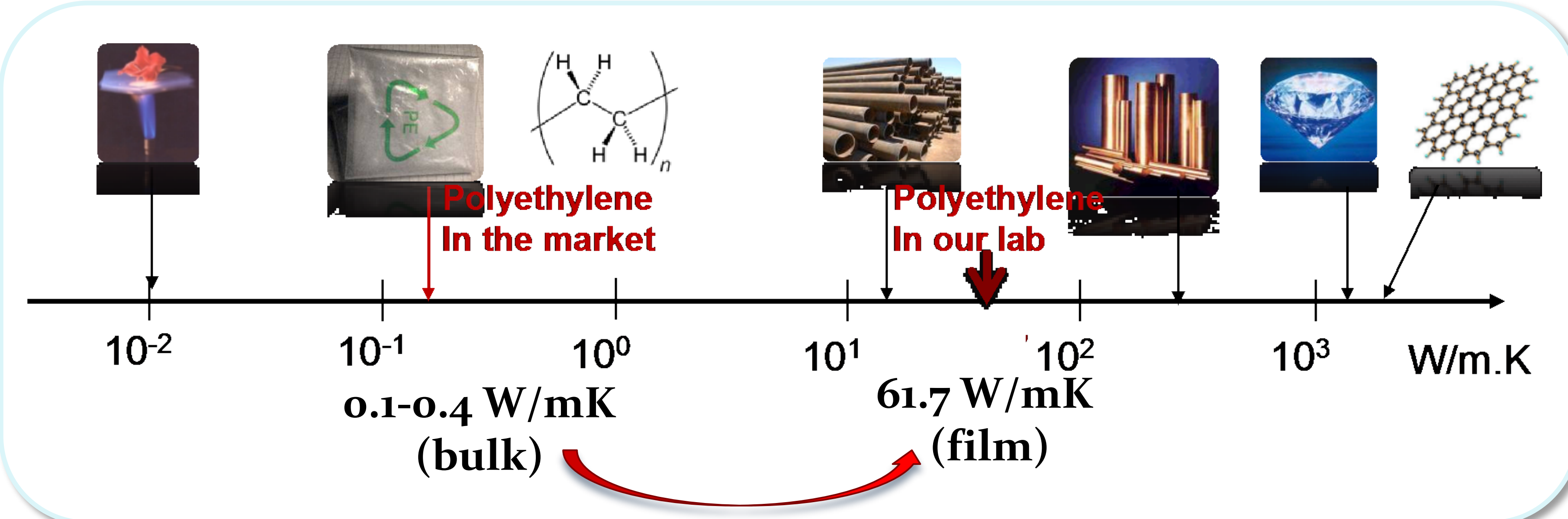
Continuous Processing of High Thermal Conductivity Polyethylene Fibers and Sheets

DE-EE0005756
Massachusetts Institute of Technology
September 01, 2012 – February 28, 2016

Professor Gang Chen,
Carl Richard Soderberg Professor of Power Engineering

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
June 14-15, 2016

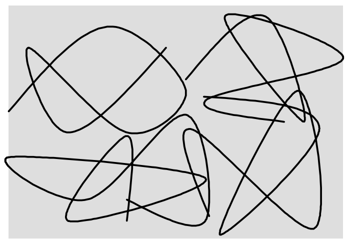
Project Objective



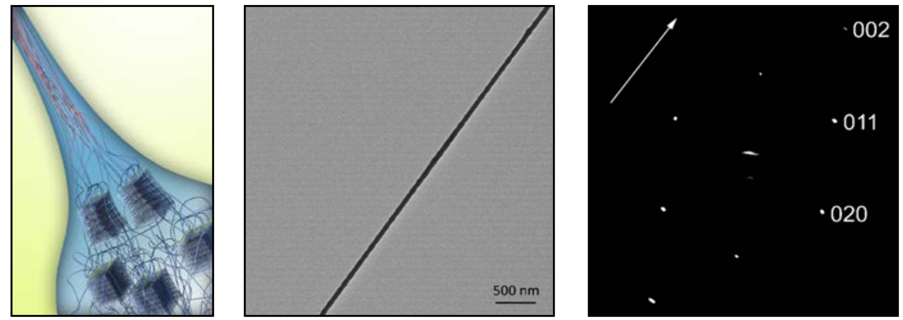
- Develop a continuous manufacturing process to fabricate aligned polyethylene chains in sheet form with high thermal conductivity values, within three budget years.
- Fabricate 1×10 cm^2 polymer sheets with thermal conductivity values as high as 60 Wm^{-1}K^{-1}.

Technical Innovation

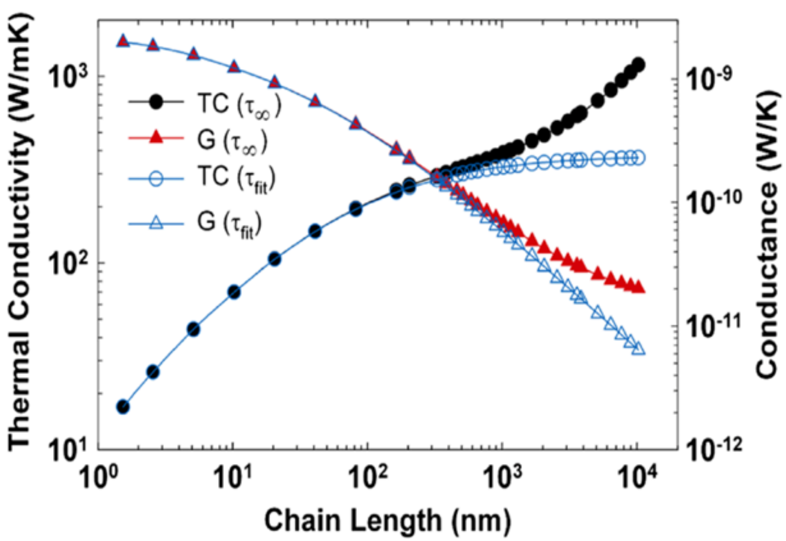
- Scientific and Technical Concept:

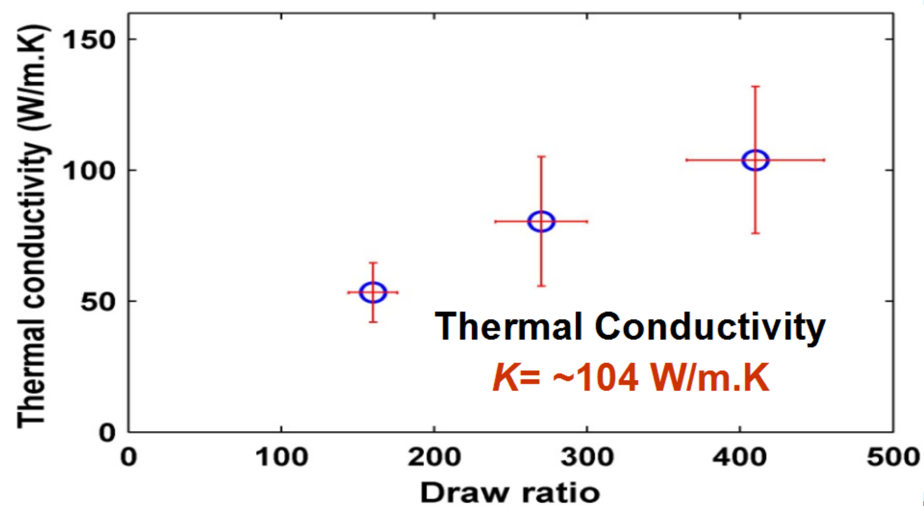


Natural 0.4 W/mK



Thermal conductivity of an individual polymer chain?

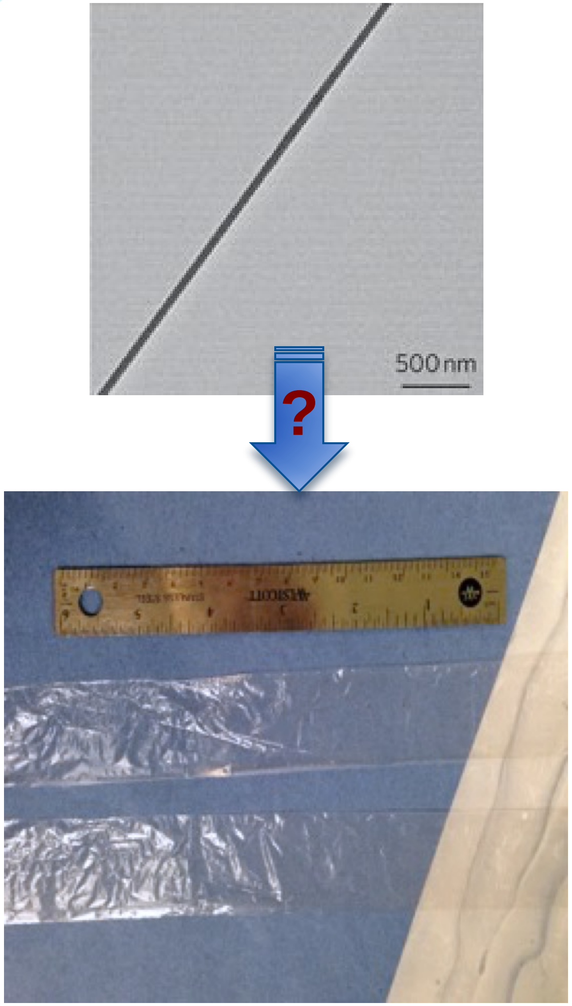




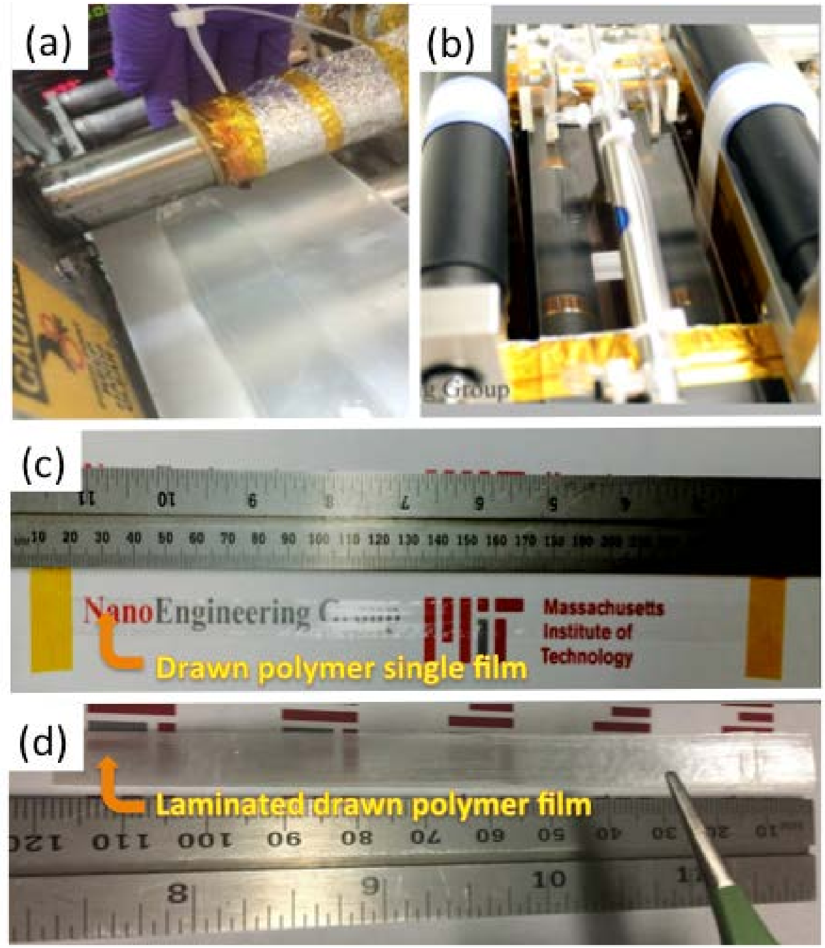
A. Henry and G. Chen, Physical Review Letters, 101, 235502, 2008.

S. Shen *et al*, *Nat. Nanotech.*, 2010, 5, 251-255.

Technical Innovation



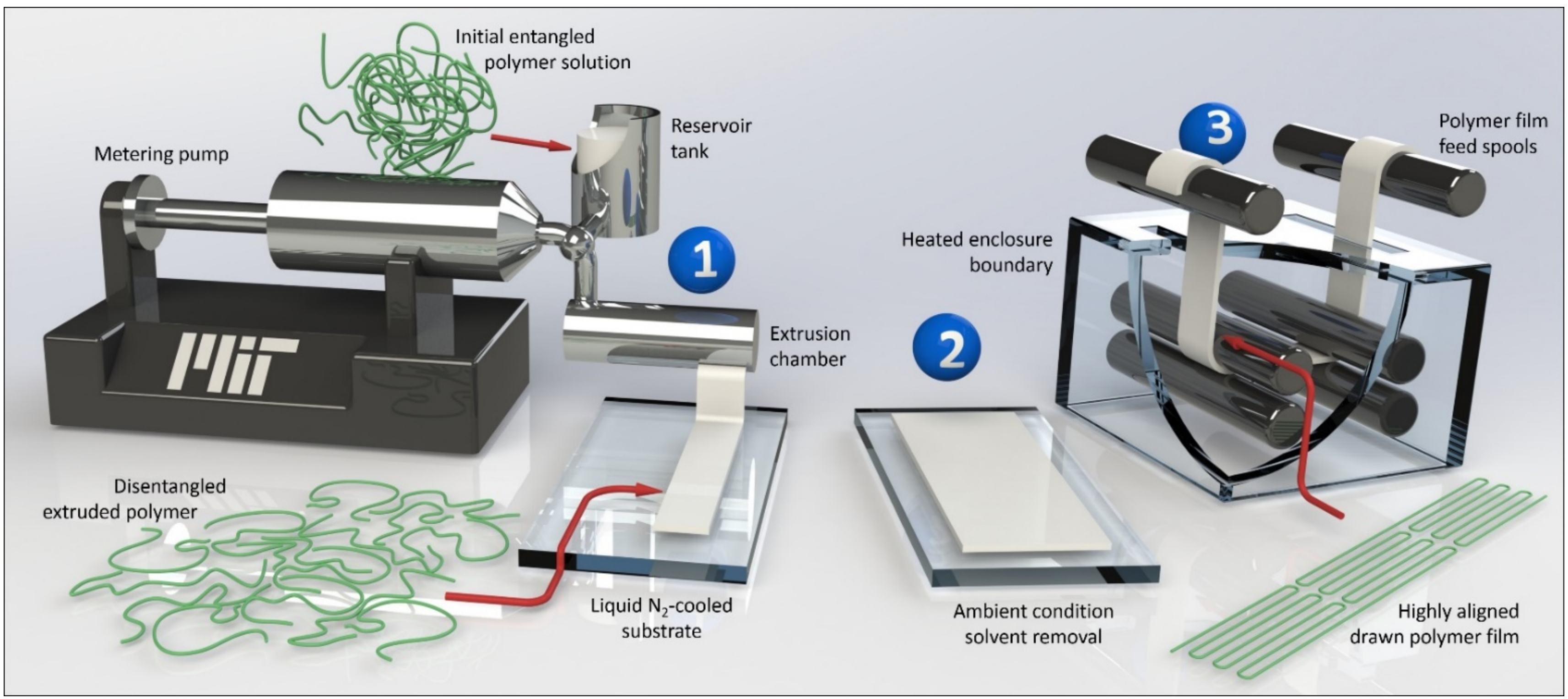
From single fiber to film?



Scale up manufacturing: (a) Extrusion process. (b) Drawing process. (c) Single polymer film. (d) Laminated film.

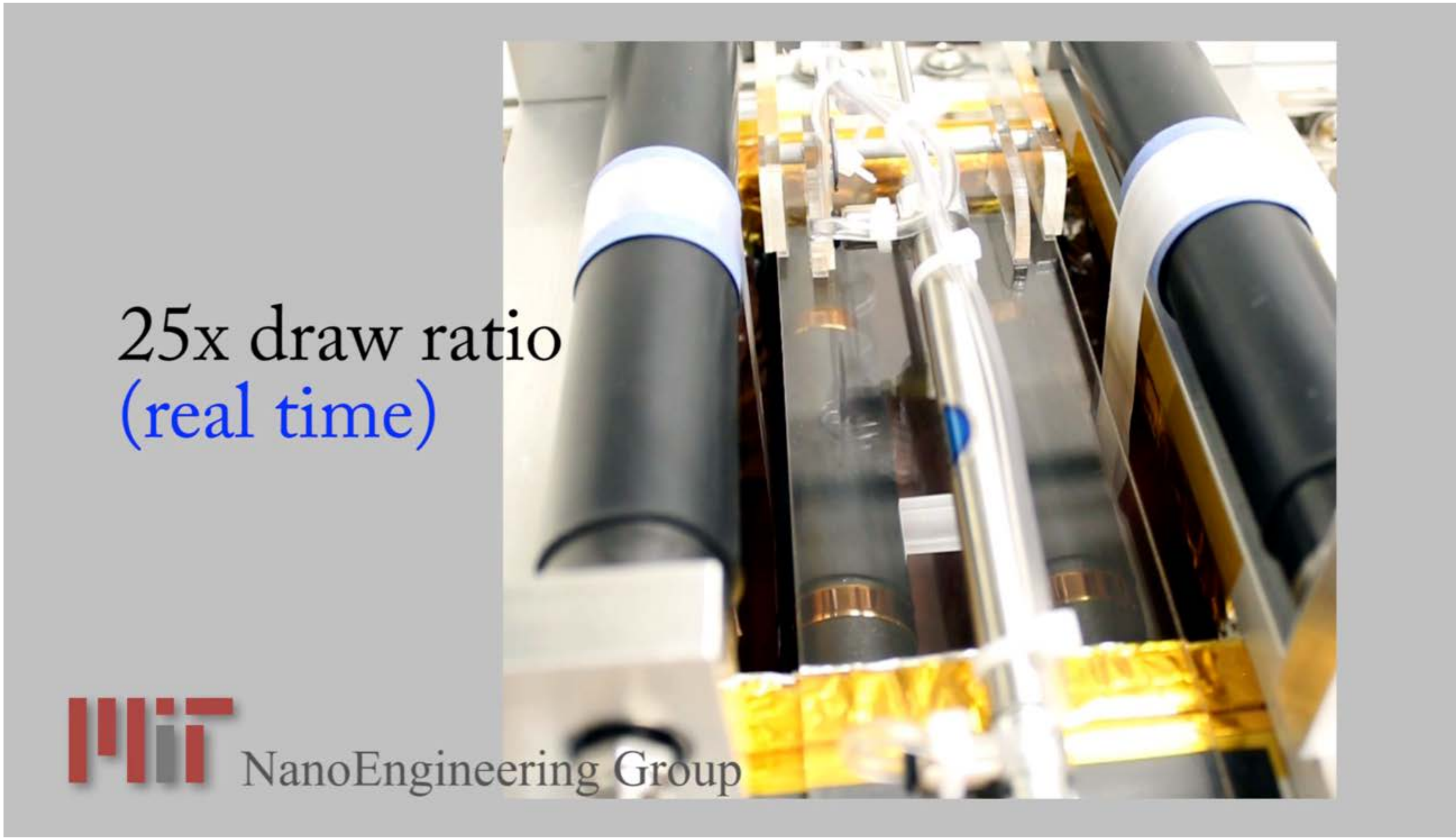
Technical Approach

Polyethylene Gels → **High shear rate extrusion** + **Hot Drawing** → **Aligned polyethylene chains in sheets**



Extrusion process

Drawing process



Transition and Deployment

- End Users:

  microelectronics packaging companies

  automobile supplier companies

  materials companies, consumer product companies…

- Mission/capabilities improvements:

  Cost and energy savings.

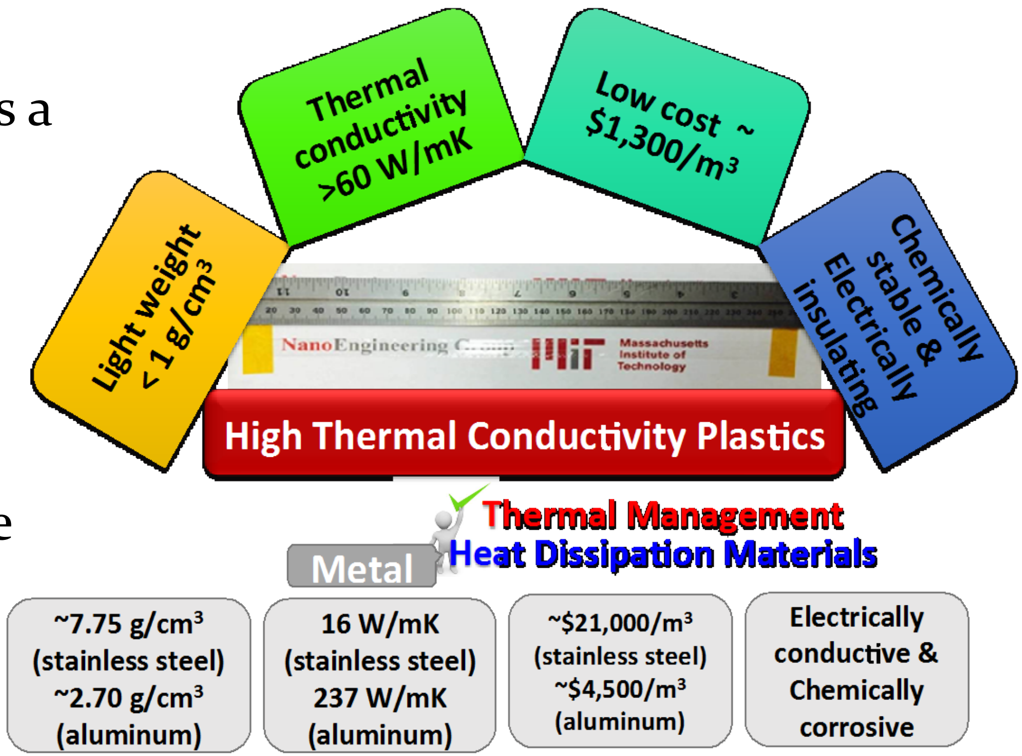
  Light weight, highly chemical resistant, bio-compatible, electrically isolating, and highly thermally conductive materials.

- Commercialization approach:

  Exploring a startup company.

Measure of Success

- What impact will success have?
  - High thermal conductivity PE is a platform material for many applications. Principle can be extended to other plastics.
- How will it be measured?
  - High thermal conductivity, ease of manufacturing, good chemically stability.
- What is the potential energy impact? Economic impact?
  - Cost and energy savings.
  - Polyethylene is also cheap and good potential for scale up.



Project Management & Budget

- Tasks and key milestones: Quarterly milestone targets and annual go/no-go criteria

Budget Year	Go/No-go Description	Verification Method	Planned Completion Date
1	Development of 1st PE processing apparatus	Demonstrate PE sheet (1×10 cm^2) fabrication	10/01/13
2	Development of 2nd PE processing apparatus	Achieve thermal conductivity values 30 W/mK	11/30/14
3	Development of 3rd PE processing apparatus	Achieve thermal conductivity values 60 W/mK	2/28/16

Total Project Budget	
DOE Investment	$1M
Cost Share	$0
Project Total	$1M

Results and Accomplishments

- Completed milestones since last review in 2015:

Milestone #	Milestone title or brief description	Milestone completion date				Milestone progress notes
		Original planned	Revised planned	Actual complete	Percent complete	
3.1	Achieve a sheet thermal conductivity of 60 W/mK.	2/28/16			100%	On schedule
3.2	Optimizing the polymer processing parameter.	11/30/15			100%	On schedule
3.3	Characterization of polymer sheets.	2/28/16			100%	On schedule
3.4	Development of third and final generation polymer processing apparatus.	10/31/15			100%	On schedule

- What results do you have to report?
    - Demonstrated polyethylene films with thermal conductivity of 61.7 W $m^{-1}K^{-1}$ (commercial films have thermal conductivity of ~0.1 - 0.4 $Wm^{-1}K^{-1}$).
- Future work:

  Starting a company or partnering with another company to scale up for commercialization of materials or aiming for specific applications.

Questions?

U. S. Department of Energy,
Advanced Manufacturing Office (AMO)
Innovative Manufacturing Initiative

Massachusetts Institute of Technology
Department of Mechanical Engineering
Principal Investigator: Prof. Gang Chen

Thank you.