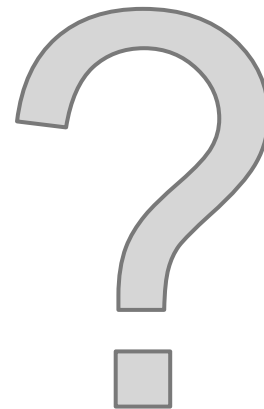
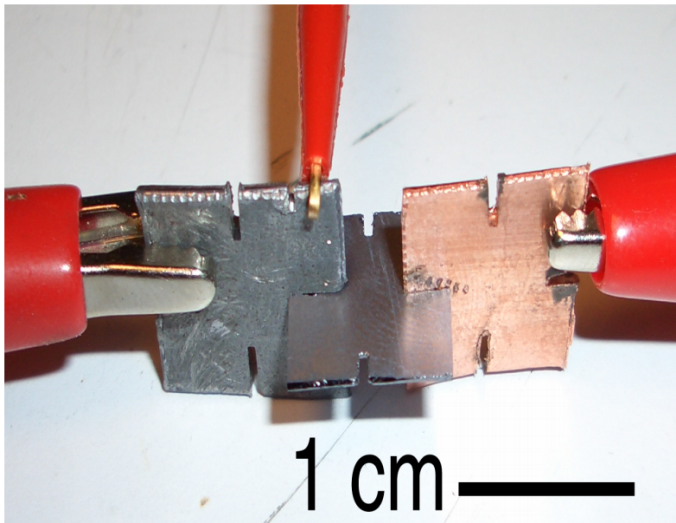
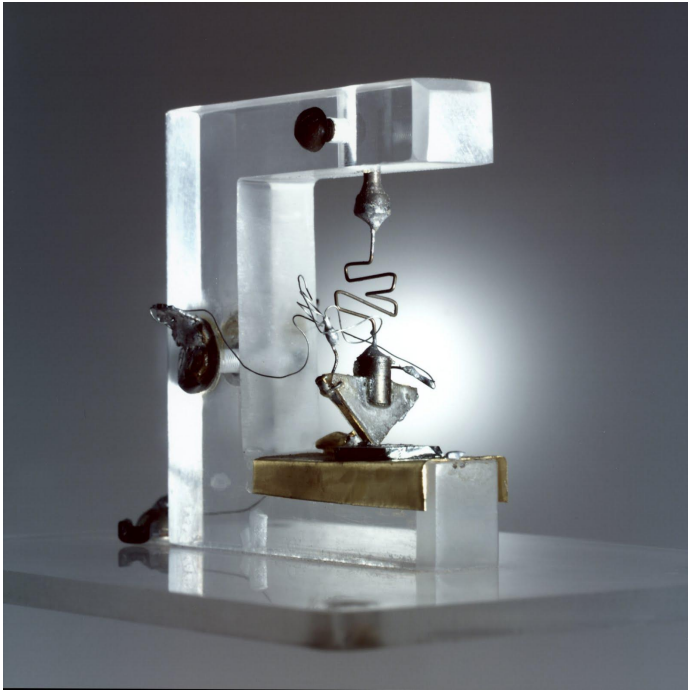


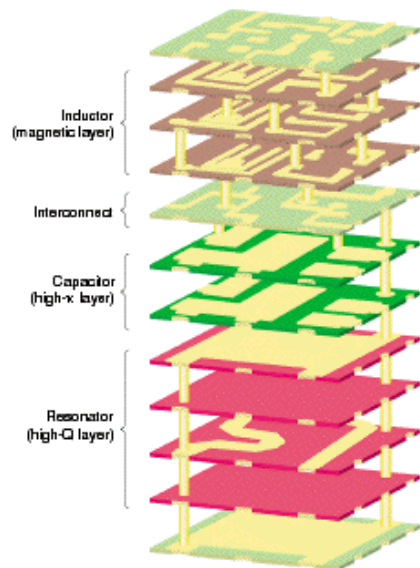
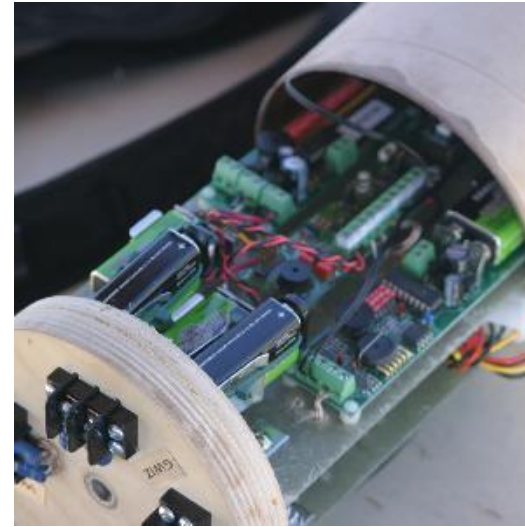
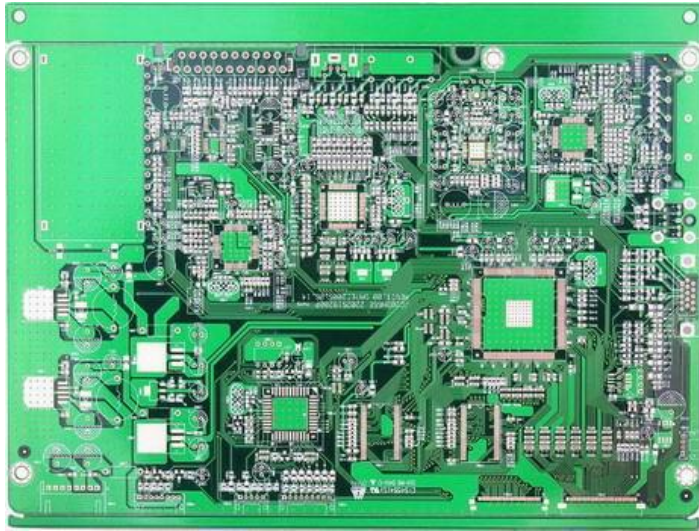
Automating Digital Micro-Assembly

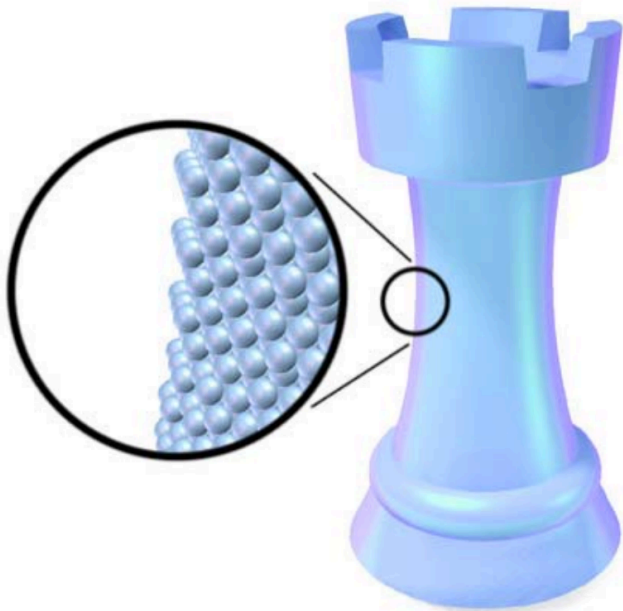
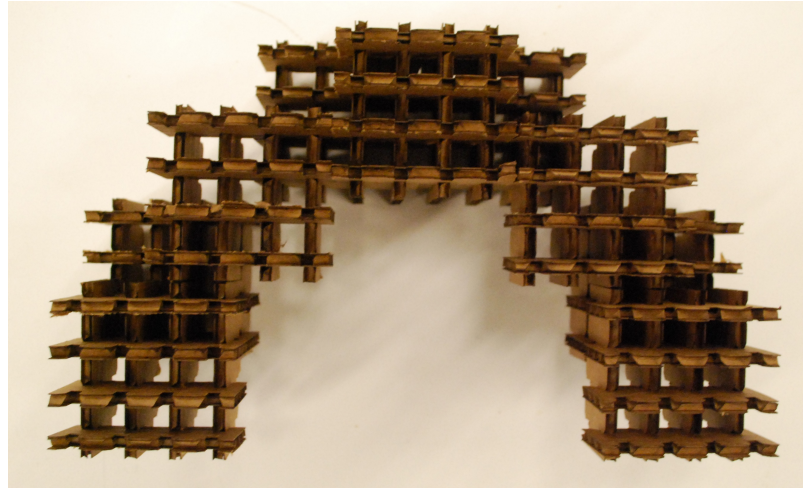
Will Langford
Center for Bits and Atoms



Popescu

There are problems with electronics...





Hiller, Lipson

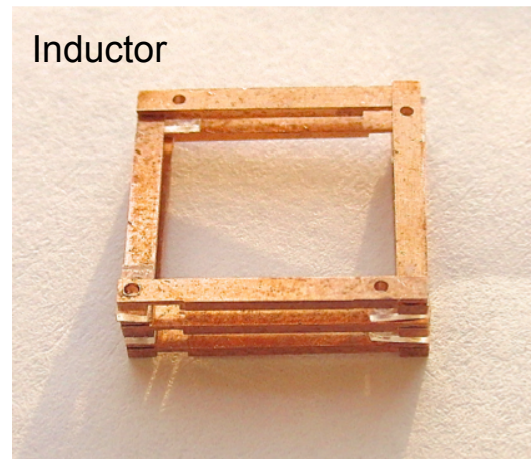
insulating



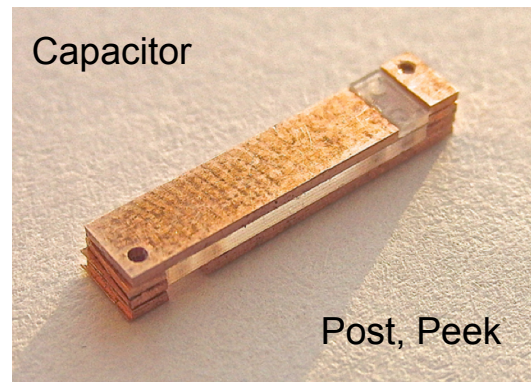
conductive



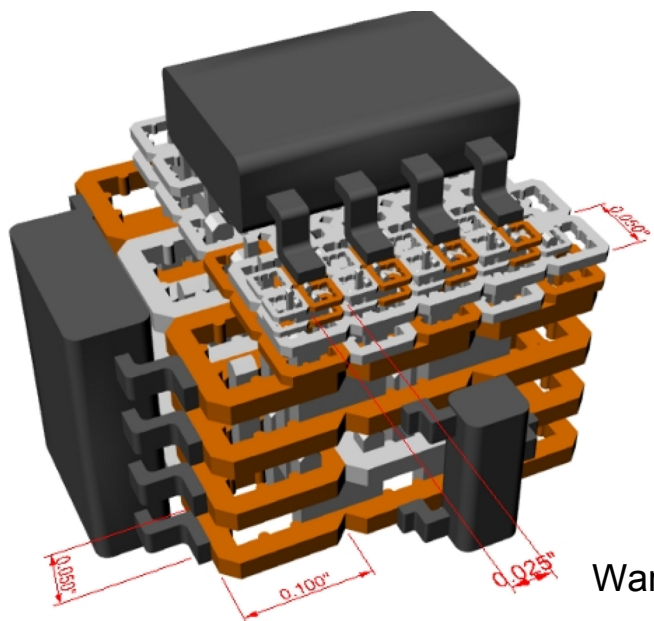
Inductor



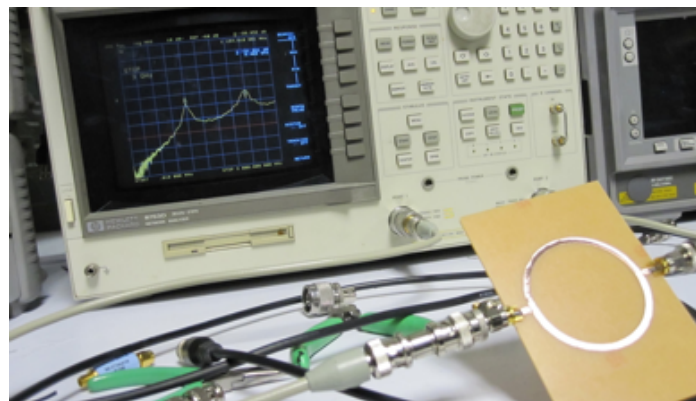
Capacitor



Post, Peek



Ward



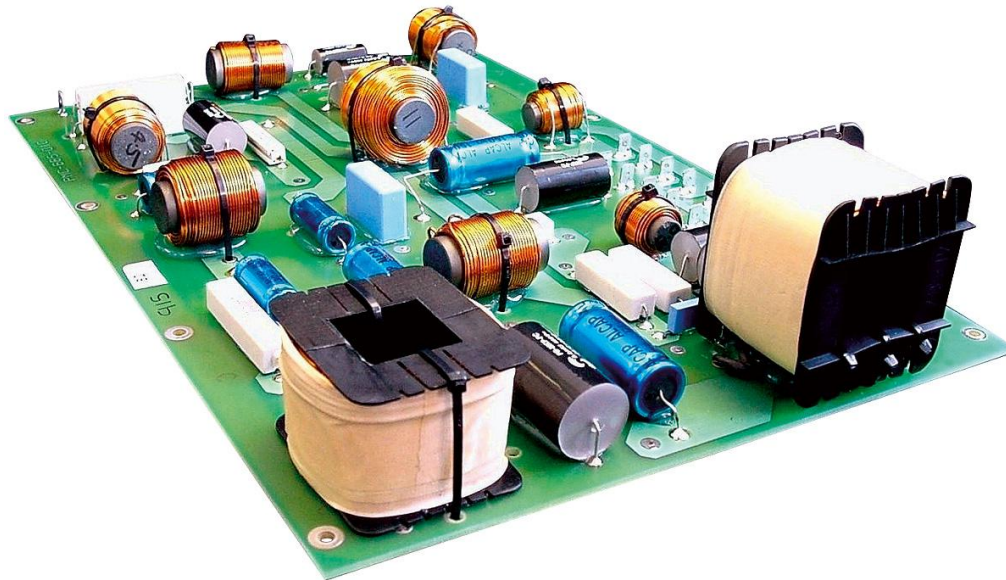
insulating



conductive



resistive



insulating



conductive



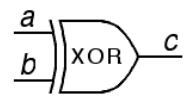
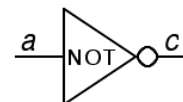
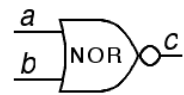
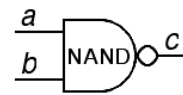
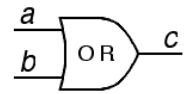
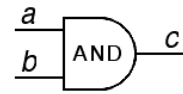
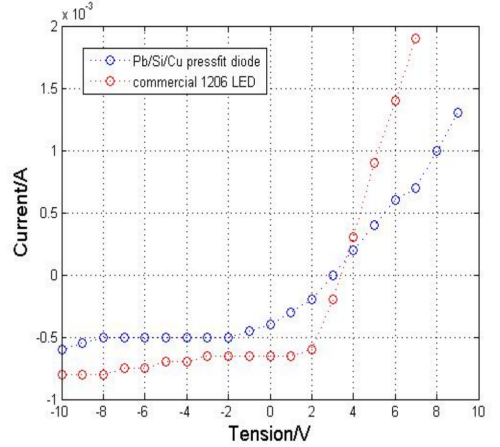
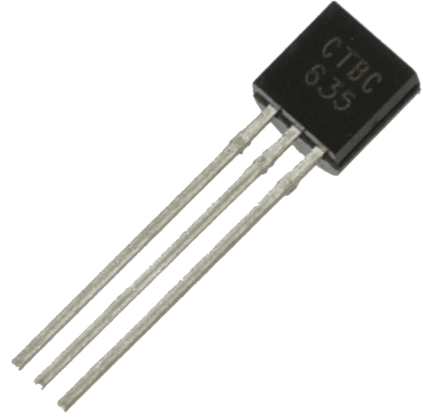
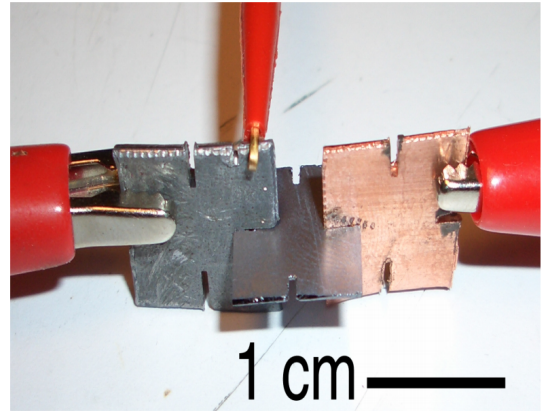
resistive

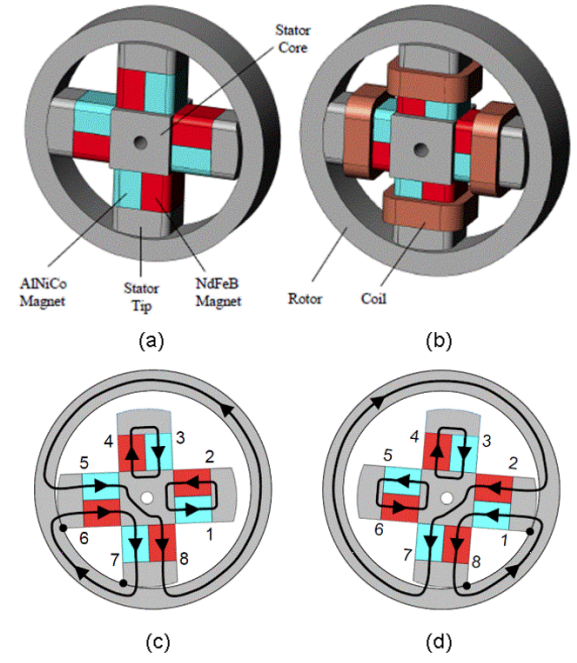








semiconducting

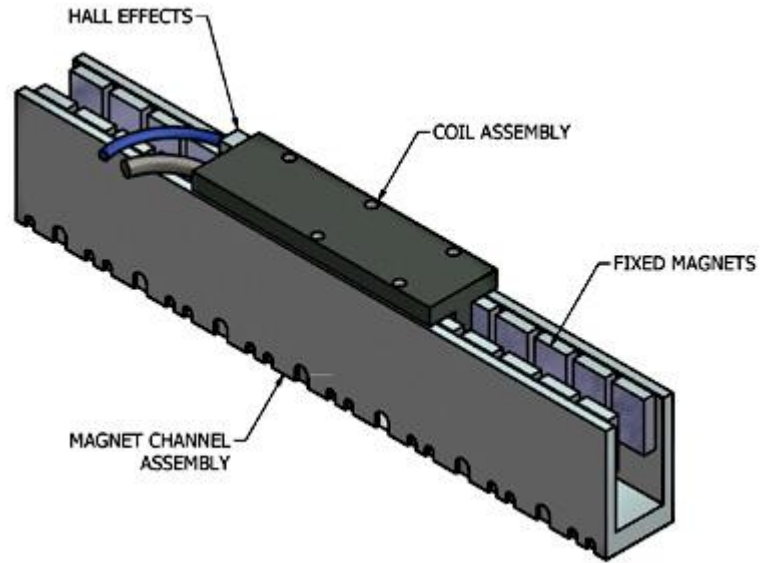


semiconducting

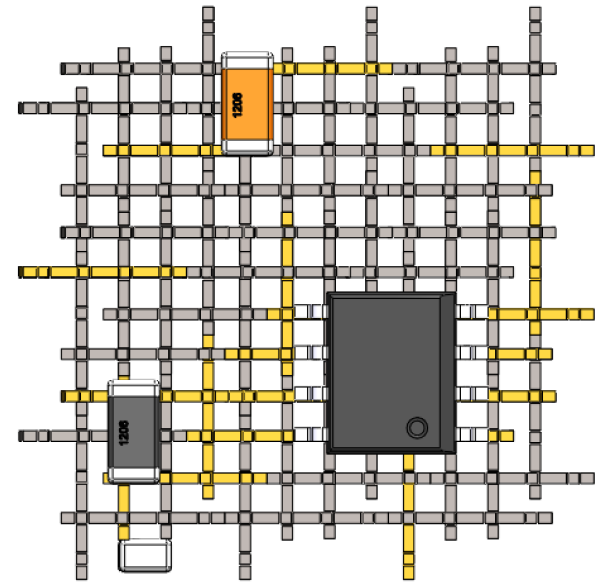
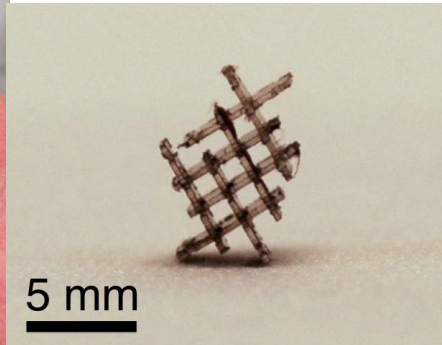
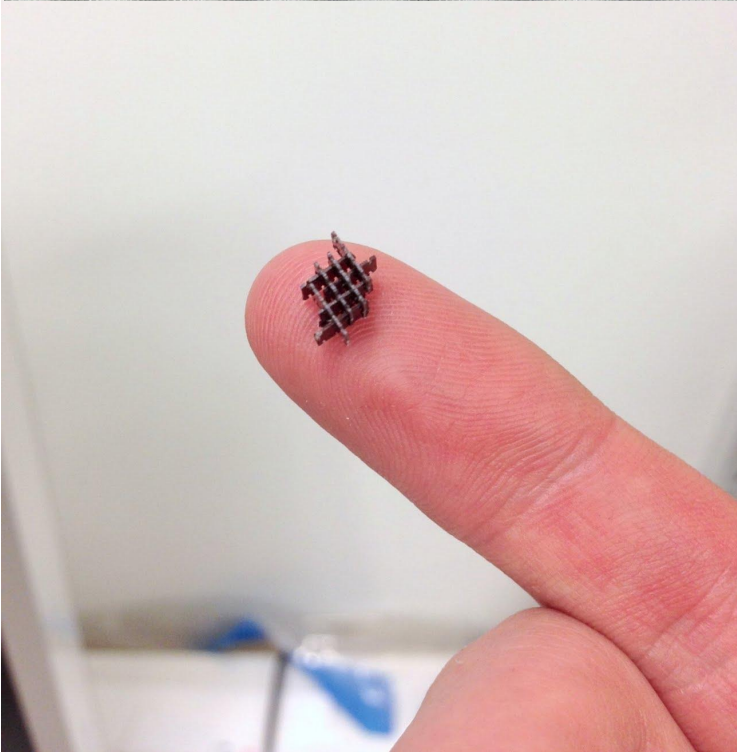
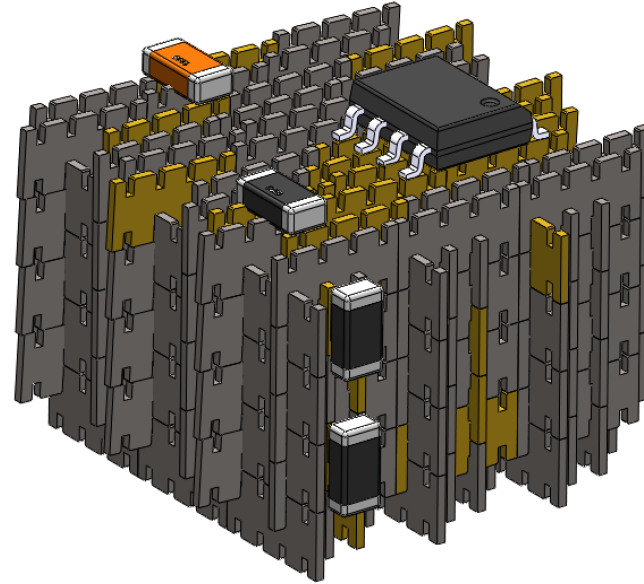
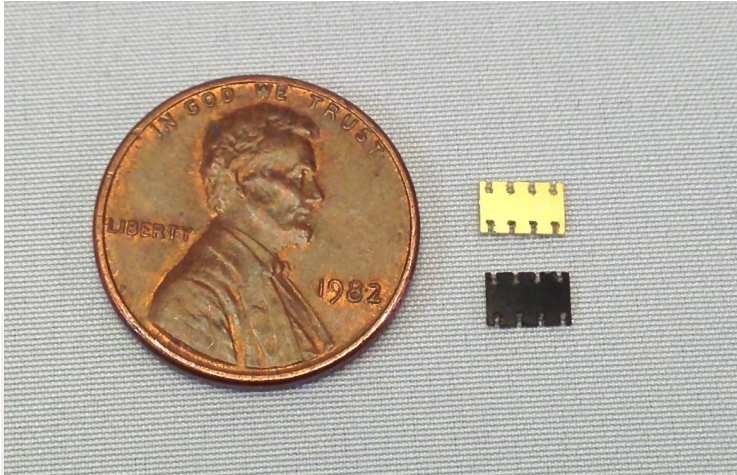




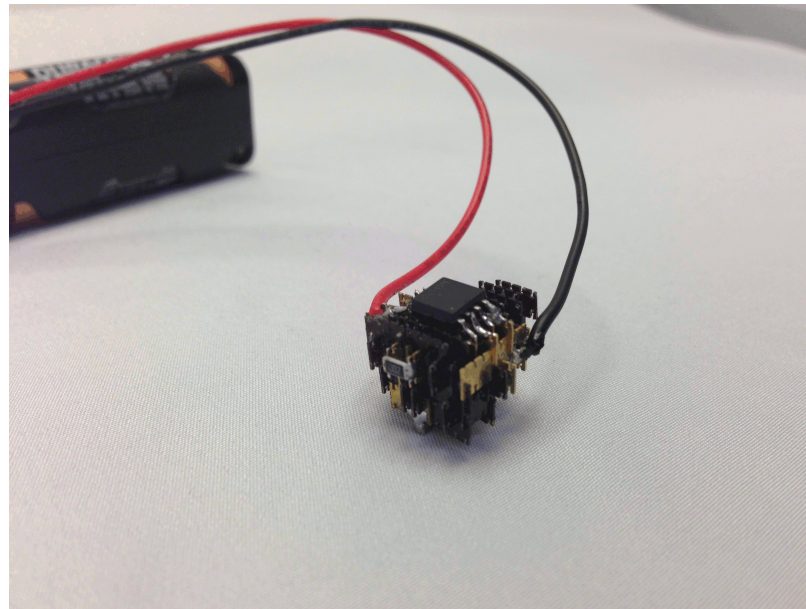
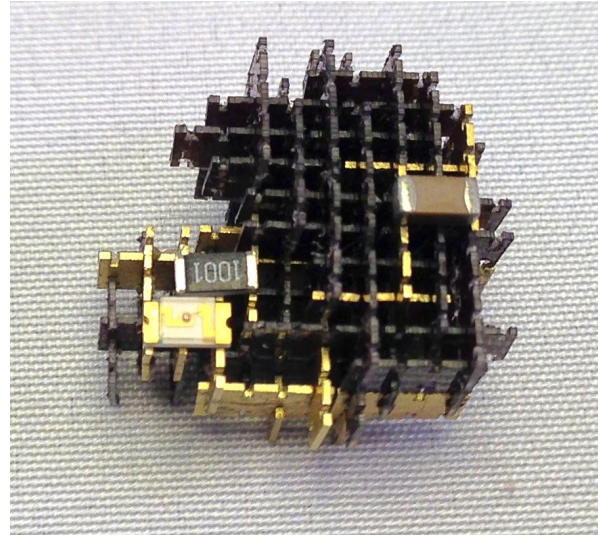
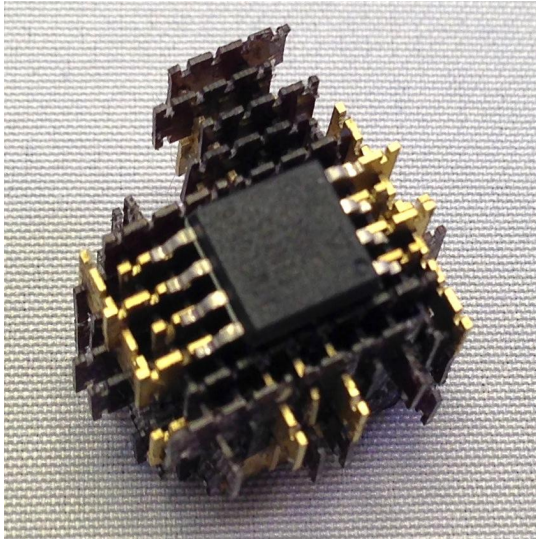
- insulating 
- conductive 
- resistive 
- semiconducting 
- semiconducting 
- magnetic 



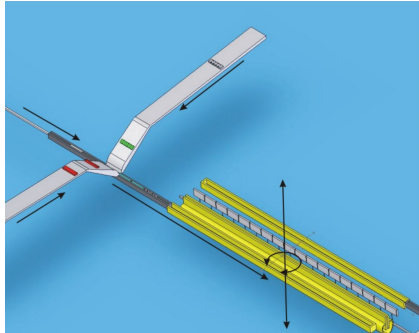
Press-fit Circuit Boards



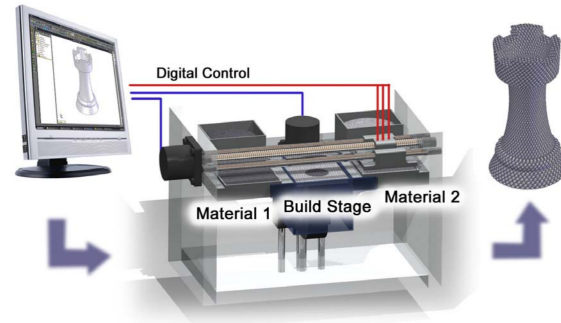
Press-fit Circuit Boards



2007



Popescu



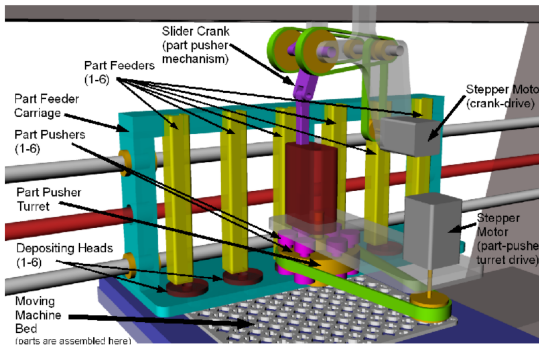
Hiller, Lipson

2009



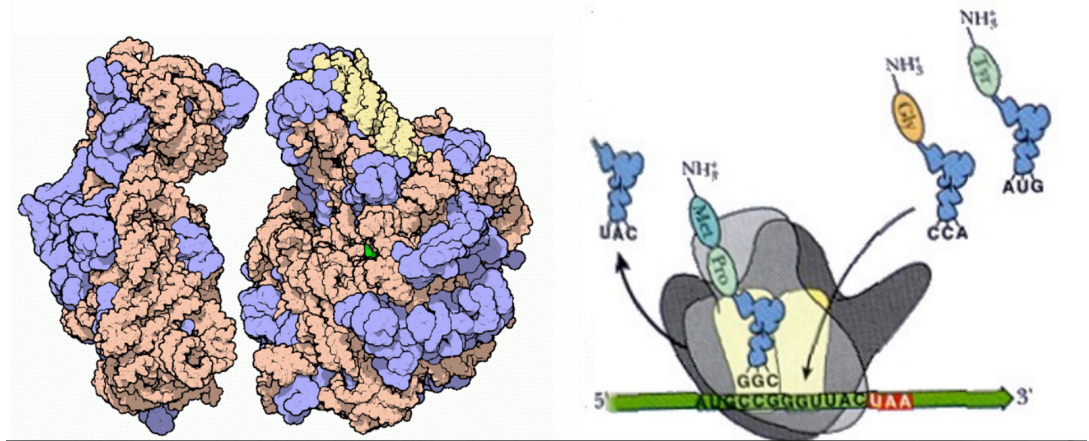
Hiller, Lipson

2010

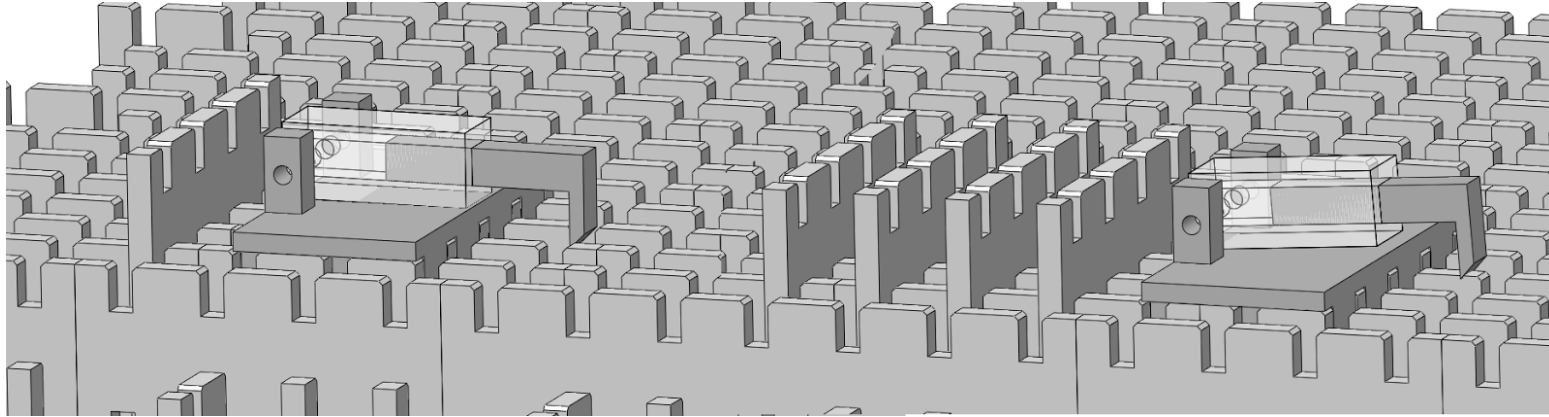


Ward

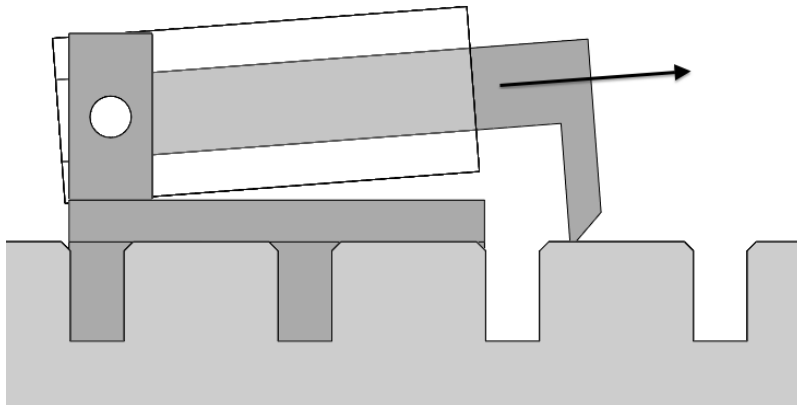
-4 billion years



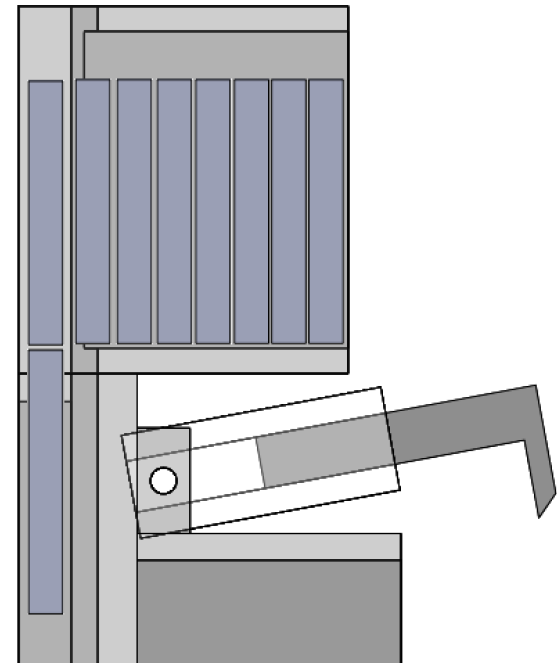
Automating Micro-Assembly

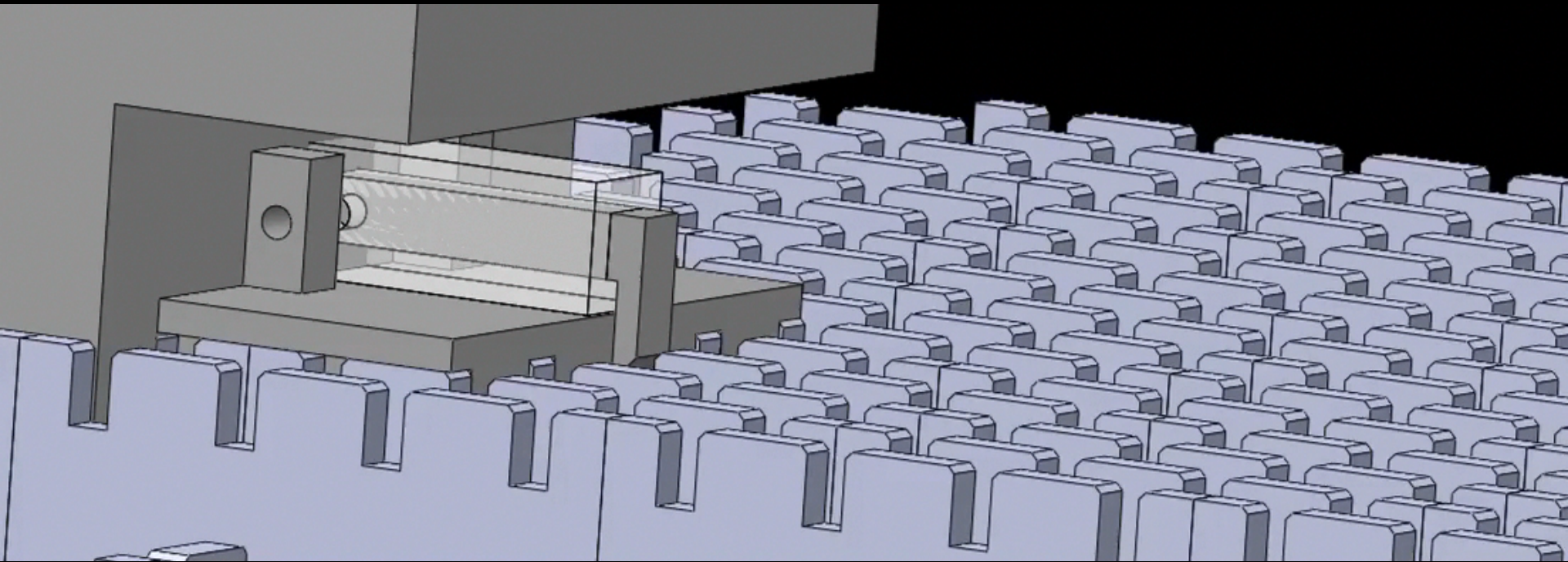


1 DOF Ratchet-Type Locomotion

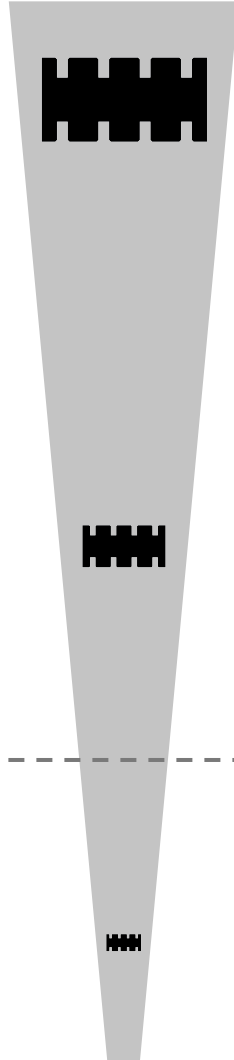
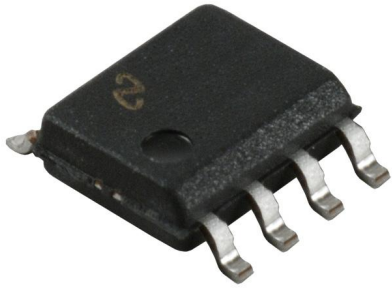


Part Dispenser





Scaling Down



5 mm

2 mm

20 um

parts/in²

100

645

6×10^6

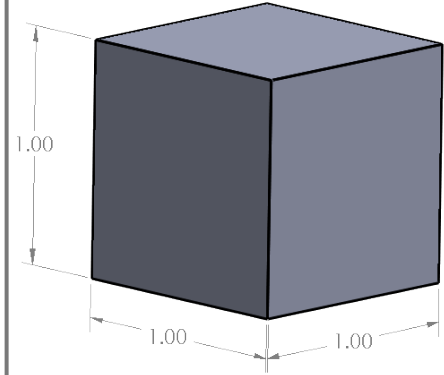
parts/sec*

1

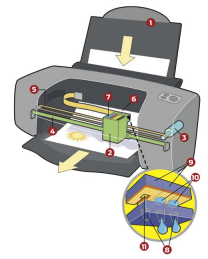
11

85×10^3

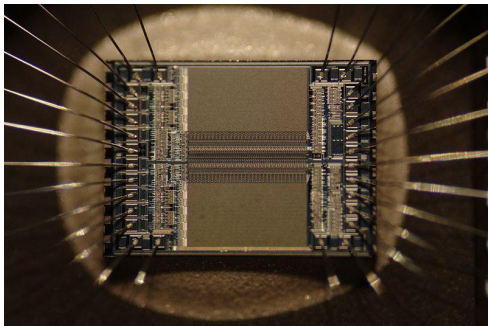
* for 1 in³ in 10 mins



(Audio)



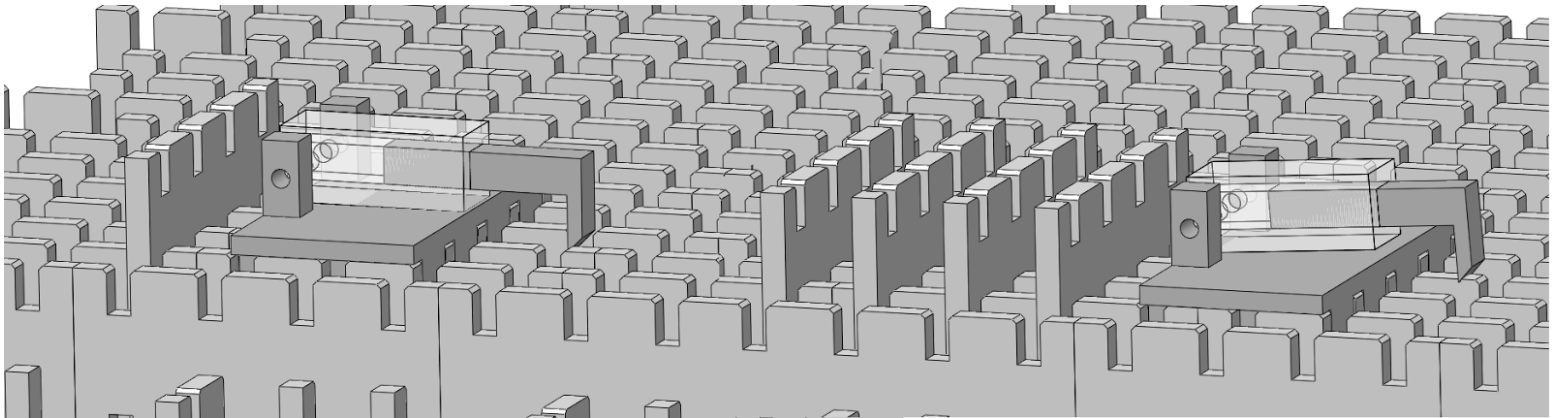
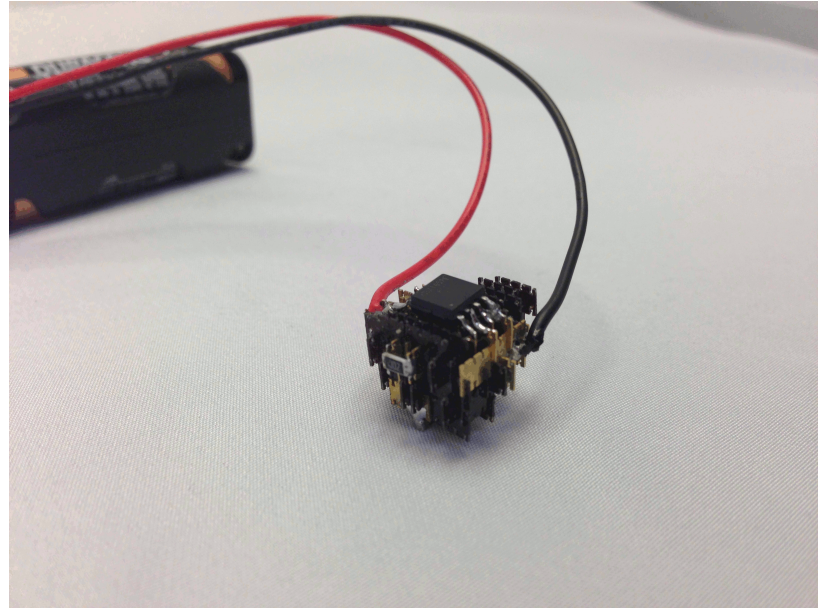
(Ultrasonic)

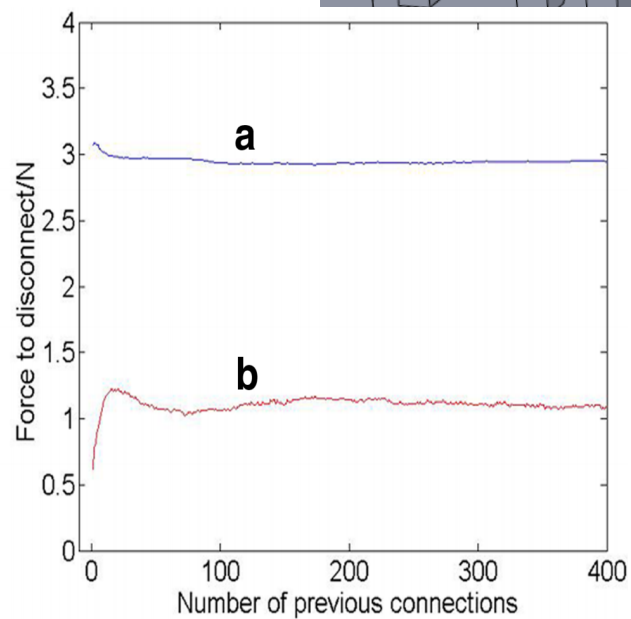
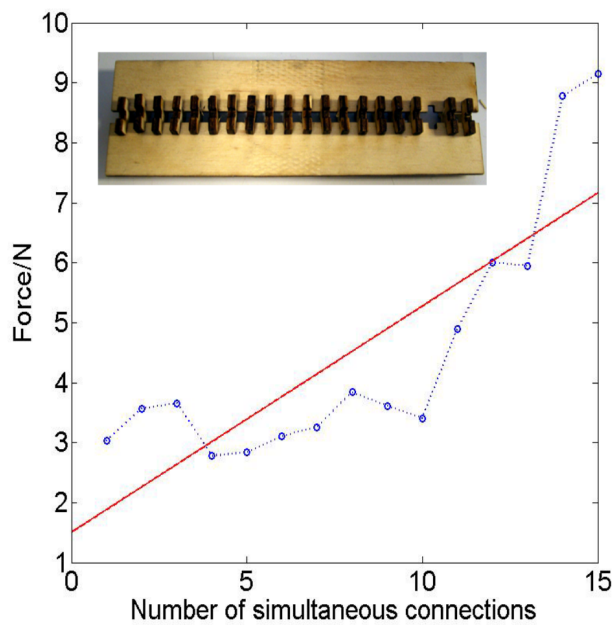
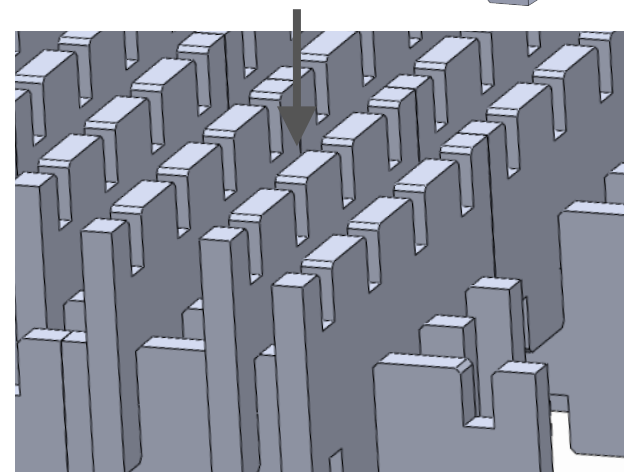
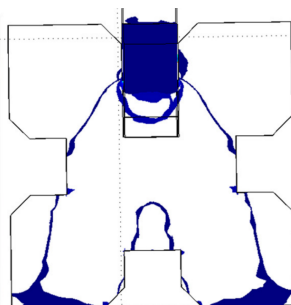
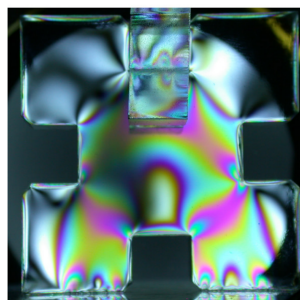
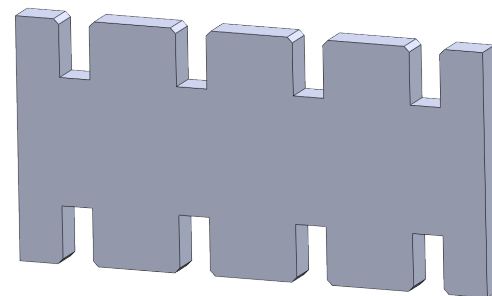




Will Langford

Will.Langford@cba.mit.edu





Recreating the History of Digital Electronics

... with 5 parts

insulating



conductive



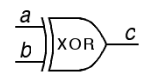
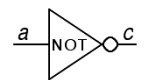
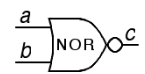
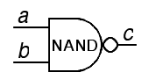
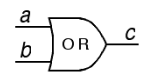
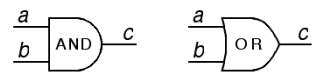
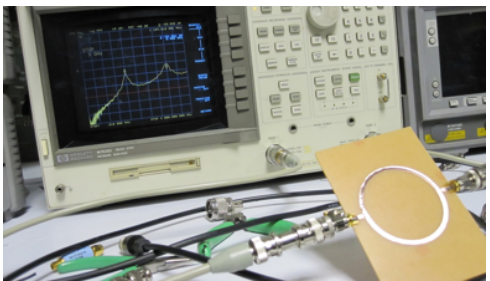
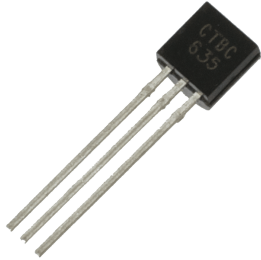
resistive



semiconducting



semiconducting



Challenges & Open Questions

How do you coordinate a
swarm of micro-robots?
(image of micro-robots)

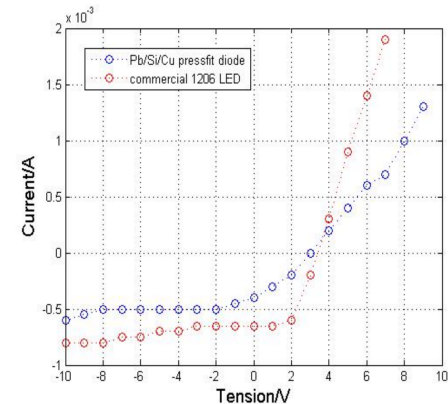
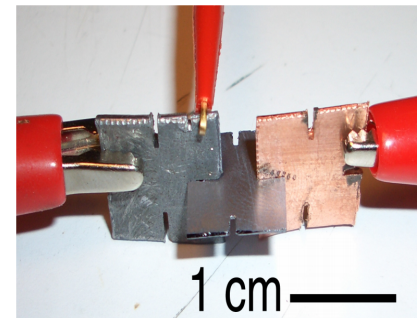
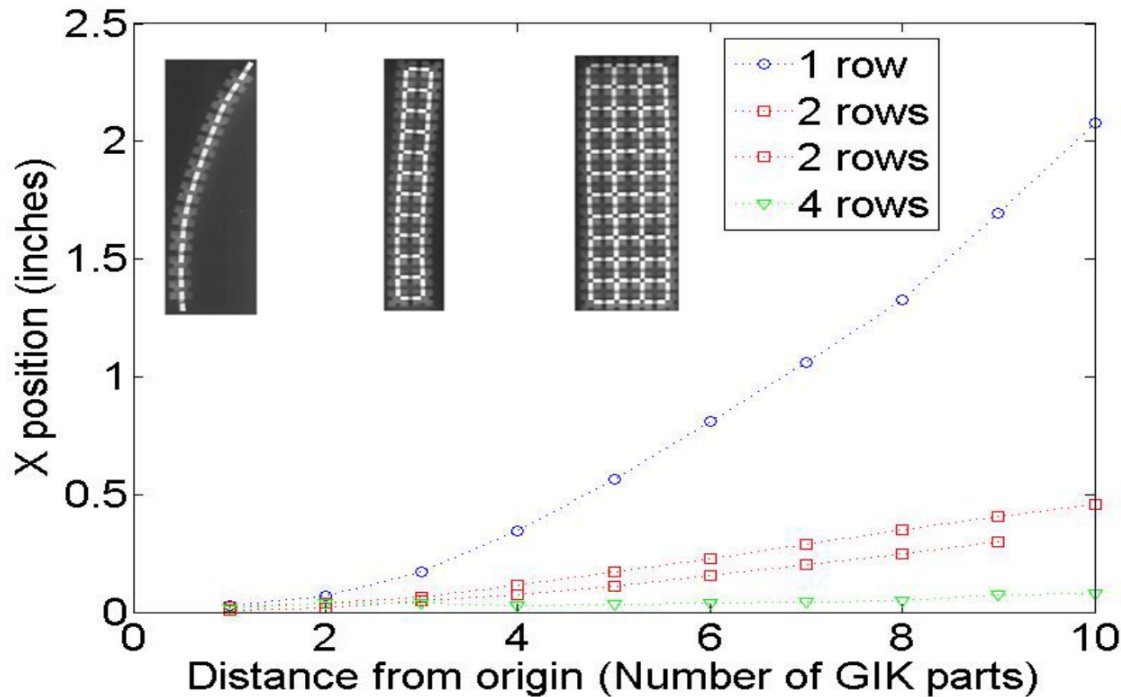
how do you supply materials to the
robots?
(image of pez dispenser)

assembly at micron (or below)
scale?

How should we design digital
objects?

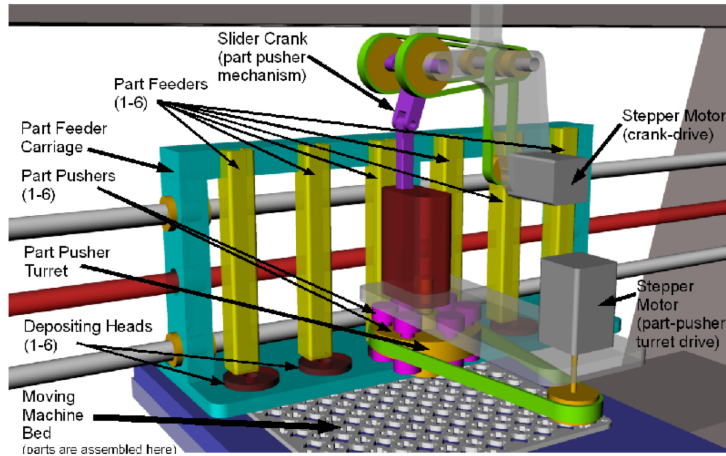
routing 3D circuits?

Digital Material



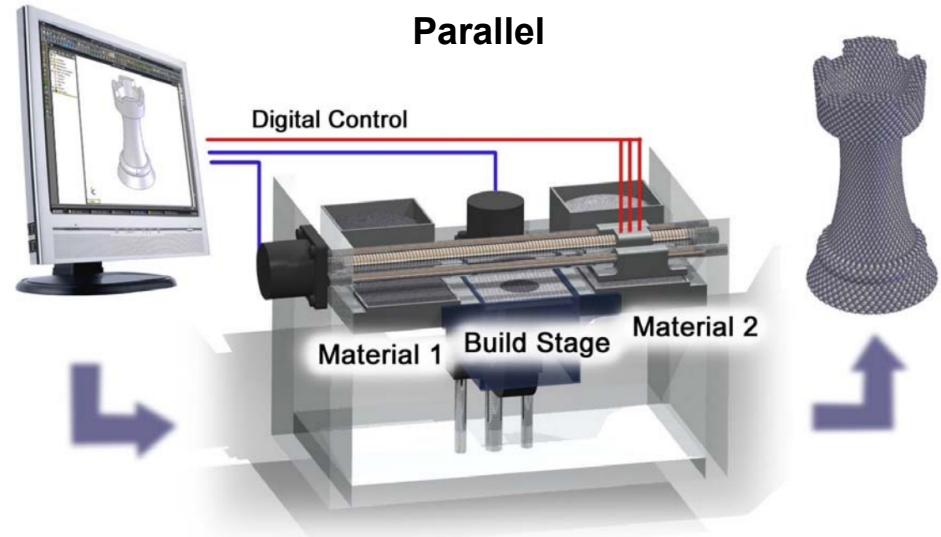
Automating Micro-Assembly

Serial



Ward

Parallel



Hiller, Lipson

