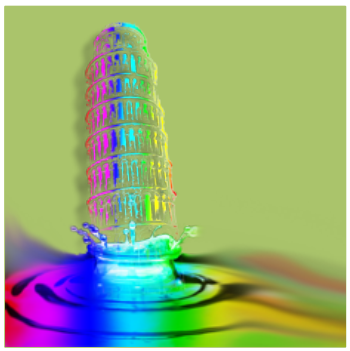
Fused Deposition Modelling (FDM)

Micro e Nano Sistemi

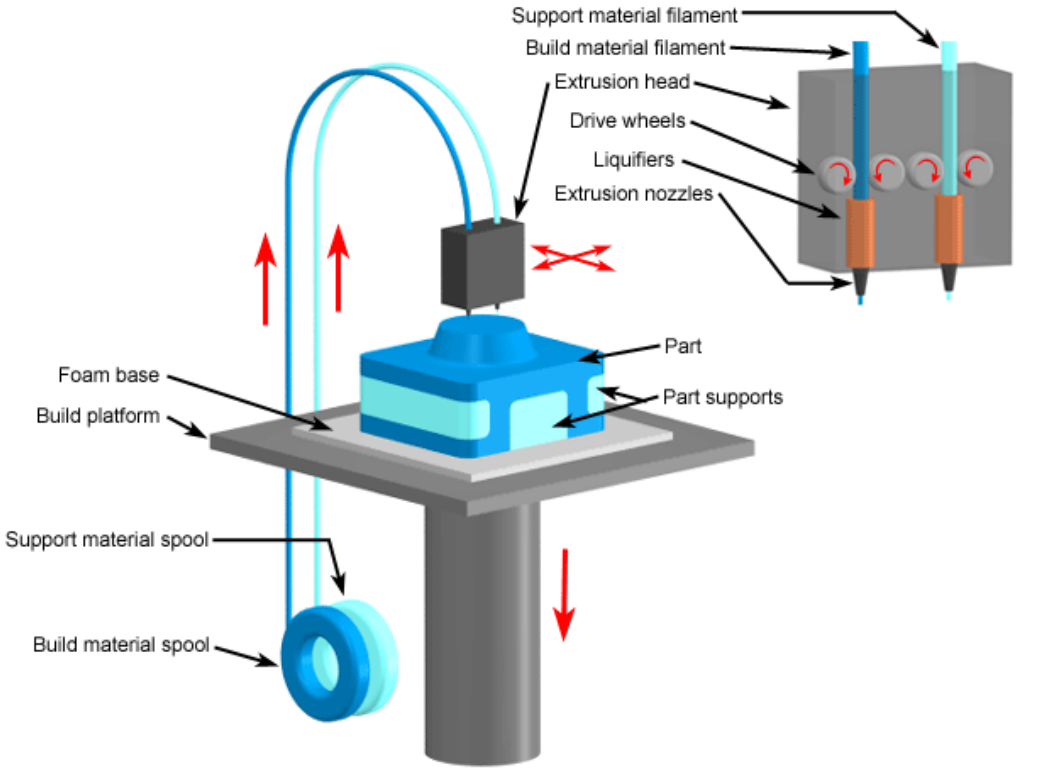


carmelo.demaria@centropiaggio.unipi.it

Fused deposition modelling (FDM)

- FDM is the second most widely used rapid prototyping technology, after stereolithography.
- A plastic filament is unwound from a coil and supplies material to an extrusion nozzle. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be turned on and off.
- The nozzle is mounted to a mechanical stage which can be moved in both horizontal and vertical directions.
- As the nozzle is moved over the table in the required geometry, it deposits a thin bead of extruded plastic to form each layer.
- The plastic hardens immediately after being squirted from the nozzle and bonds to the layer below. The entire system is contained within a chamber which is held at a temperature just below the melting point of the plastic.

FDM


Support material filament
Build material filament
Extrusion head
Drive wheels
Liquifiers
Extrusion nozzles
Part
Part supports
Foam base
Build platform
Support material spool
Build material spool
Copyright © 2008 CustomPartNet

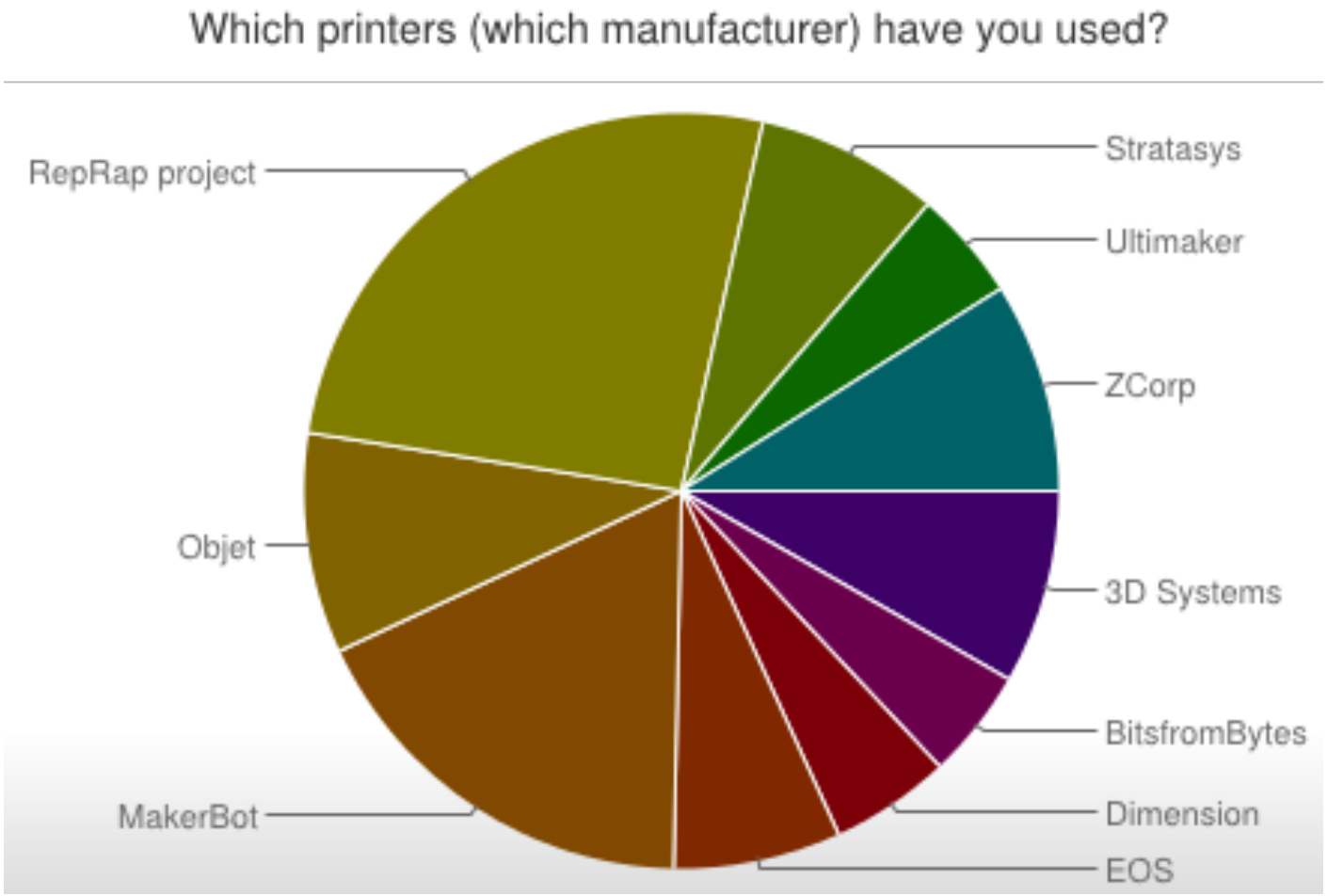
Caso di studio

PROGETTO REPRAP

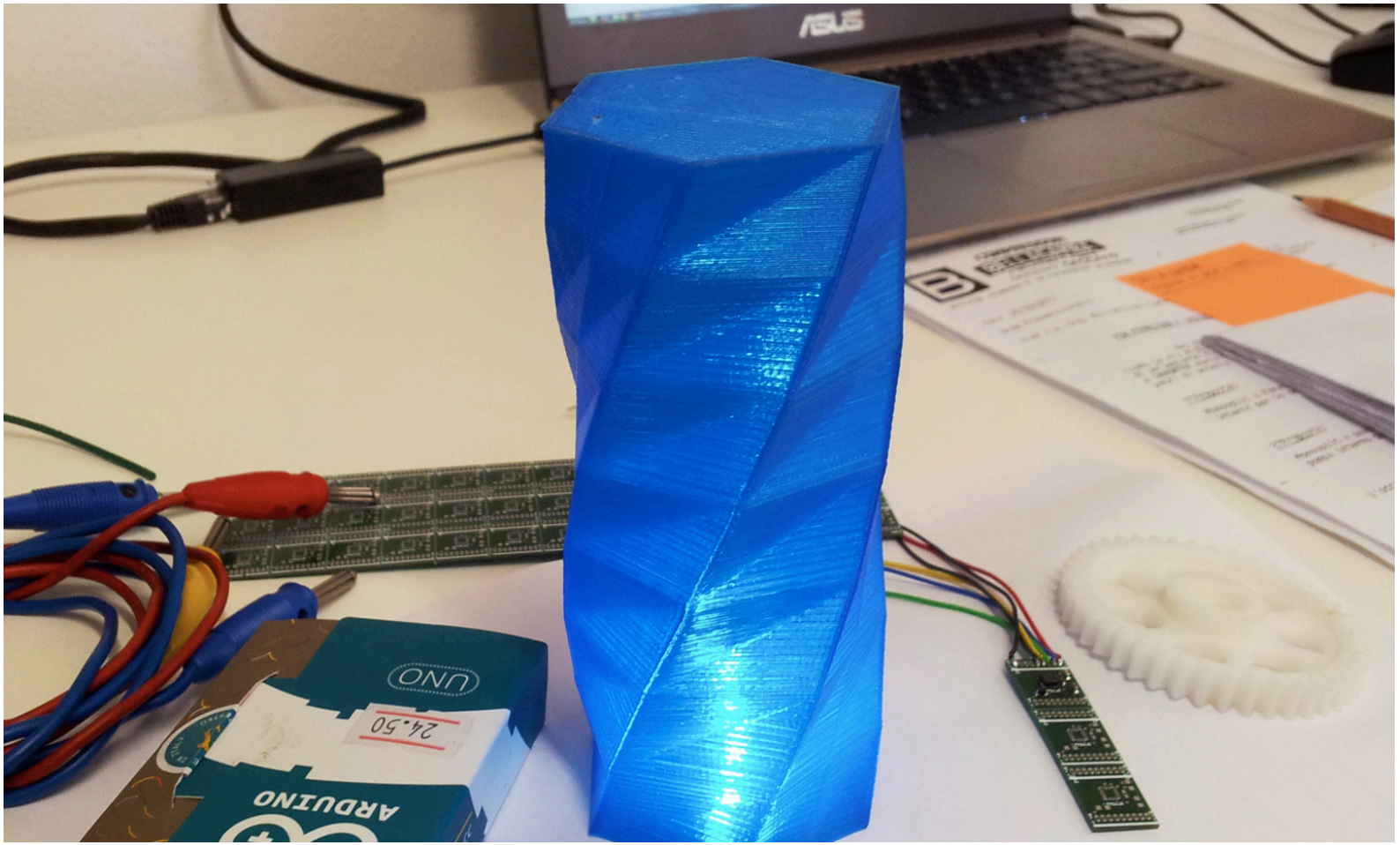
Open 3D printing: the RepRap project

- RepRap is first general-purpose self-replicating manufacturing machine.
- RepRap takes the form of a free desktop 3D printer capable of printing plastic objects.
- Since many parts of RepRap are made from plastic and RepRap prints those parts, RepRap self-replicates by making a kit of itself - a kit that anyone can assemble given time and materials.

The RepRap project



The RepRap Project



Main components of a 3D printer system

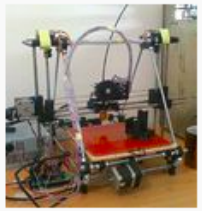
Software (CAD/CAM)

Firmware (Electronic)

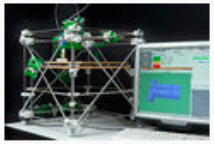
Hardware

extruder

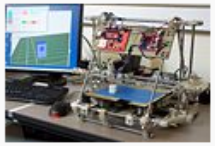
How many RepRaps?



Prusa (*license: GPL*)



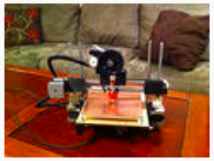
Darwin (*license: GPL*)



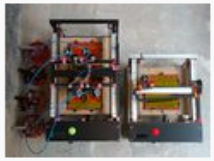
Mendel (*license: GPL*)

Huxley (*license: GPL*)

RepRap Morgan (*license: GPL*)



Printrbot (*license: CC-BY-SA*)



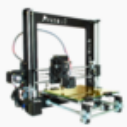
Cartesio (*license: CC-BY-SA*)

RepRapPro Mendel (*license: GPL*)

RepRapPro Huxley (*license: GPL*)

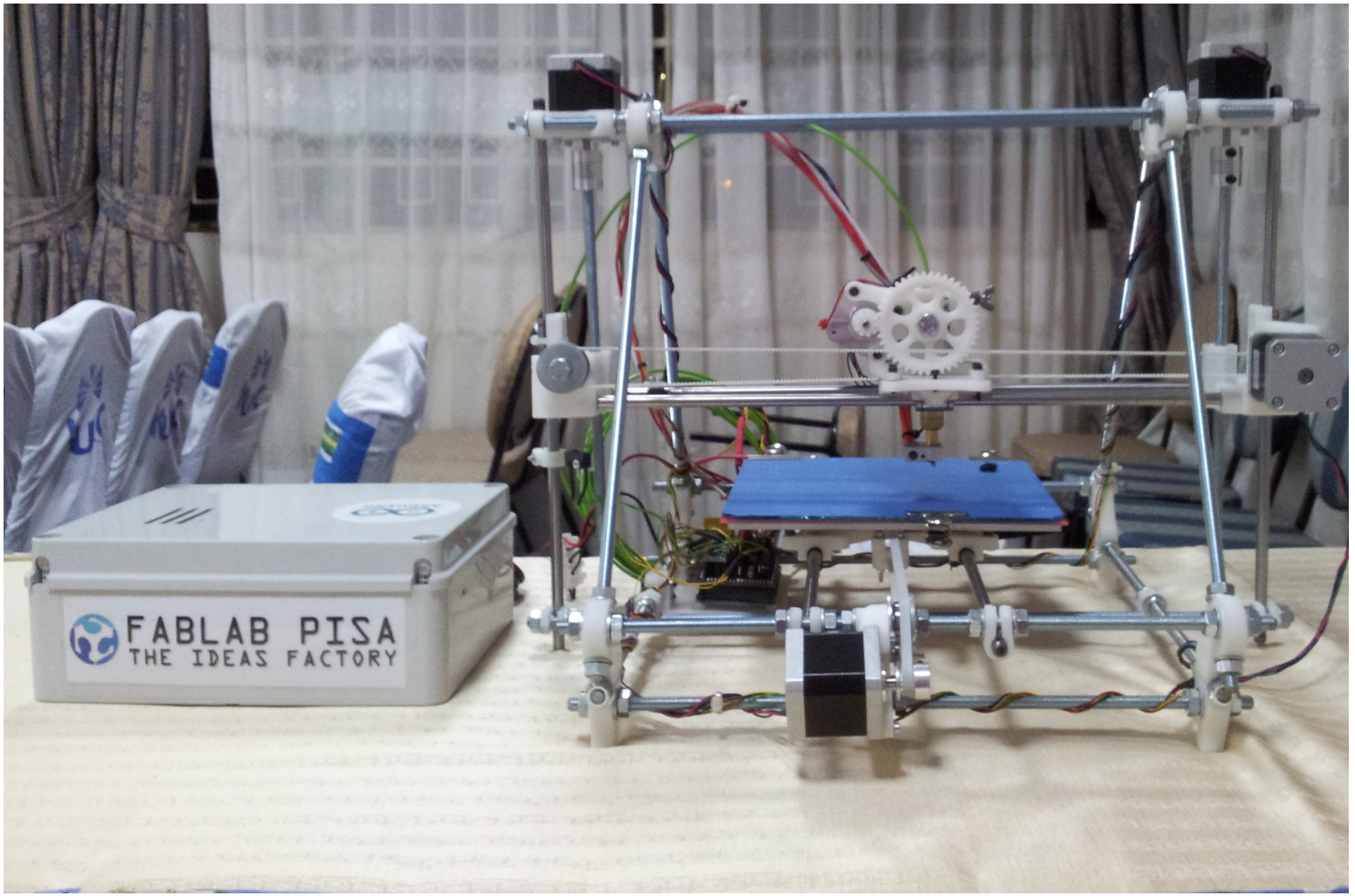
Eventorbot (*license: CC-BY-SA*)

3drag (*license: CC-BY-SA*)



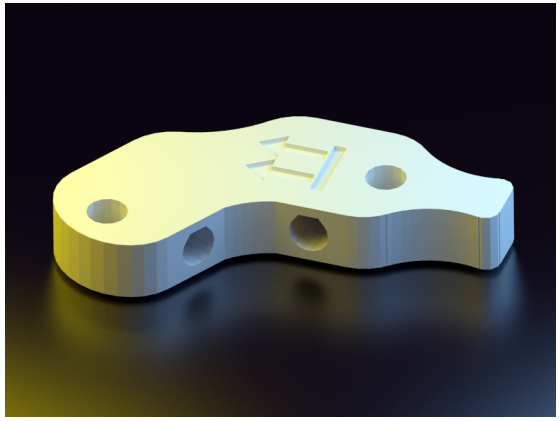
Prusa i3 Rework Introduction (*license: GPL*)

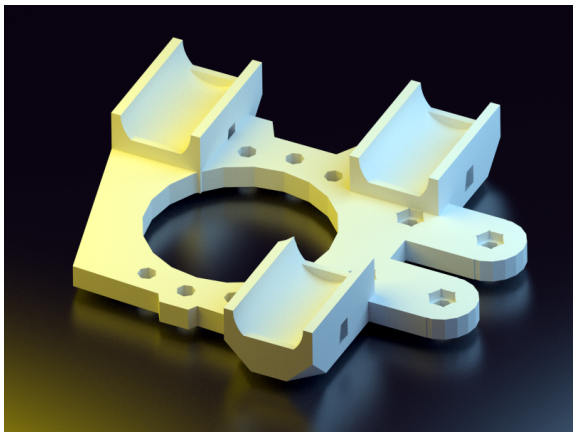
Prusa Mendel Model

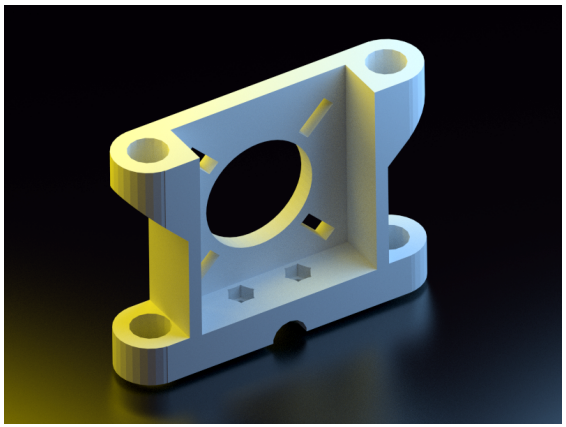


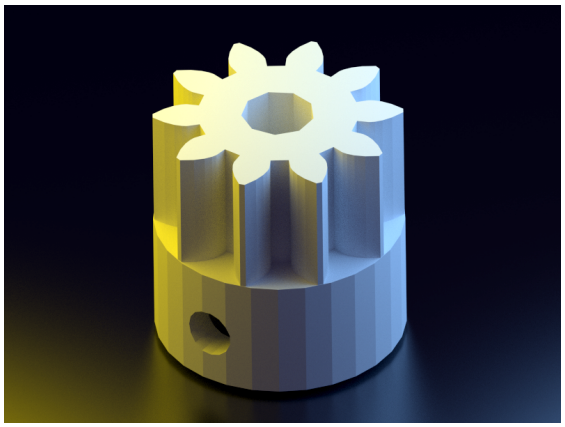
Mechanical structure

- 3D positioner
- Plastic parts + “vitamins”

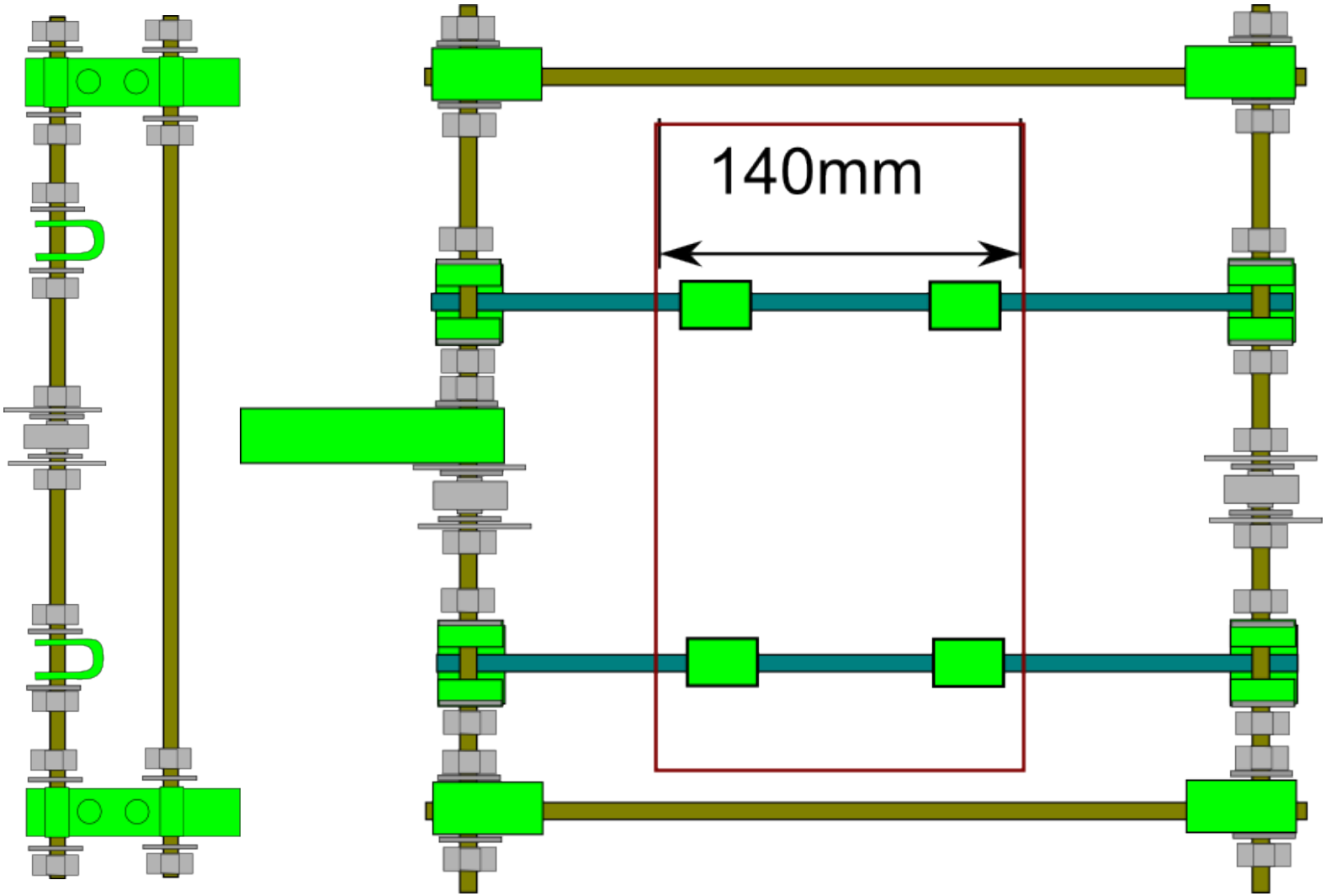




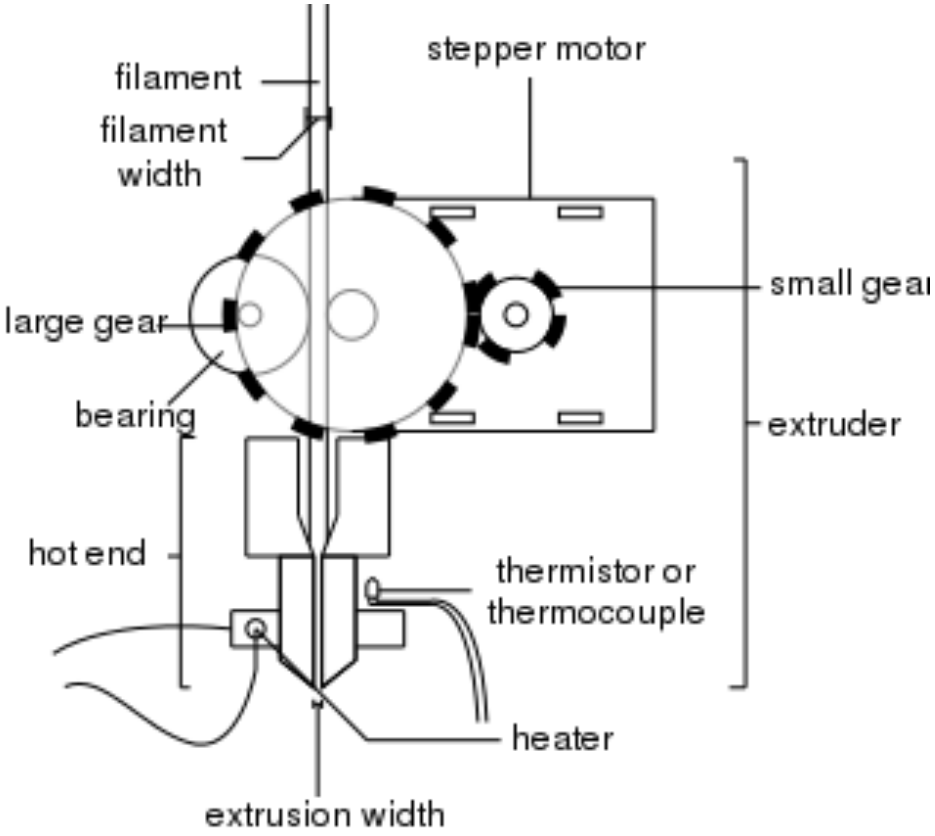




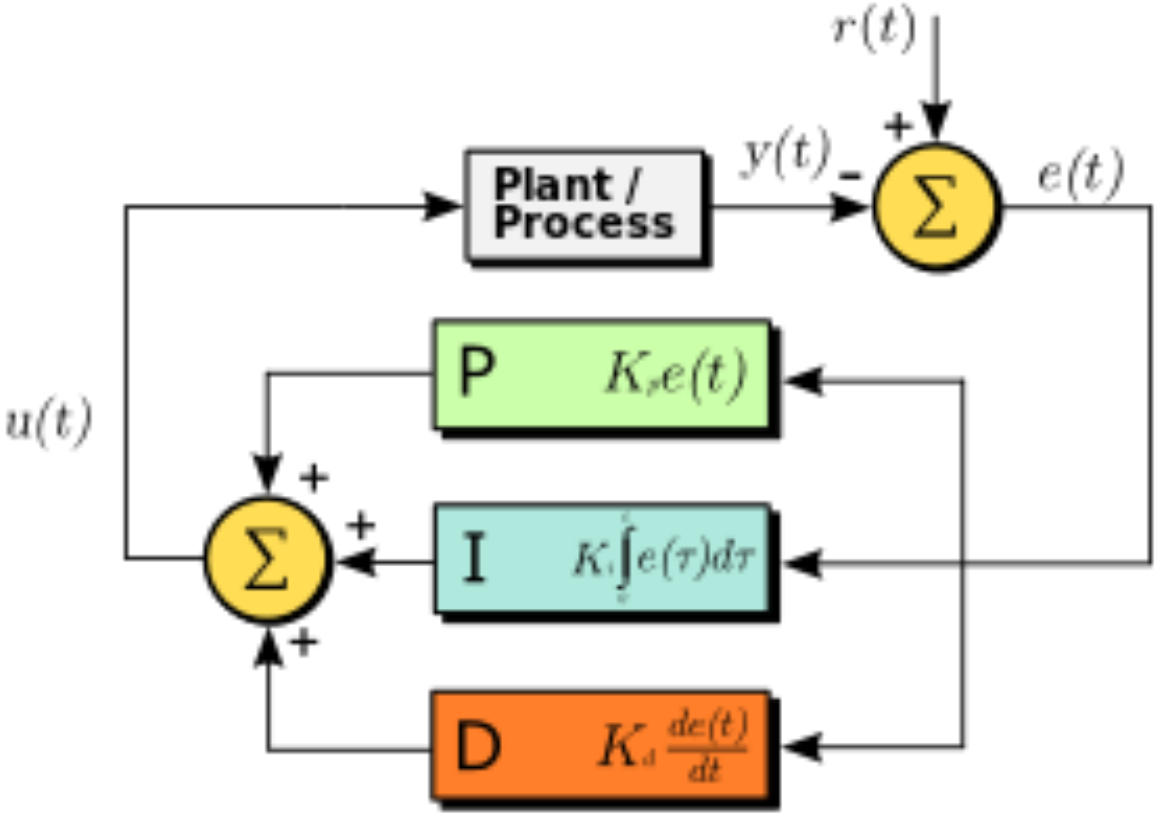
Mechanical structures



Extruder


filament
filament width
stepper motor
small gear
large gear
bearing
extruder
hot end
thermistor or thermocouple
heater
extrusion width

Temperature controller



Filament material

- FFF = Fused Filament Fabrication
- Filament: fine diameter plastic that exits from an extruder (some may refer to the plastic feed stock as filament as well)
- Typically, the diameter of the filament varies between 1mm and 0.3mm, with 0.5mm typical for many users.
- The standard extruder produces filament using high pressure and heat to force molten plastic thru a very tiny hole.

Filament material

- “Standard” materials:
  - Poly-Lactic-Acid (PLA) (soft and hard)
  - Acrylonitril-Butadiene-Stirene (ABS)
- “Experimental” materials:
  - Nylon
  - Polycarbonate (PC)

Filament: stretching

- As a machine will rarely extrude filament without additional constraint, this die swell diameter does not entirely determine the final metrics that determine your printer quality.
- For example, if the head motion moves fast enough, the extruded filament will stretch, and result in a thinner than normal result.
- One can use these principles to adjust within some margin print quality against print speed.
- There are limits though - if you extrude slower, and move faster, the filament will stretch and break beyond some threshold -- an undesirable result. At the other end, if extrude faster, and move slower, the filament will bulge, produce nodules and blobs -- another undesirable effect.

Filament: Die swell

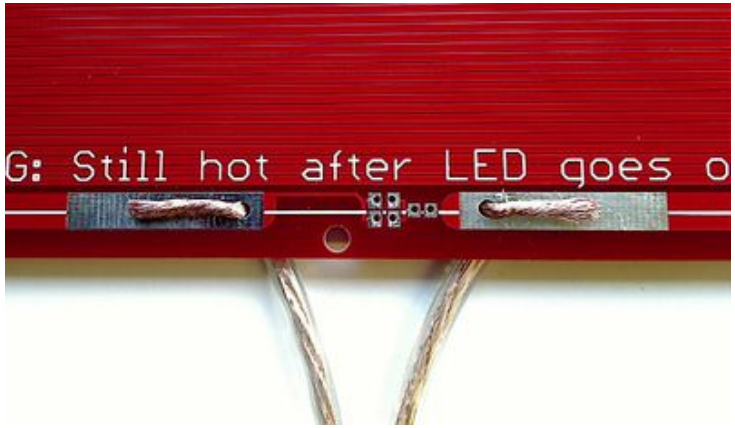
- As the plastic deforms and exits the hole, it may 'rebound' somewhat and produce, when not constrained by any other factors, a final diameter slightly larger than the hole.
- The resulting Die Swell varies by material, temperature, and the hole diameter (data from Nophead Blog)

Material	Nozzle Diameter (mm)	Minimum Range (mm)	Maximum Range (mm)
ABS	0.5	0.3	0.5
ABS	0.3	0.25	0.4
PLA	0.4	0.3	0.4 *

* poor quality because PLA does not have much die swell.

HotPlate


HOT ZONE
DO NOT TOUCH!
HOT ZONE
DO NOT TOUCH!
CAUTION:
Before touching, power off the heatbed and wait at least 10 minutes!
Still hot after powered off!
Do not leave unattended!
Keep away from children!
WARNING: Still hot after LED goes out!


G: Still hot after LED goes o

Electronics

1. Community based, tested and supported electronics
    1. 4pi
    2. Generation 7 Electronics
    3. Melzi
    4. RAMPS
    5. Sanguinololu
    6. SmoothieBoard
2. RAMPS derivatives
    1. Megatronics
    2. 3Drag controller
3. Commercial alternatives
    1. R2C2 Electronics
    2. Generation 6
    3. Generation 4

Ramps

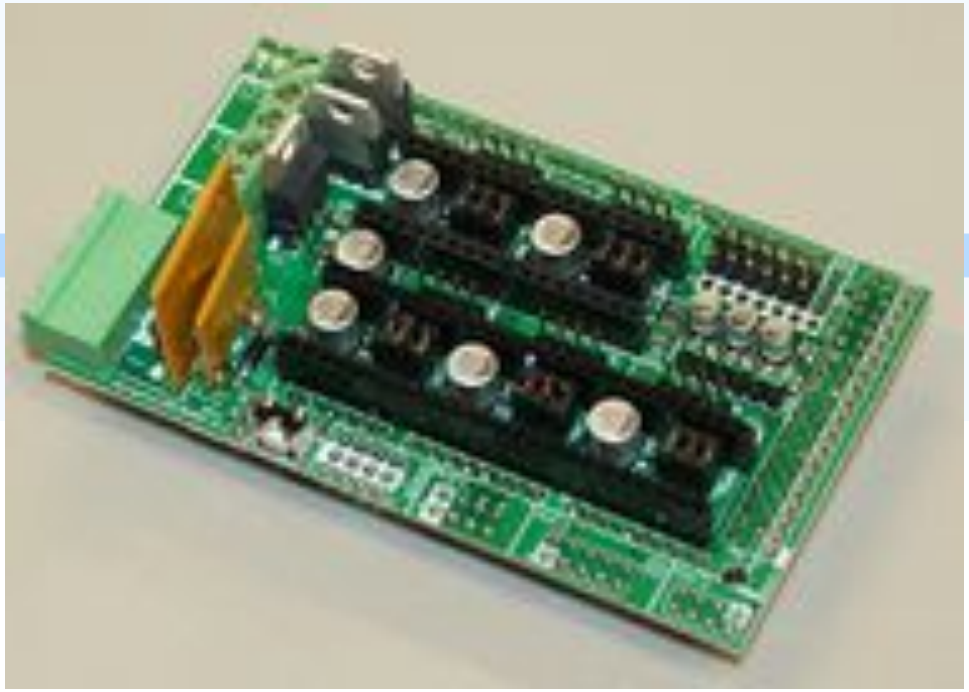
ELECTRONICS INFO	
Details	**Description**
Name : RAMPS **Creator** : johnnyr **Status** : active	Arduino MEGA based modular RepRap electronics. RAMPS is the most often used RepRap electronics in 2012. It shares circuitry concepts (stepper driver, thermistor, heater MOSFETs, etc.) with many other electronics.

Features

- License=GPL
- Built on stable Arduino Mega base
- Modular - easier to troubleshoot
- ATmega based
- up to 1/16 microstepping
- etch resist prepared up to v1.3, v1.4 is optimized for smd

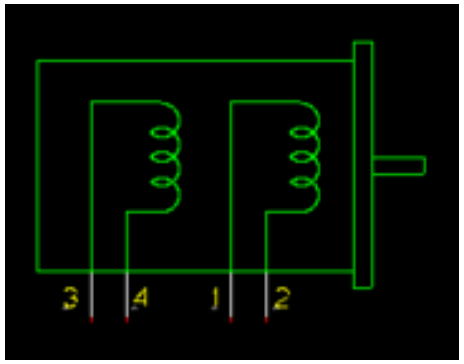
Compatible Firmware

- Marlin
- Sprinter
- Teacup

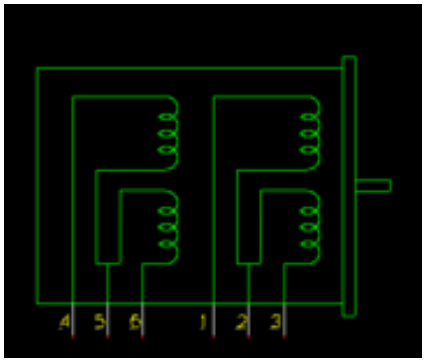


Stepper Motors

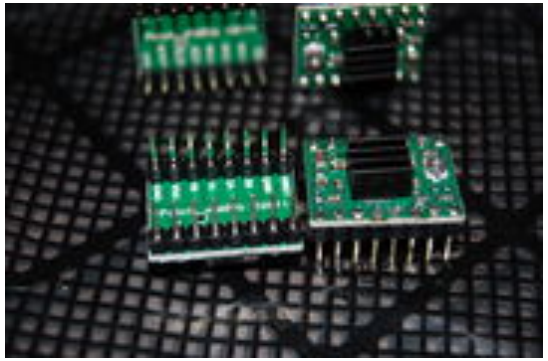
Stepper motor
(NEMA standard)



Bipolar

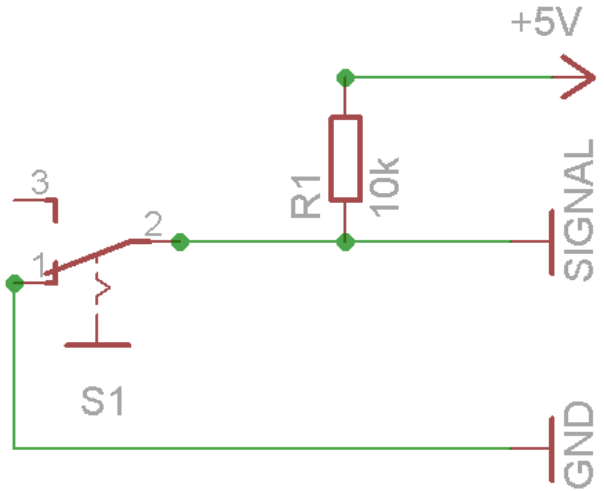


Unipolar

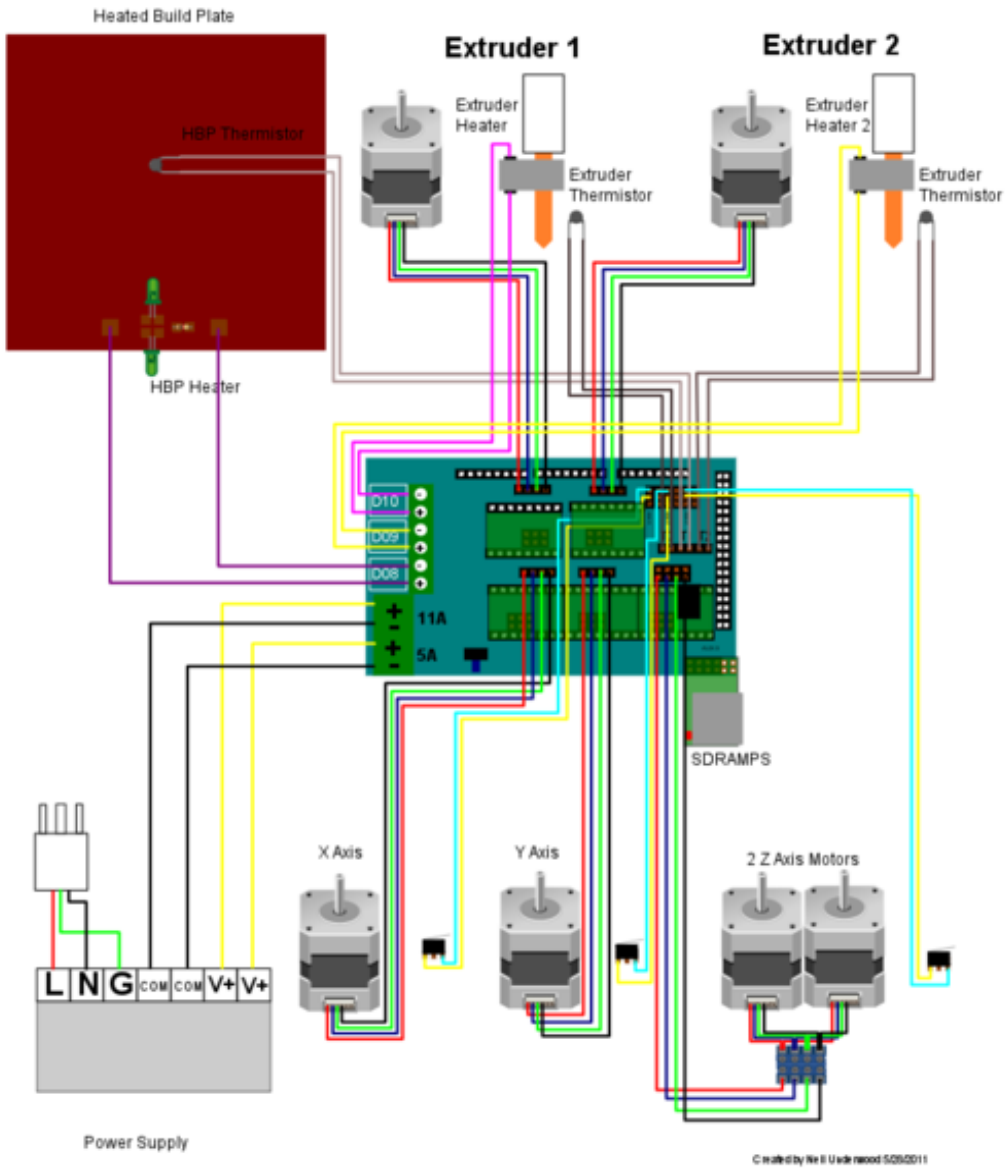


Pololu stepper driver

Mechanical Endstops



RepRap Arduino Mega Pololu Shield 1.4



Arduino

ARDUINO

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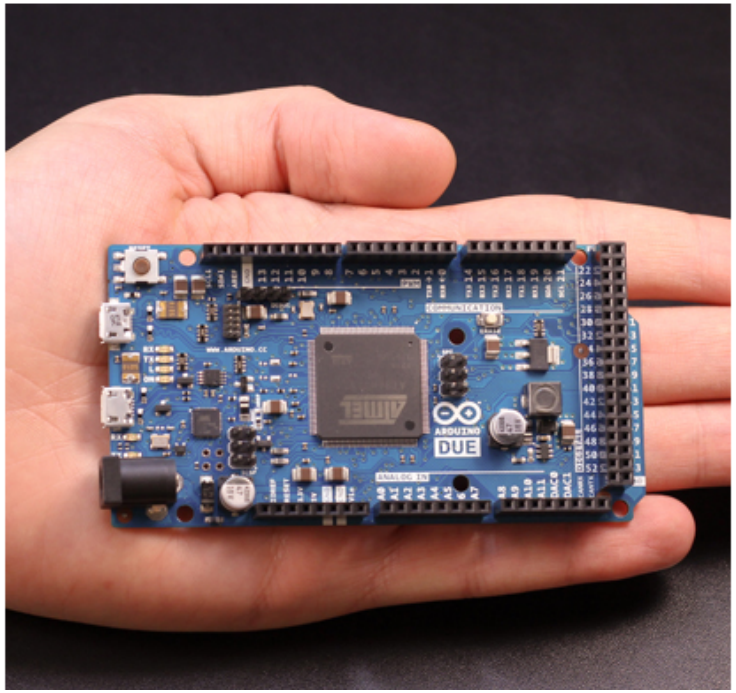
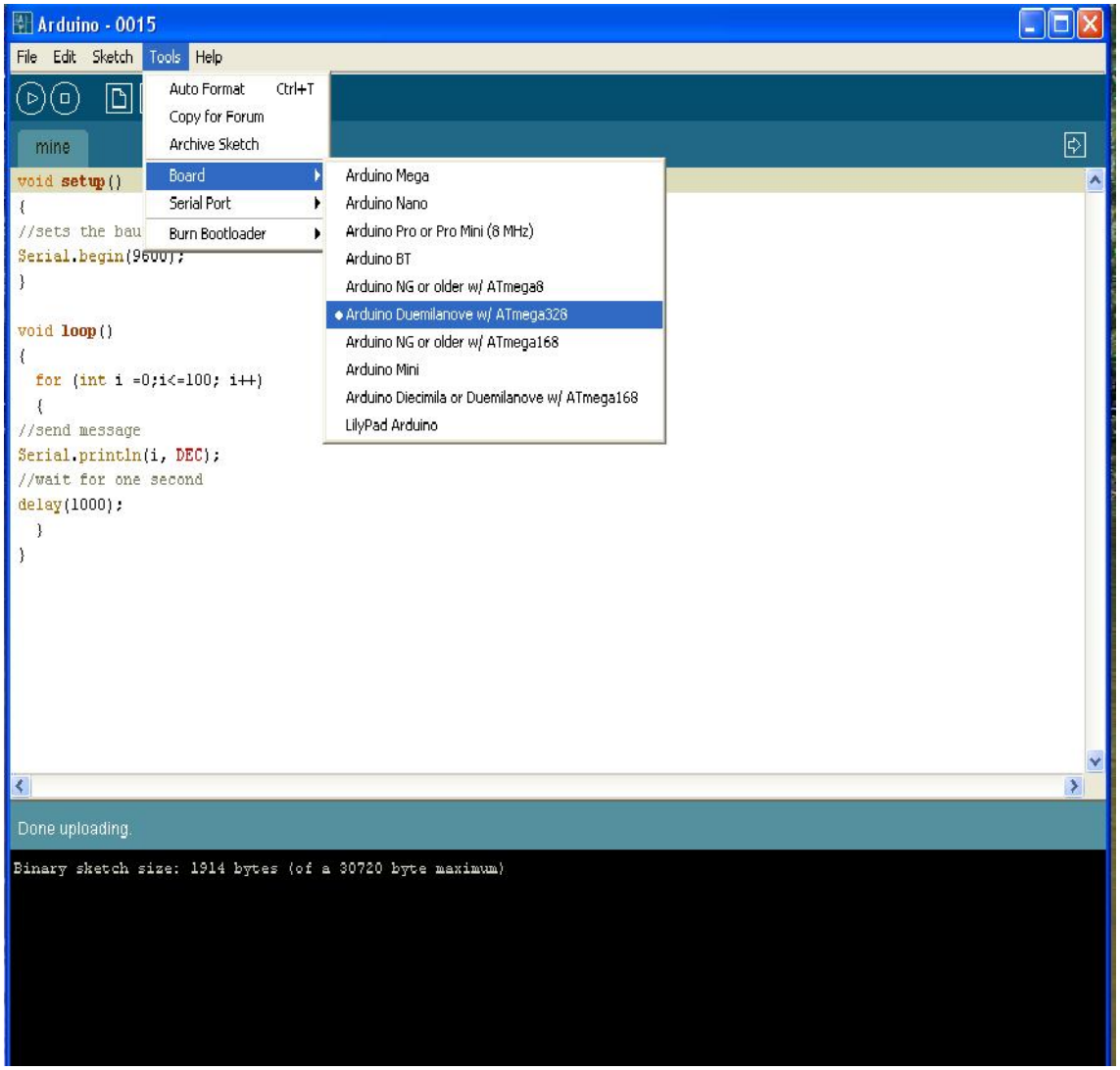


Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists and anyone interested in creating interactive objects or environments.

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software running on a computer (e.g. Flash, Processing, MaxMSP).

Arduino

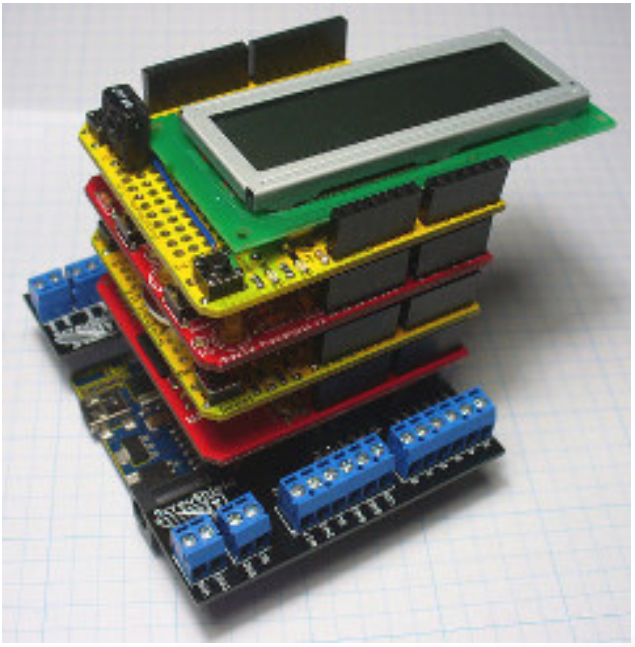


IDE (Integrated Development Environment)

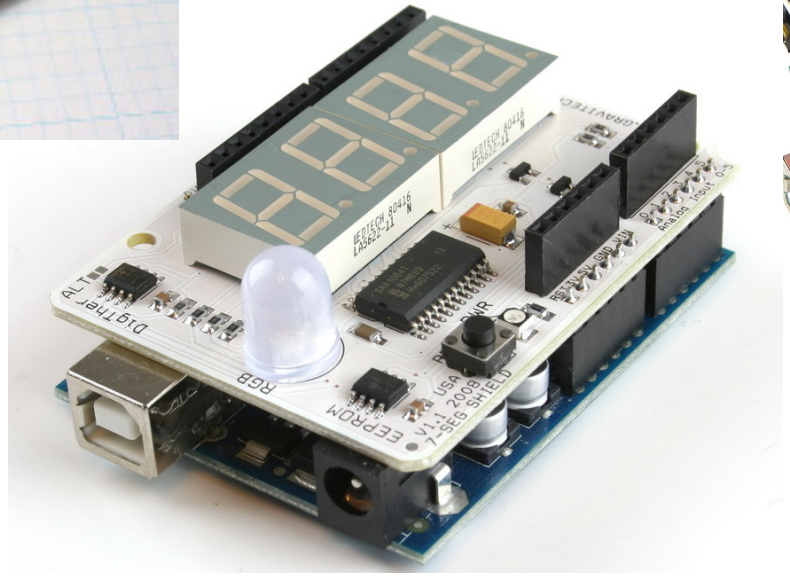
The Arduino development environment contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

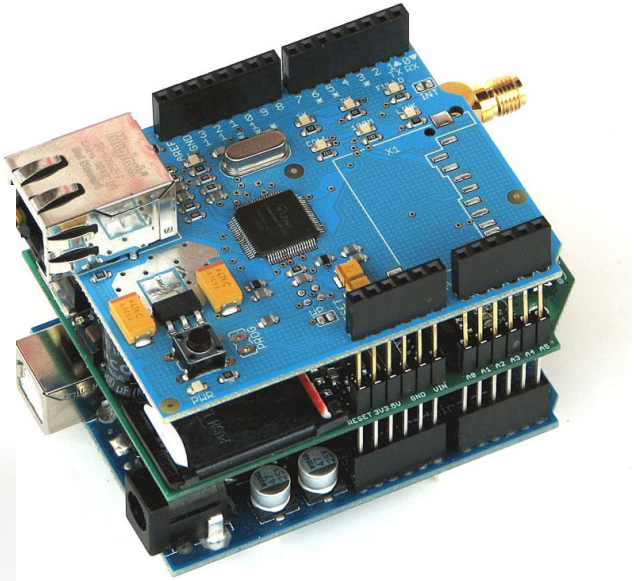
Software written using Arduino are called sketches.

Arduino



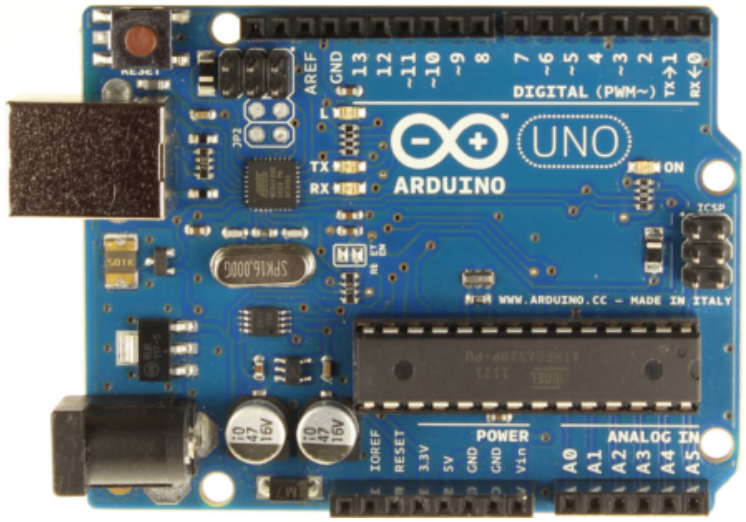
Shields are boards that can be plugged on top of the Arduino PCB extending its capabilities. The different shields follow the same philosophy as the original toolkit: they are easy to mount, and cheap to produce.





Arduino UNO

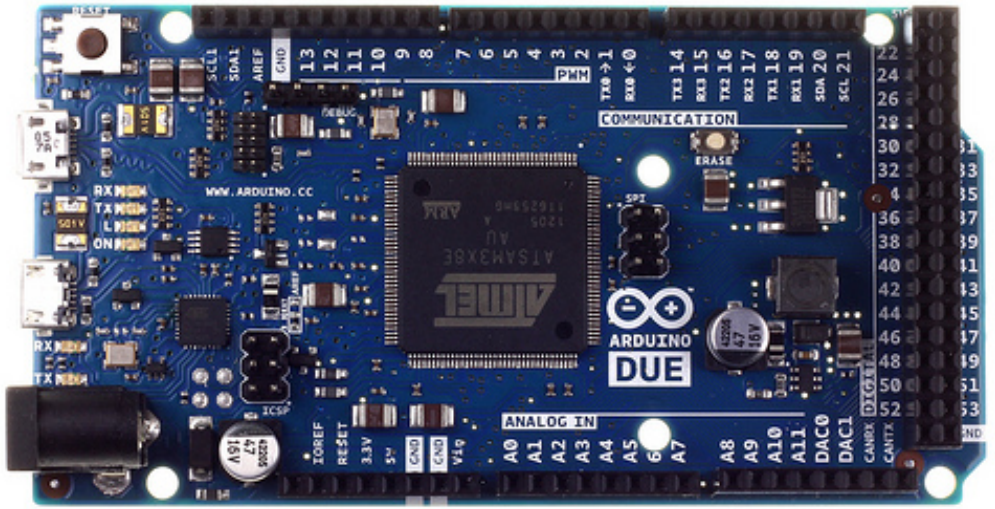
- The Arduino Uno is a microcontroller board based on the ATmega328.
  - 14 digital input/output pins
  - 6 PWM outputs (8 bit resolution)
  - 6 analog inputs (10 bit resolution)
  - 16 MHz ceramic resonator
  - USB connection
  - Power jack
  - ICSP header
  - reset button



- It contains everything needed to support the microcontroller
- simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

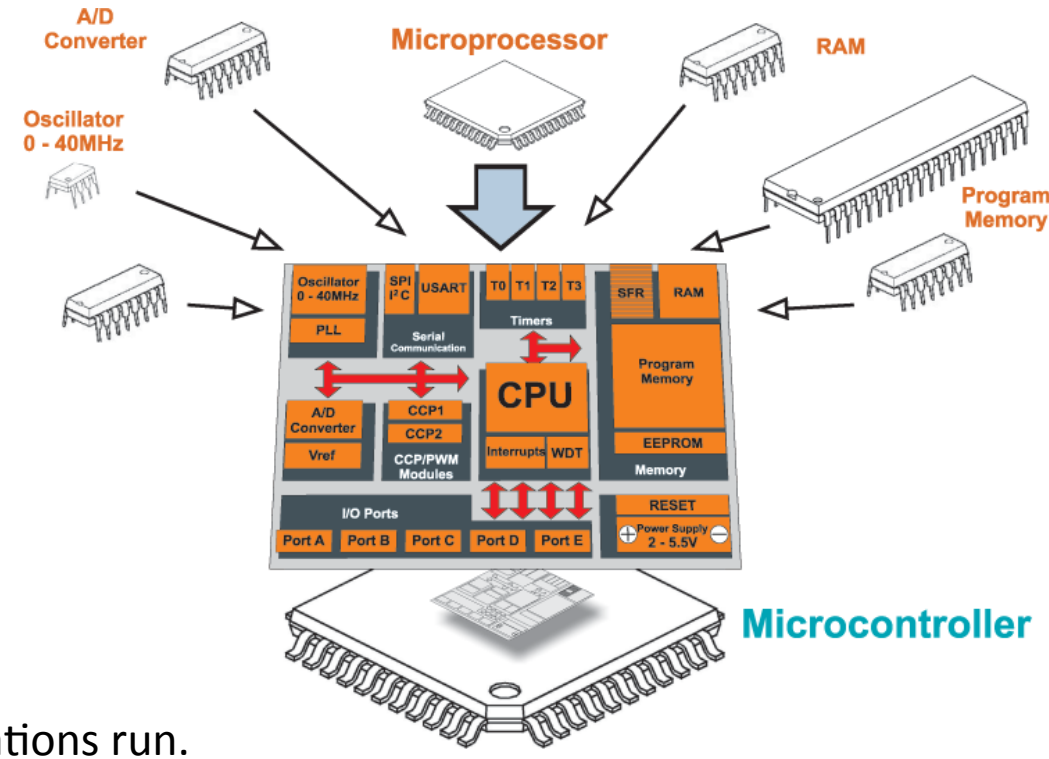
Arduino DUE

- The Arduino Due is a microcontroller board based on the Atmel SAM3X8E ARM Cortex-M3 CPU.
  - the first Arduino board based on a 32-bit ARM core microcontroller.
  - 54 digital input/output pins
  - 12 PWM outputs
  - 12 analog inputs
  - 4 UARTs (hardware serial ports)
  - 84 MHz clock,
  - USB OTG capable connection
  - 2 DAC (digital to analog)
  - 2 TWI,
  - power jack
  - SPI header
  - JTAG header
  - reset button
  - erase button.



Difference between microprocessor and microcontroller

- Microprocessor is an IC which has only the CPU inside them. It doesn't have RAM, ROM, and other peripheral on the chip. Application of microprocessor includes Desktop PC's, Laptops, notepads etc.
- Microcontroller has a CPU, in addition with a fixed amount of RAM, ROM and other peripherals all embedded on a single chip.
- Microcontrollers perform specific tasks where the relationship of input and output is defined.
- Microprocessor find applications where tasks are unspecific like software, games, websites, photo editing
- Microcontroller doesn't have video output.
- Microcontroller are programmed with firmware
- Microprocessors run operating systems on which software applications run.



Firmwares

- List of firmwares
  - Sprinter
  - Teacup
  - sjfw
  - Marlin
  - Sailfish
  - Makerbot
  - Grbl
  - Repetier-Firmware

Is 3D printing environmental friendly?

- http://www.greenbiz.com/blog/2013/07/19/3d-printing-environmental-win

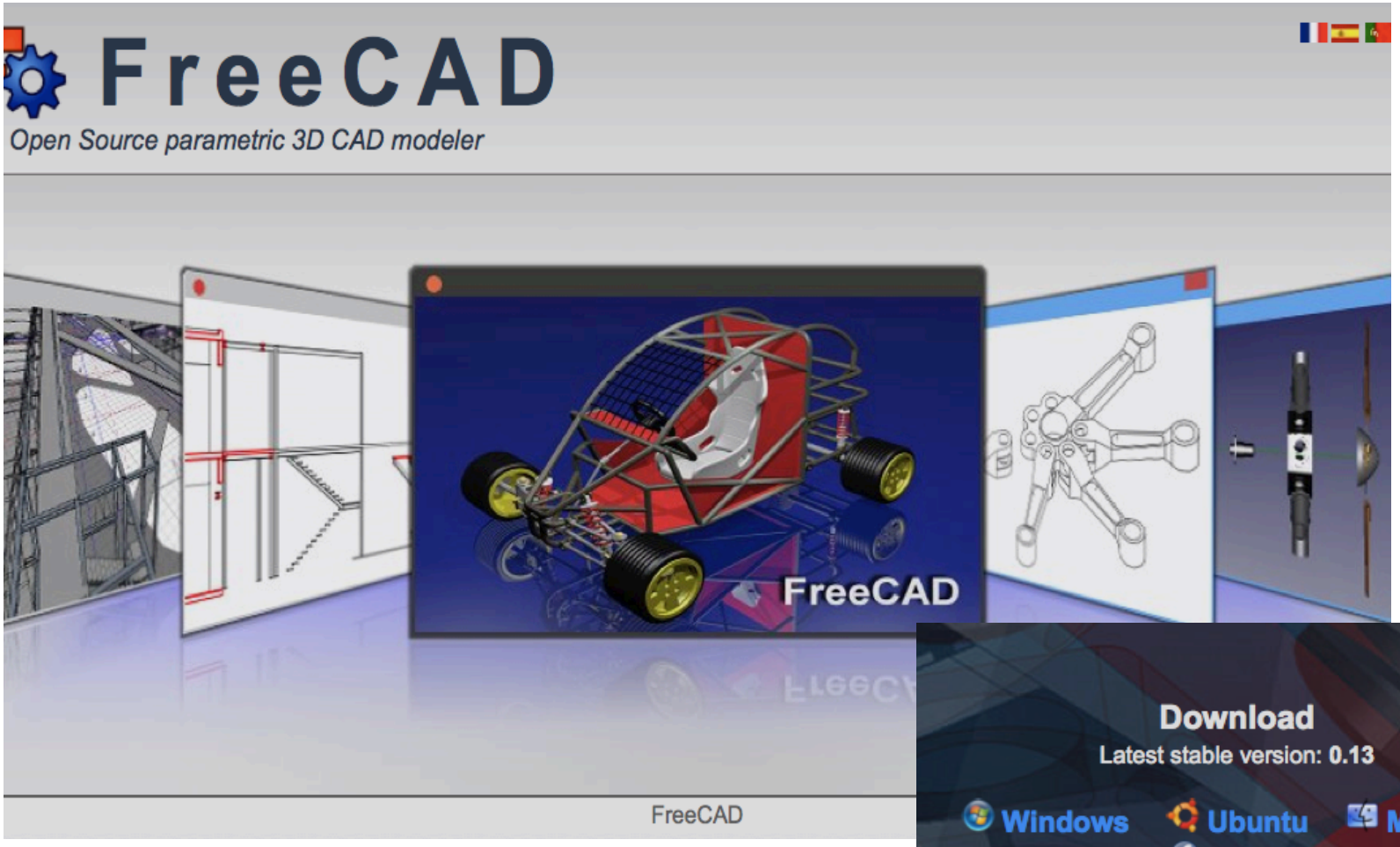
Is FMD a safe technology?

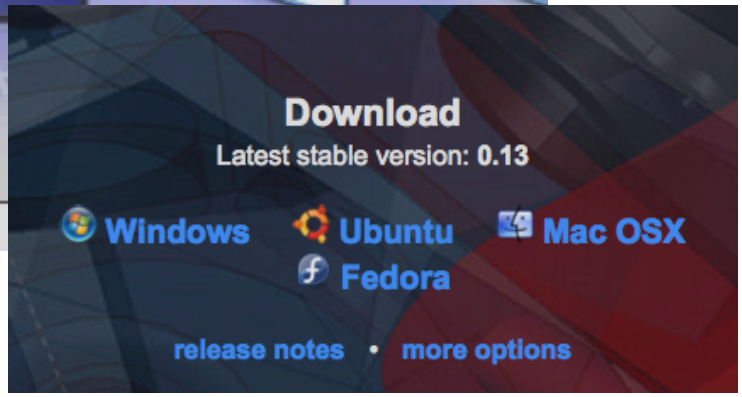
- http://phys.org/news/2013-07-3d-printers-shown-emit-potentially.html
- http://www.webnews.it/2013/07/25/le-stampanti-3d-sono-nocive-per-la-salute/?utm_source=newsletter&utm_medium=email&utm_campaign=Newsletter:+Webnews&utm_content=26-07-2013+le-stampanti-3d-sono-nocive-per-la-salute&ref=post

Open Software for rapid design and prototyping

- Programming languages
  - Java (eclipse)
  - C# (monodevelop)
- Script languages
  - Phython
  - **Processing**
- Code management
  - SVN (software versioning and revision control system)
  - GitHub
- Web site creation
  - **Wordpress** (blog like sites)
  - Joomla (portal and community) (University of Pisa website)
  - PhPBB (Forum)
  - **MediaWiki** (Wiki creation)
- Drawing and printing
  - **FreeCad** (drawing)
  - **Slicer** (3D model slicer for 3D printer)
  - **Pronterface** (3D printer management)

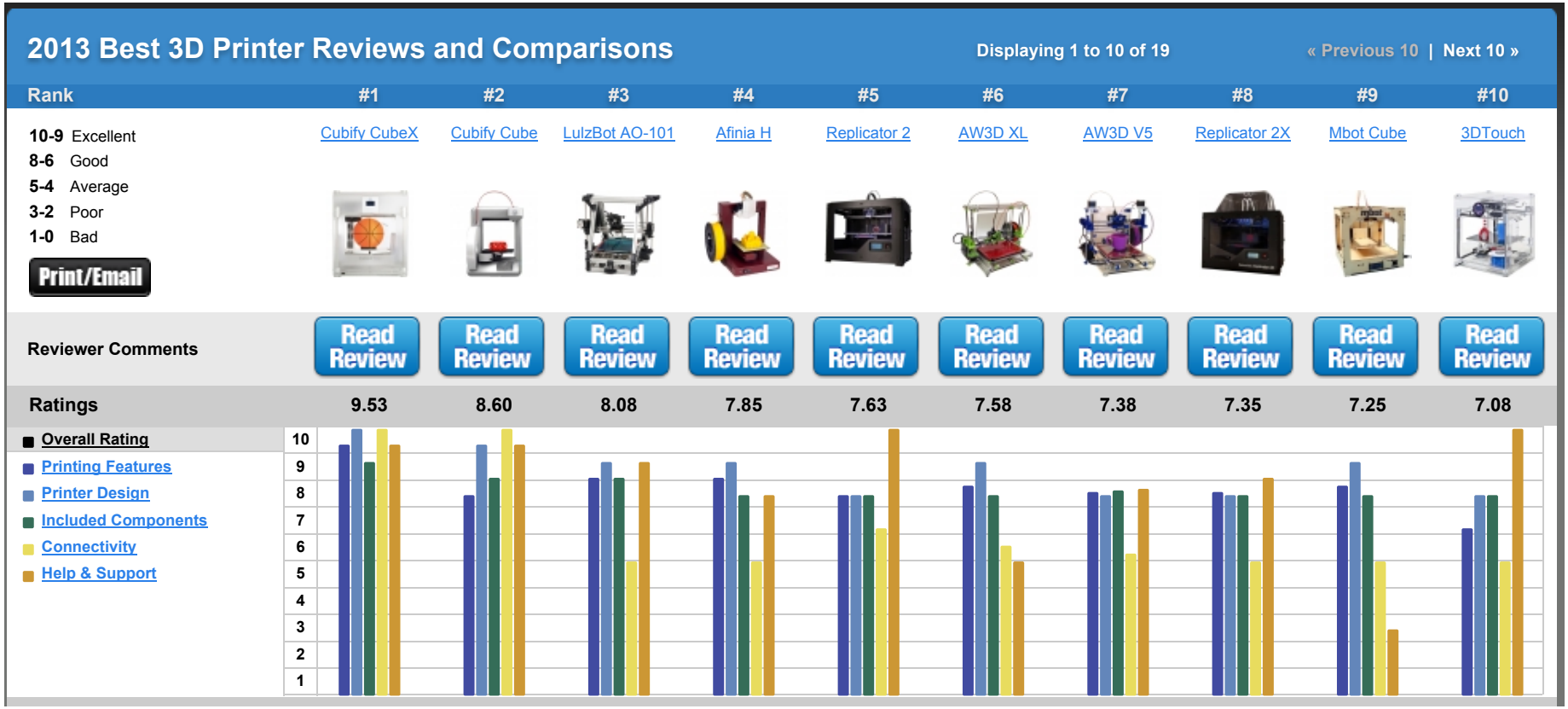
FreeCAD





www.freecadweb.org

Stampanti 3D a basso costo



Esercizi

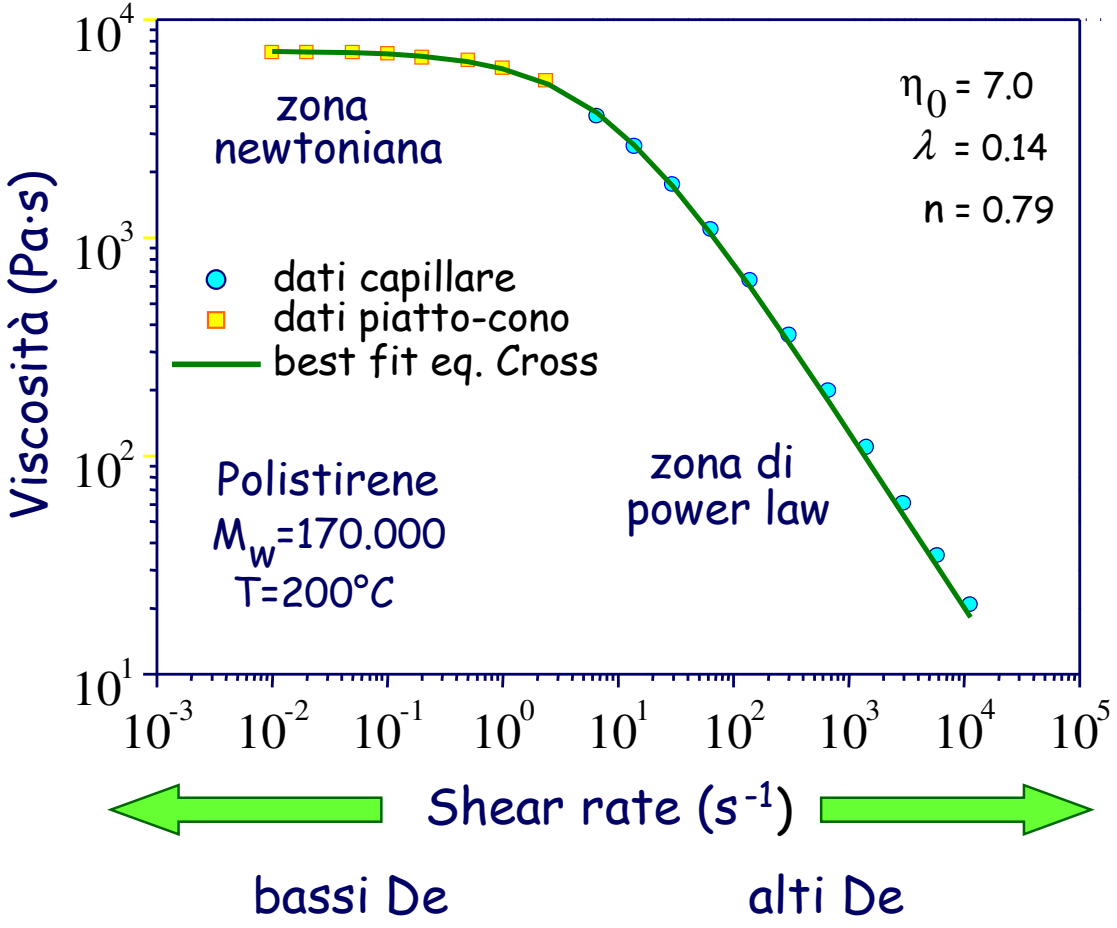
	Cura	Slic3r
Slice time		
Estimated print time		
Used Material		
Gcode size		

CENNI DI REOLOGIA DEI POLIMERI

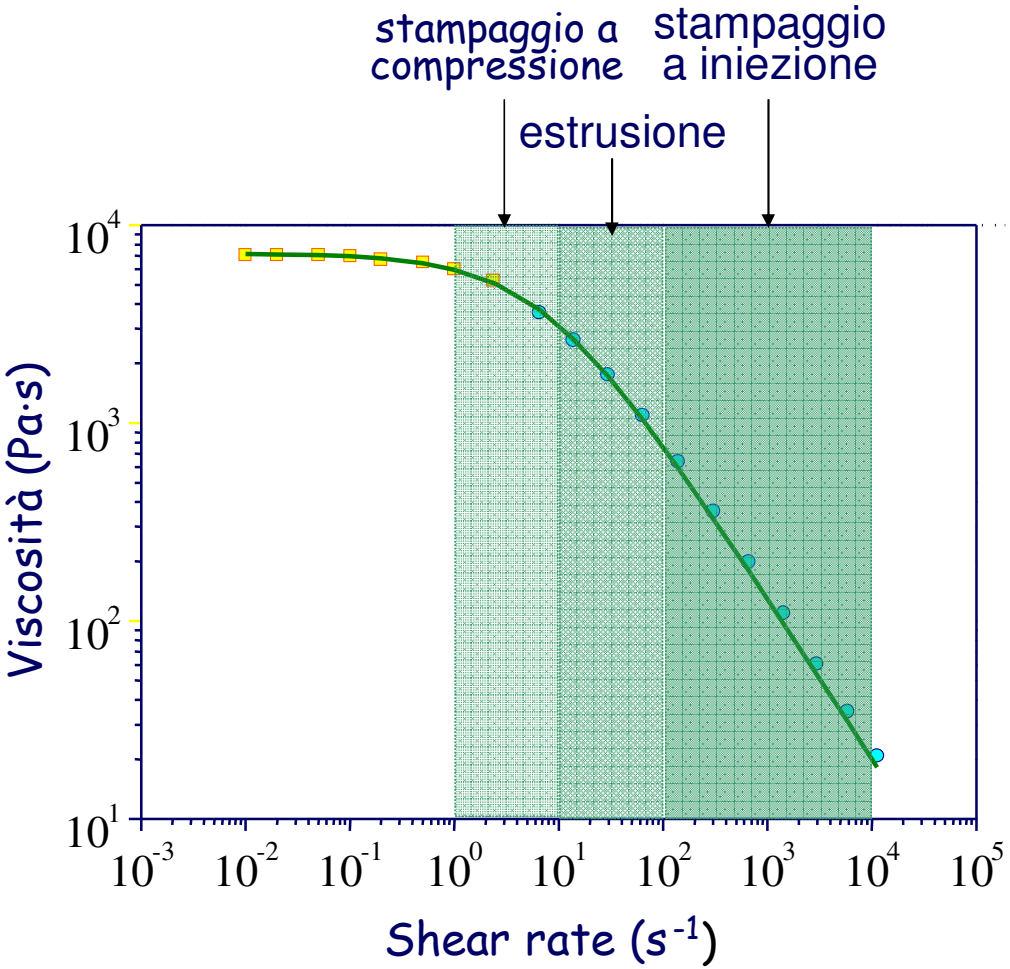
Variabili che influenzano la reologia dei polimeri

- Variabili reologiche:
  - deformazione
  - velocità di deformazione
- Variabili strutturali-compositive:
  - peso molecolare medio
  - polidispersità (Mw/Mn)
  - architettura molecolare (es: presenza di ramificazioni)
  - presenza di una fase dispersa (quantità, dimensionale media e distribuzione, forma)
  - contenuto di additivi (es: plastificanti)
- Variabili termodinamiche:
  - pressione
  - temperatura

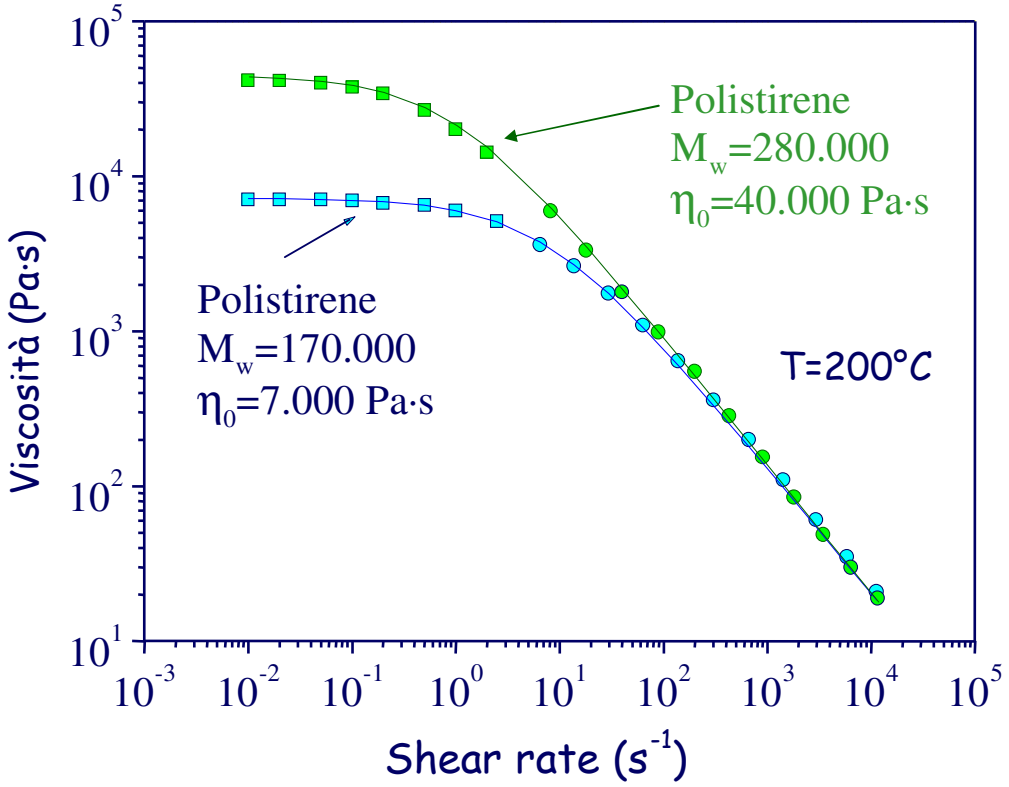
curva di flusso (viscosità in regime stazionario): comportamento shear thinning



viscosità e condizioni tipiche di processo



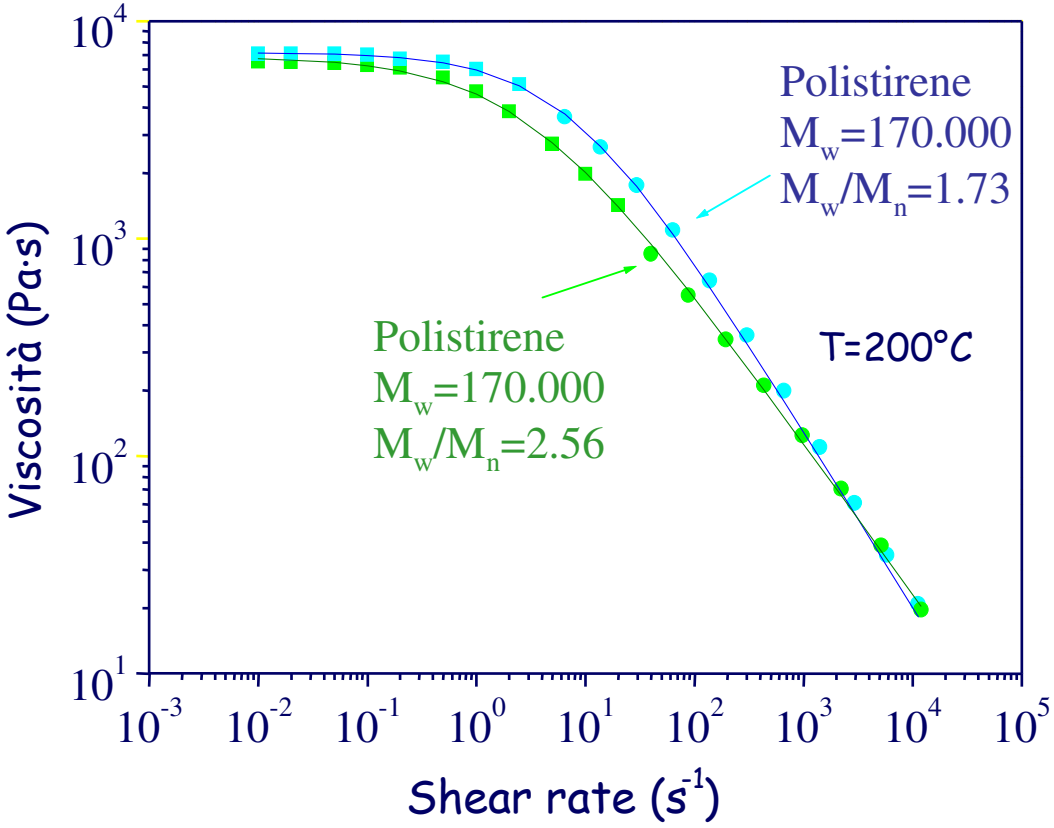
Effetto del peso molecolare



Una caratteristica distintiva dei polimeri ad alto peso molecolare:

$$\eta_0 \propto M_w^{3.4}$$

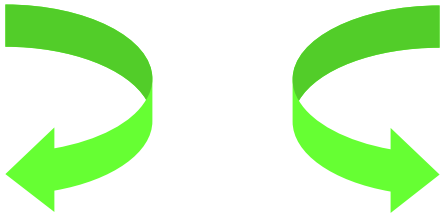
Effetto della polidispersità



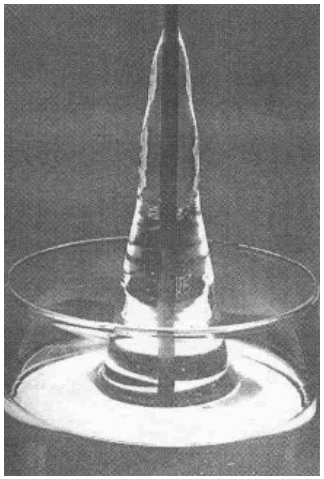
Maggiore è la polidispersità e più larga è la curva di viscosità

Fenomeni dovuti all'elasticità del fuso

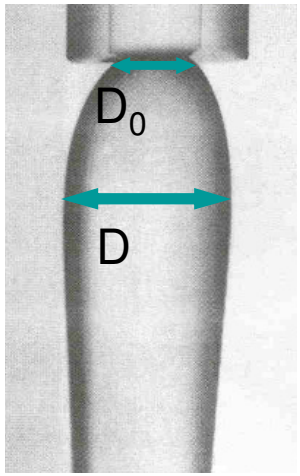
le componenti elastiche sono legate agli sforzi normali



rod climbing

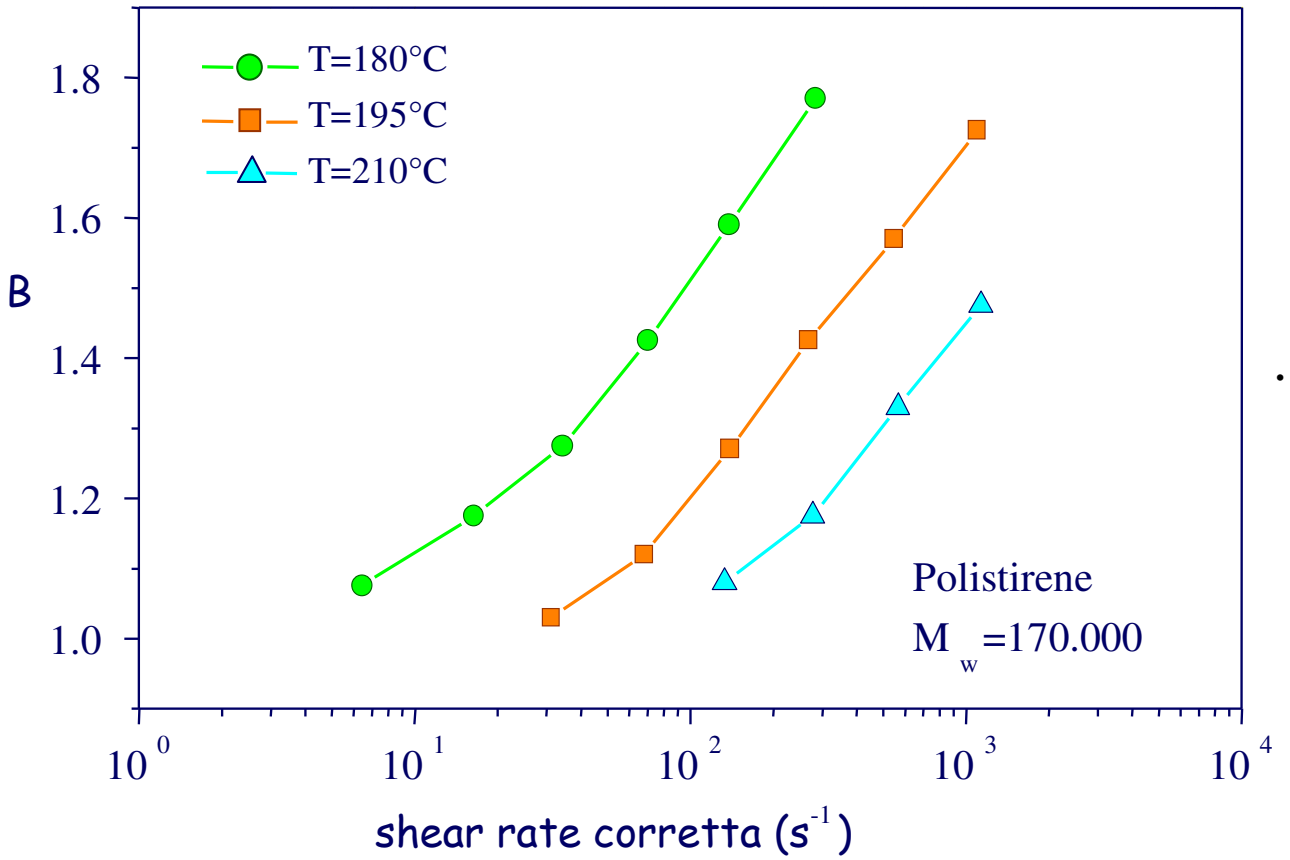


die swell

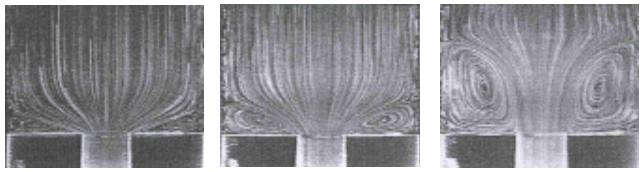


$$B = \frac{D}{D_0}$$

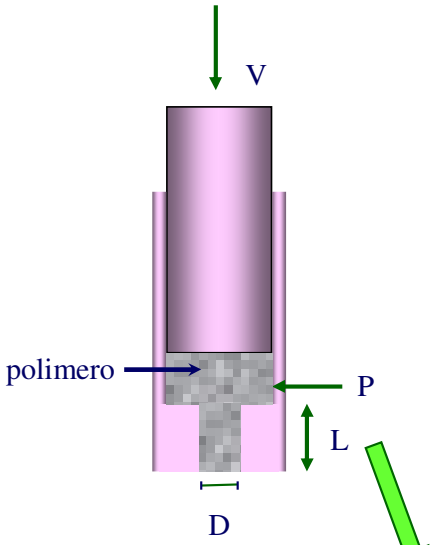
Il die swell del polistirene



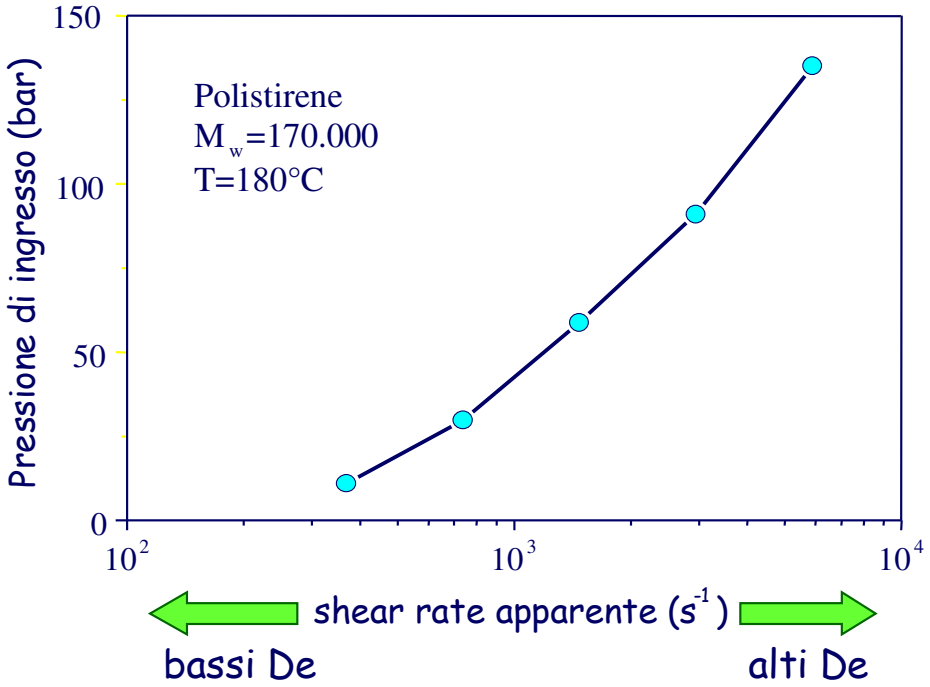
Altra manifestazione dell'elasticità del fuso: la pressione di ingresso



shear rate crescente



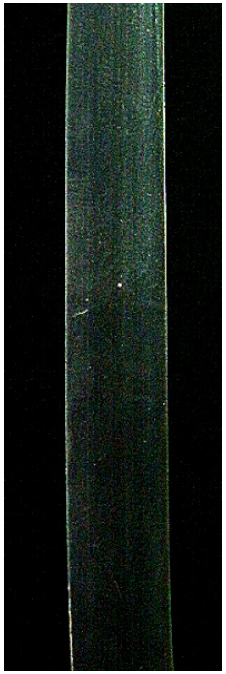
$$P = P_{ing} + P_{visc}$$



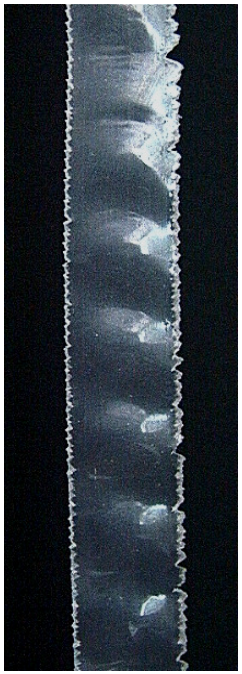
La melt fracture aumenta all'aumentare della shear rate

copolimero SIS a 120°C

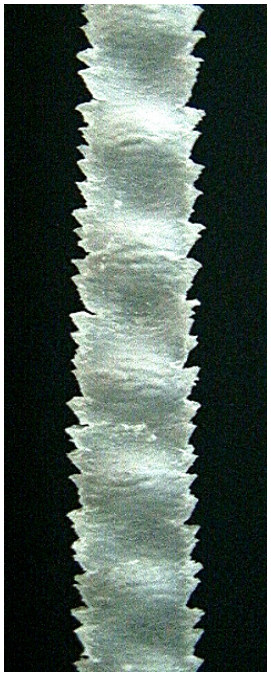
6 s^{-1}



46 s^{-1}



184 s^{-1}

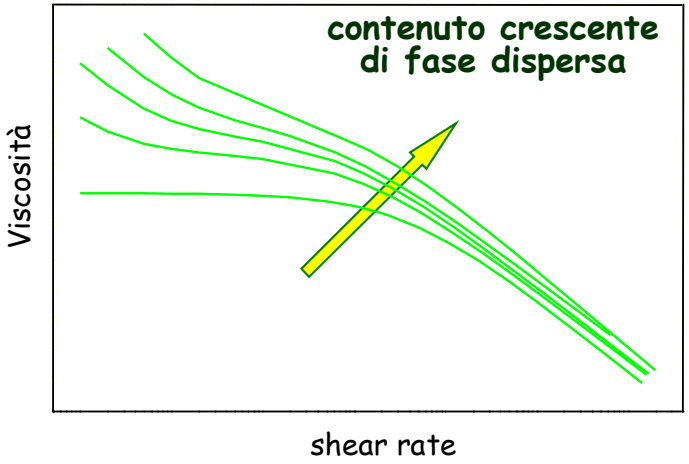


shear rate crescente

Comportamento reologico di sistemi polimerici multifasici

- Alcuni tipi di sistemi multifase:
  - polimeri rinforzati con cariche minerali o fibre
  - polimeri tenacizzati con fase gommosa dispersa
  - blend immiscibili
  - copolimeri a blocchi
  - schiume
- Variabili che influenzano la reologia di sistemi multifase:
  - quantità di fase dispersa
  - media e distribuzione delle dimensioni particelle
  - fattore di forma delle particelle
  - distanza inter-particellare media
  - deformabilità della fase dispersa

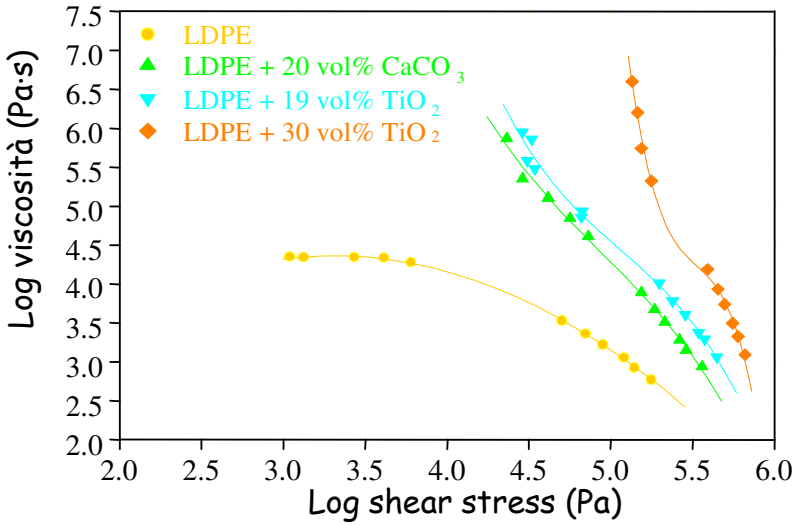
Un importante effetto della fase dispersa: lo yield stress



a basse shear rate scompare il plateau newtoniano

C.Y. Ma, J.L. White, F.C. Weissert, K. Min, *SPE Tech. Papers*,31 (1985)

la presenza di yield stress è meglio evidenziata in un grafico viscosità-sforzo



polimeri con fase gommosa (reticolata) dispersa