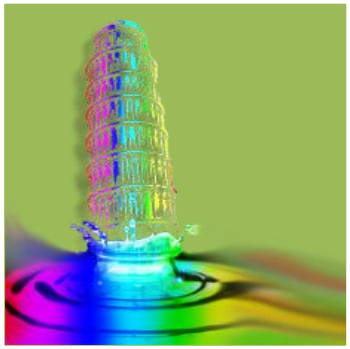
CENTRO E. PIAGGIO
Bioengineering and Robotics Research Center

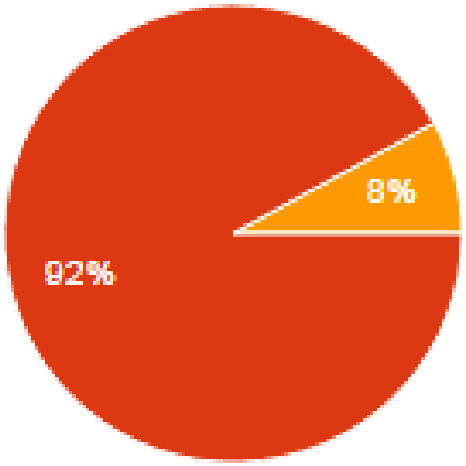


Fused deposition Modelling

carmelo.demaria@centropiaggio.unipi.it

Question #1 14/10/2015

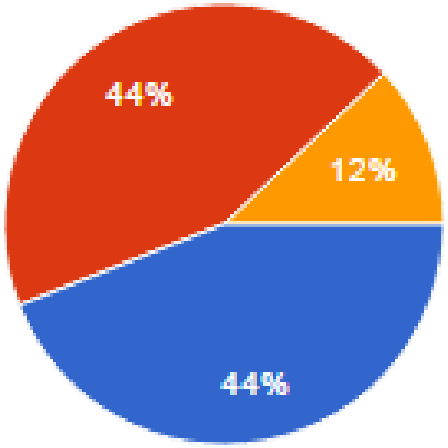
The FDM technology is based on



powder	0	0%
filament	23	92%
liquid	2	8%
Other	0	0%

Question #2 14/10/2015

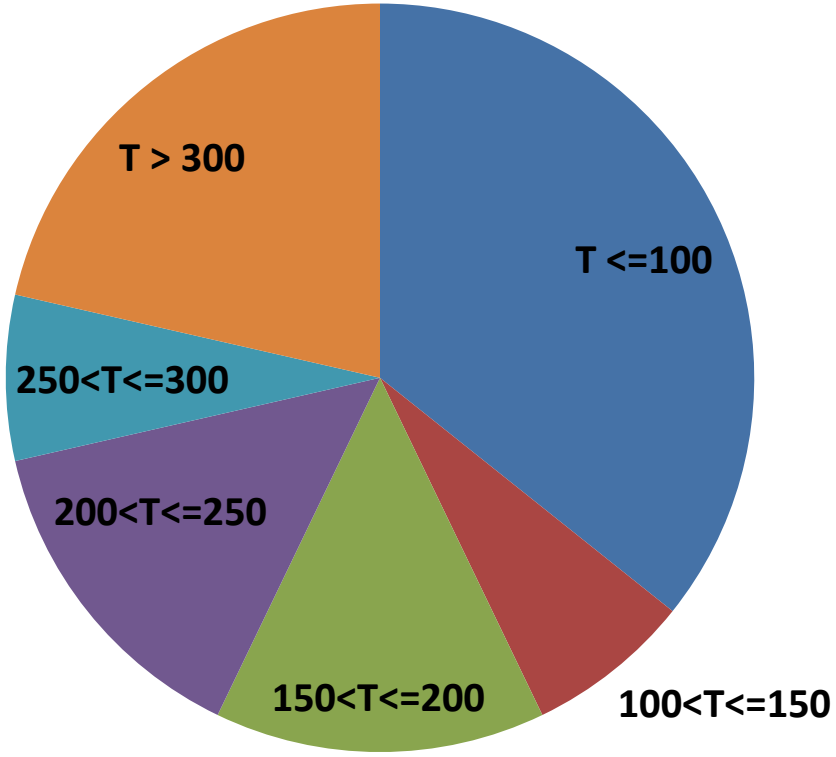
Indicates which of the following material has the lower working temperature (for FDM technology)



Polylactic acid	**11**	44%
Acrylonitrile butadiene styrene	**11**	44%
Polycarbonate	3	12%

Question #3 14/10/2015

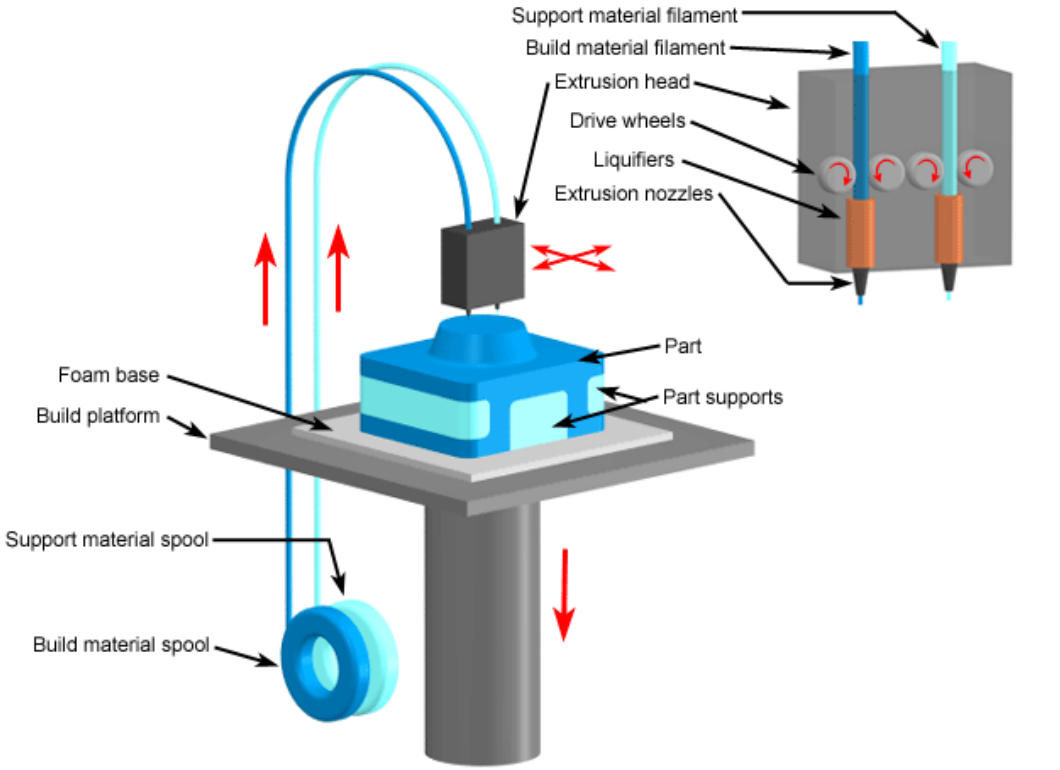
Indicate the working temperature of ABS (FDM technology)



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.

Fused deposition modelling

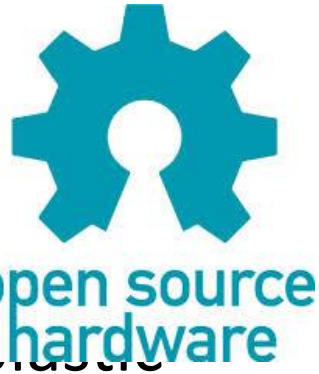


The Rep Rap Project

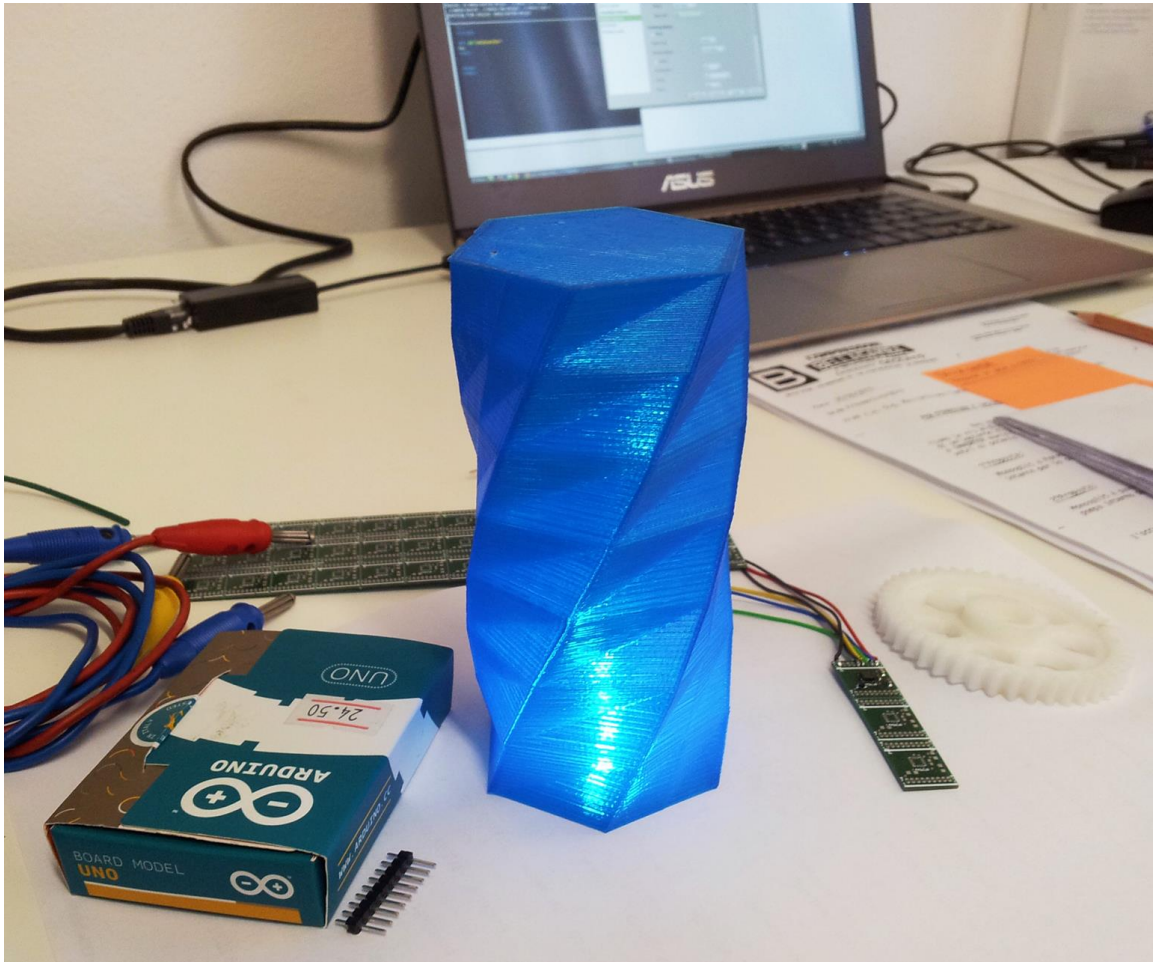
OPEN 3D PRINTING

Open 3D printing: the RepRap project

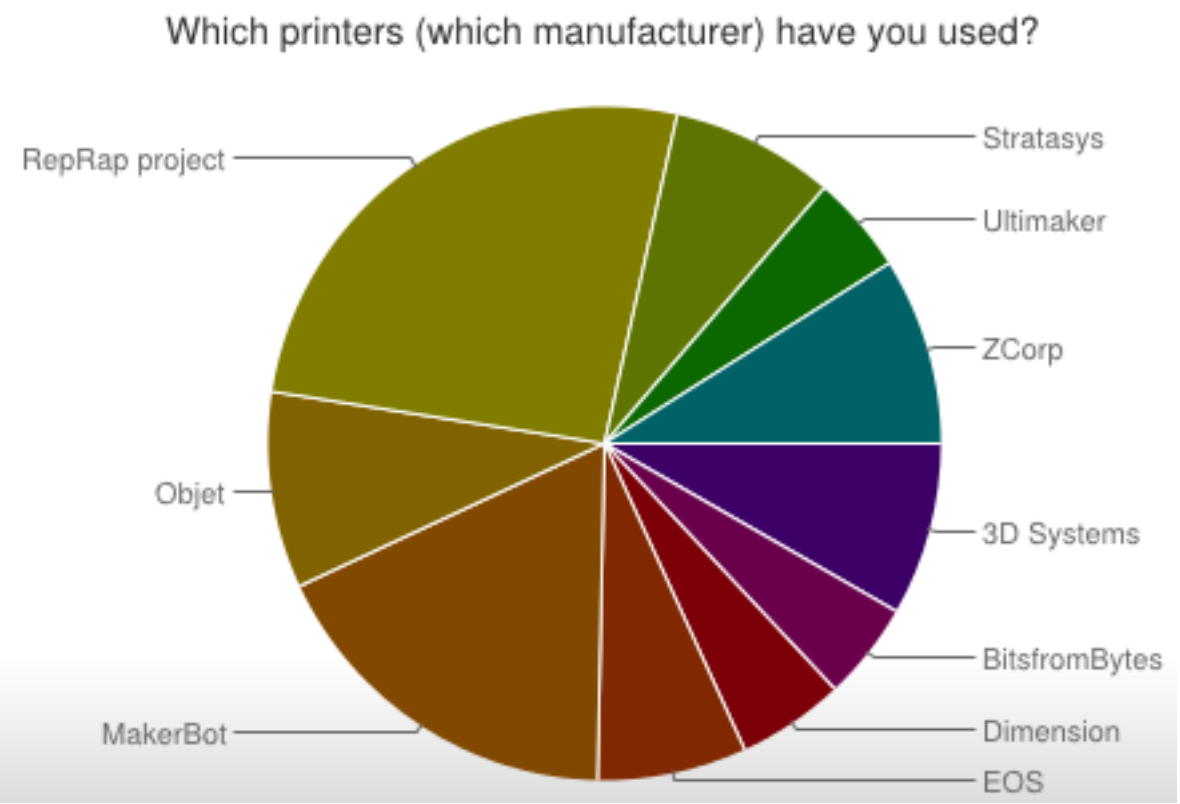
- RepRap is first general-purpose self-replicating manufacturing machine.
- RepRap takes the form of a free desktop 3D capable of printing plastic objects.
- Since many parts of RepRap are made from plastic and RepRap prints those parts, RepRap self-replicates by making a kit of itself - a kit that anyone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



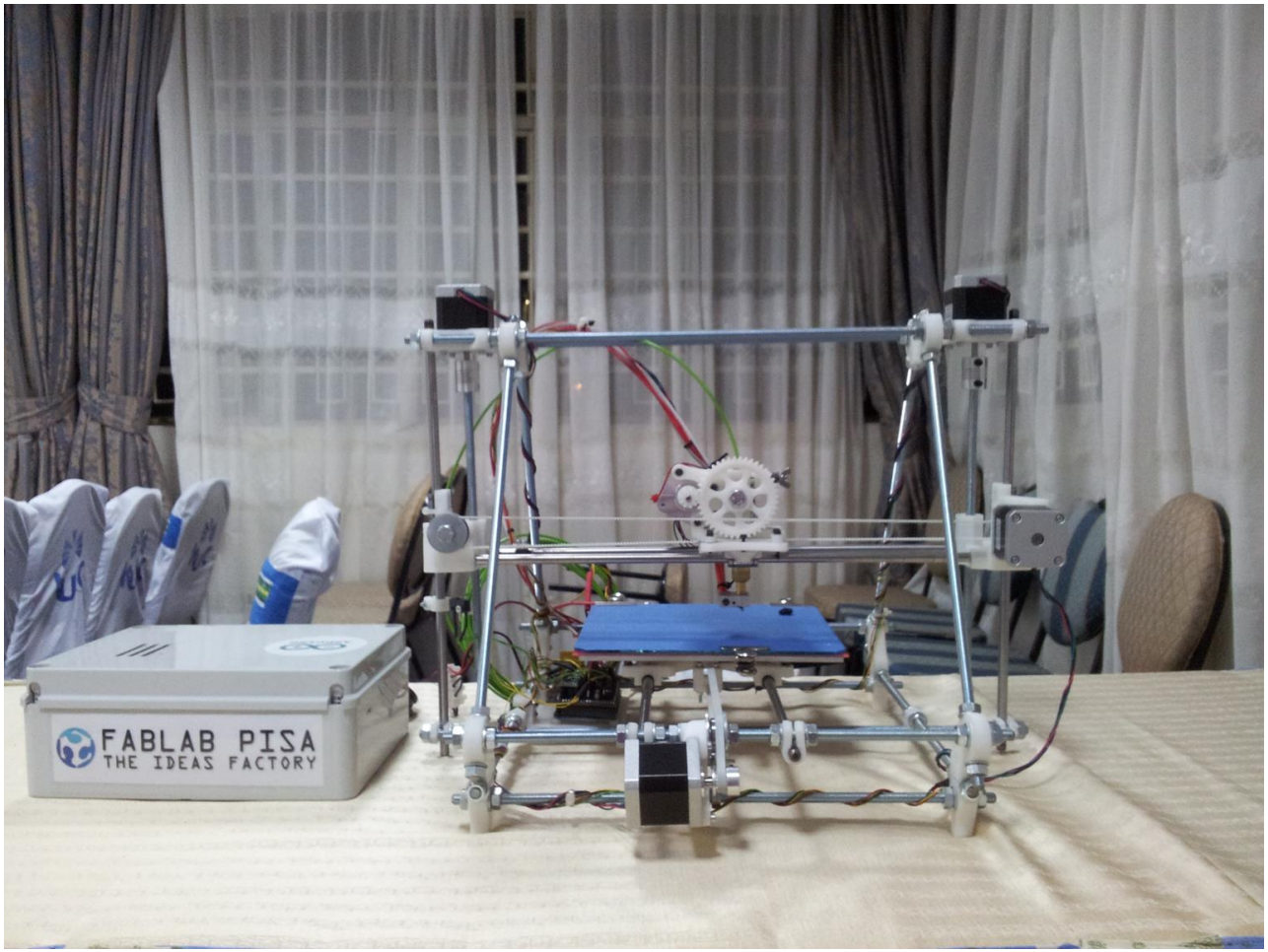
The RepRap Project



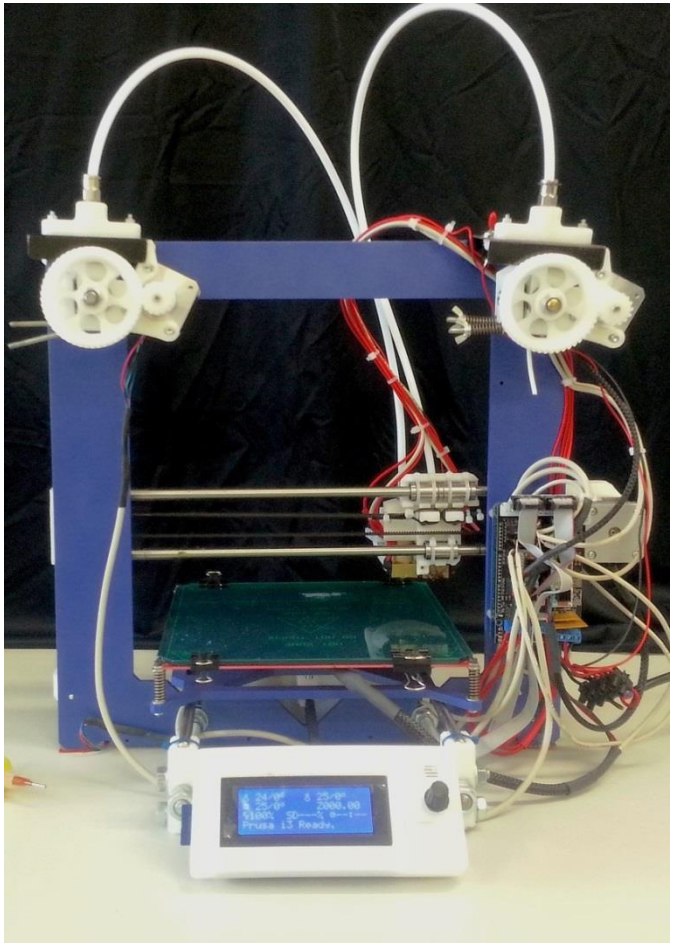
The RepRap Project



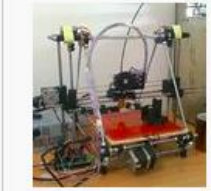
The RepRap Project



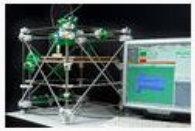
The RepRap Project



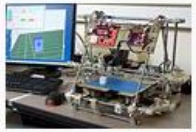
How many RepRaps?



Prusa (*license: GPL*)



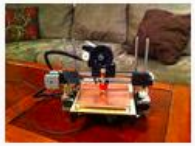
Darwin (*license: GPL*)



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*)

With basics of polymer rheology

MATERIALS FOR FDM

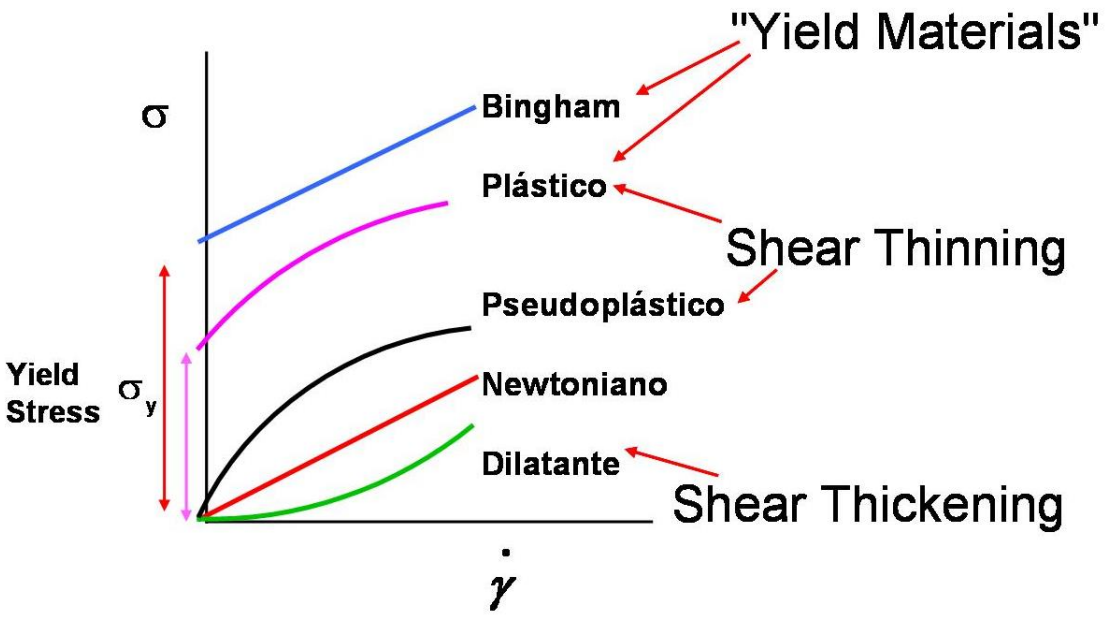
Materials

- 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 1 mm and 3mm
- The standard extruder produces filament using high pressure and heat to force molten plastic thru a very tiny hole.

Materials

- “Standard” materials:
  - Poly-Lactic-Acid (PLA) (soft and hard)
  - Acrylonitril-Butadiene-Stiren (ABS)
- “Experimental” materials:
  - Nylon
  - Polycarbonate (PC)
  - Poly vinyl alcohol (PVA)
  - Conductive (carbon and graphen loaded materials)
  - Metallic loaded plastics

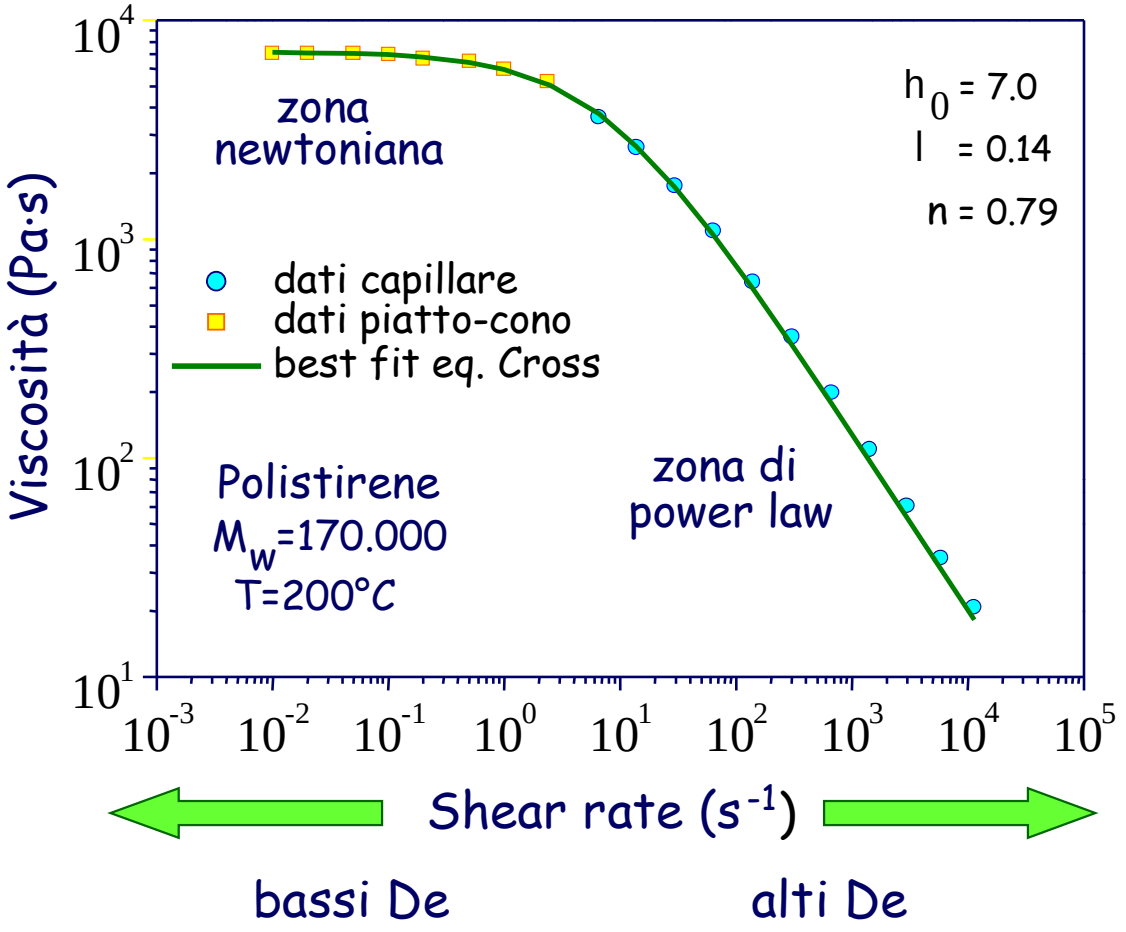
Rheology


"Yield Materials"
σ
Bingham
Plástico
Shear Thinning
Pseudoplástico
Yield Stress
σy
Newtoniano
Dilatante
Shear Thickening
γ̇

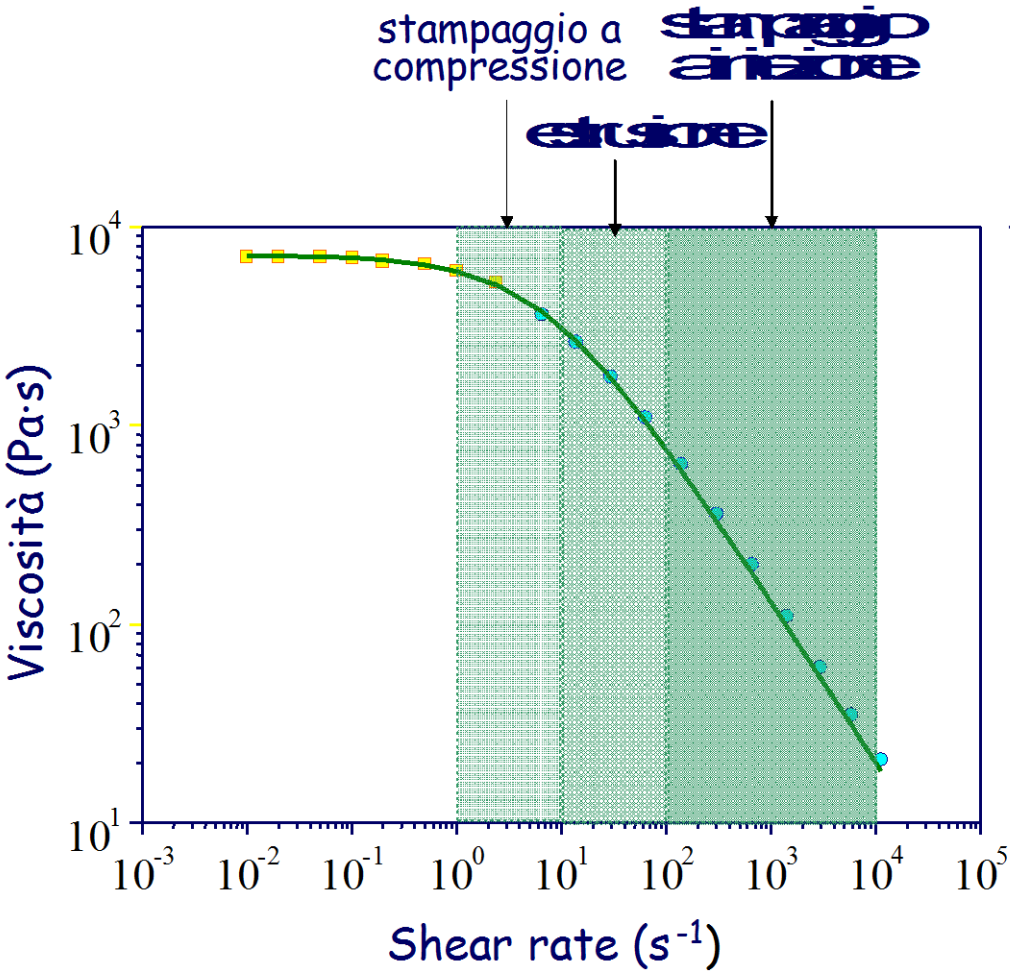
Variabili che influenzano la reologia dei polimeri

- 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

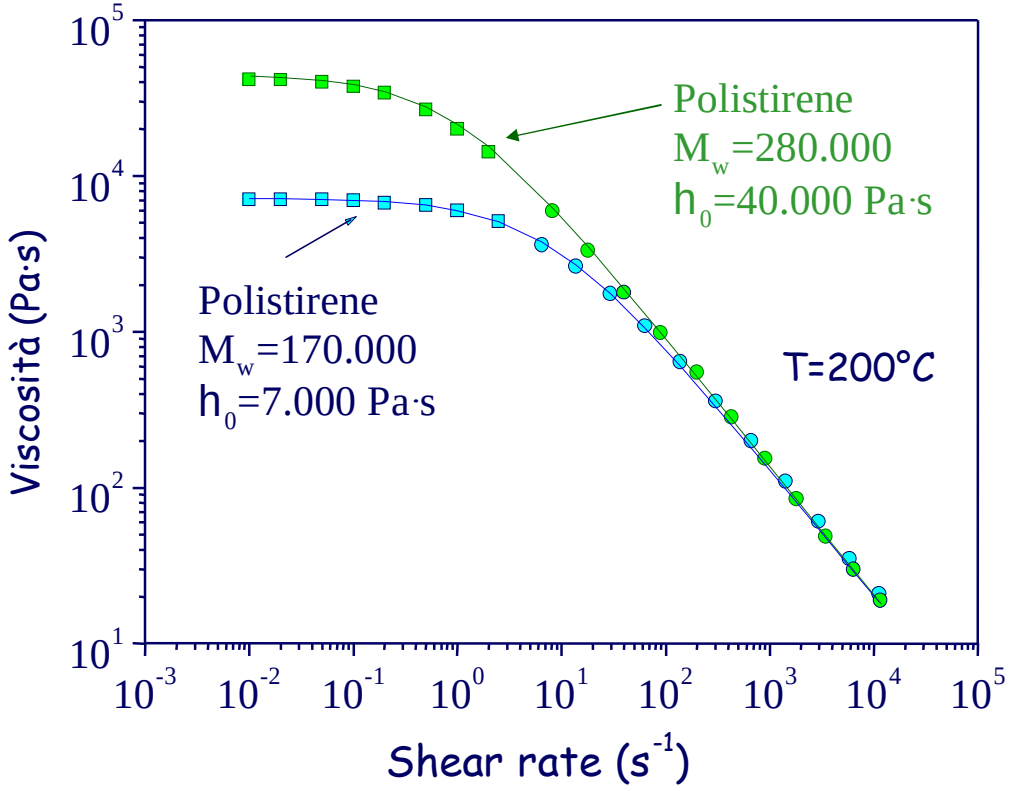
Curva di flusso (viscosità in regime stazionario): comportamento shear thinning



Viscosità e condizioni tipiche di processo



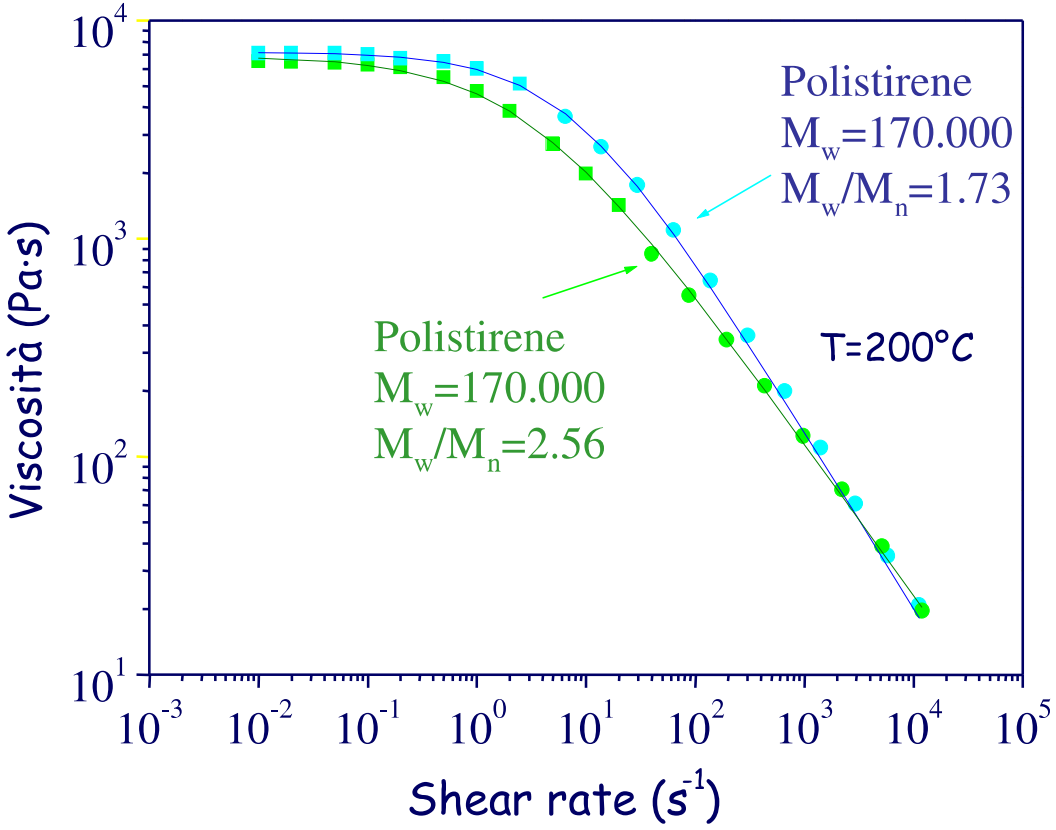
Effetto del peso molecolare



Una caratteristica distintiva dei polimeri ad alto peso molecolare:

$$h_0 \mu M_w^{3.4}$$

Effetto della polidispersità

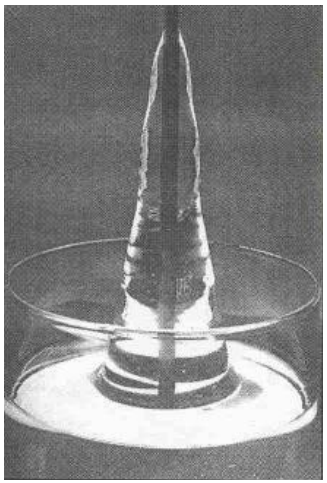


Maggiore è la polidispersità e più larga è la curva di viscosità

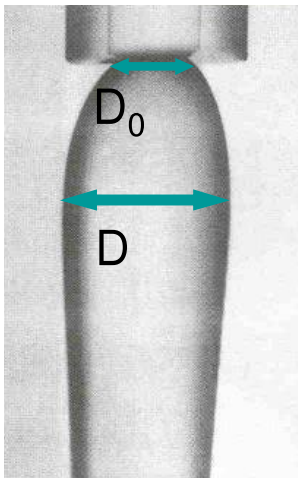
Fenomeni dovuti all'elasticità del fuso

le componenti elastiche sono legate agli sforzi normali

rod climbing

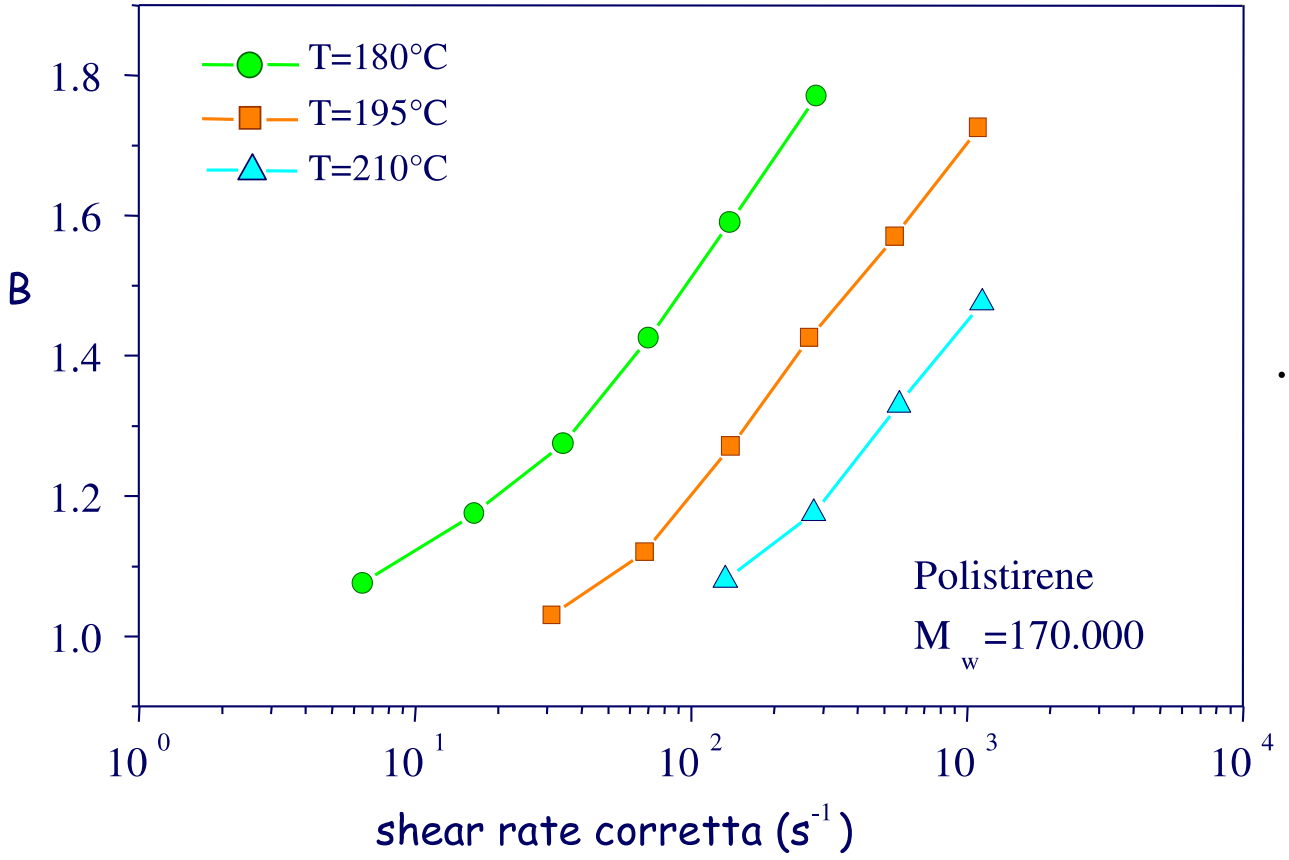


die swell

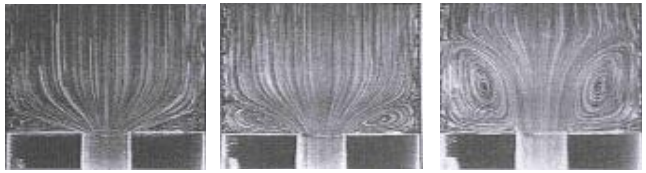


$$B = \frac{D}{D_0}$$

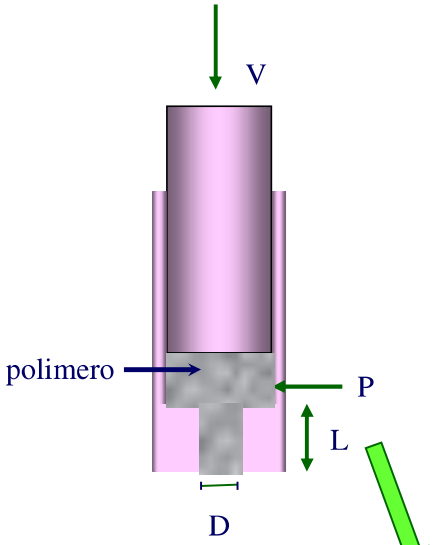
Il die swell del polistirene



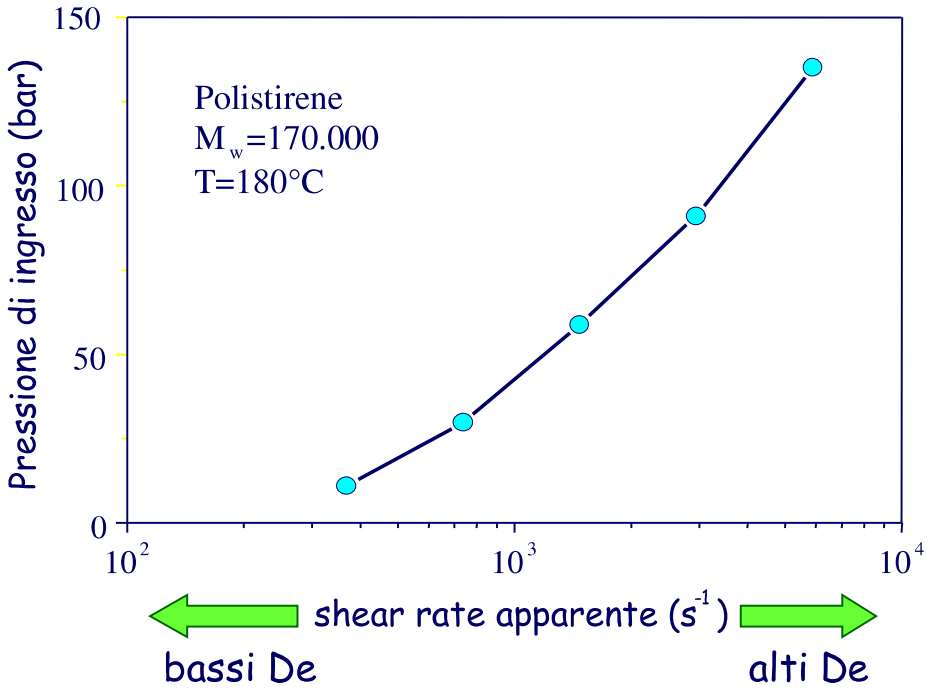
Altra manifestazione dell'elasticità del fuso: la pressione di ingresso



shear rate crescente

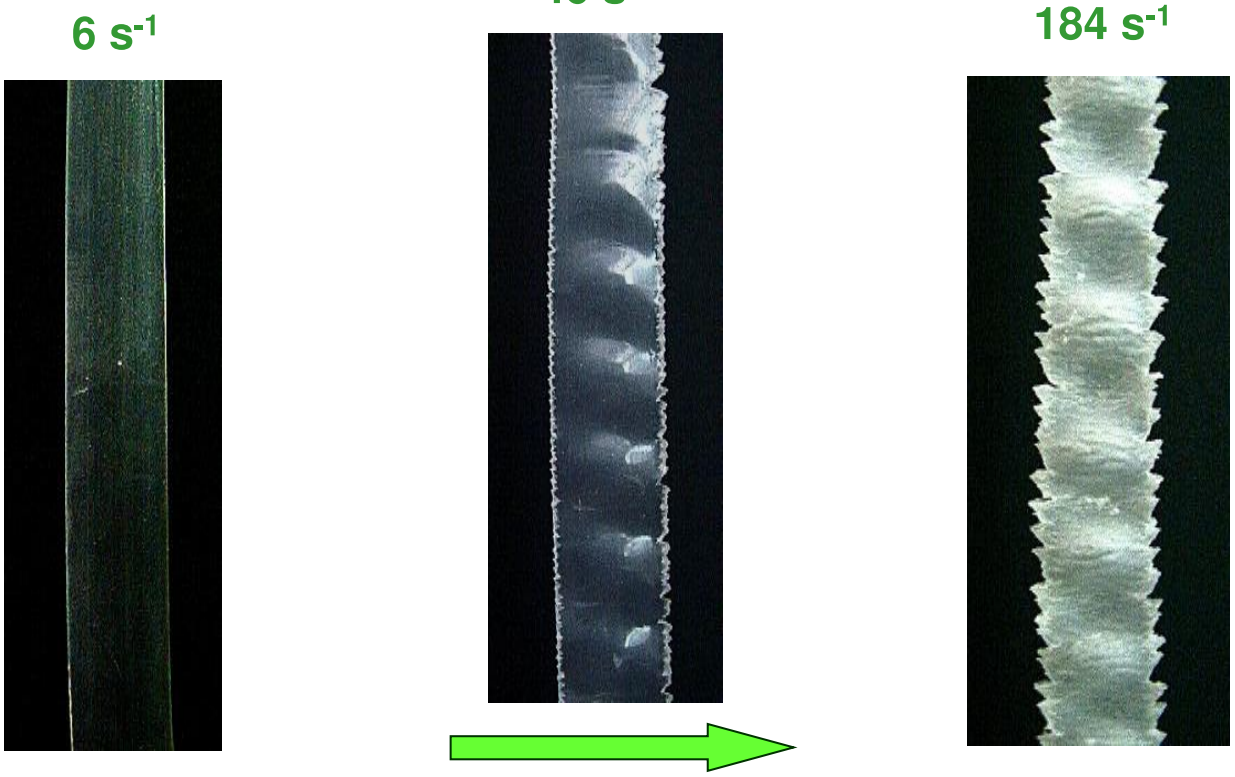


$$P = P_{ing} + P_{visc}$$



La melt fracture aumenta all'aumentare della shear rate

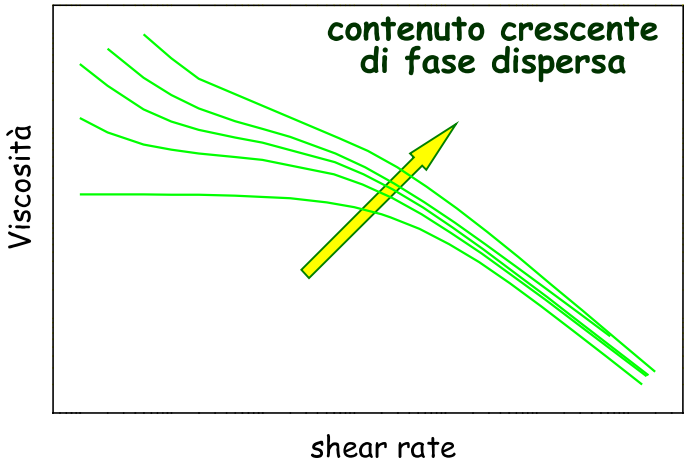
copolimero SIS a 120°C



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

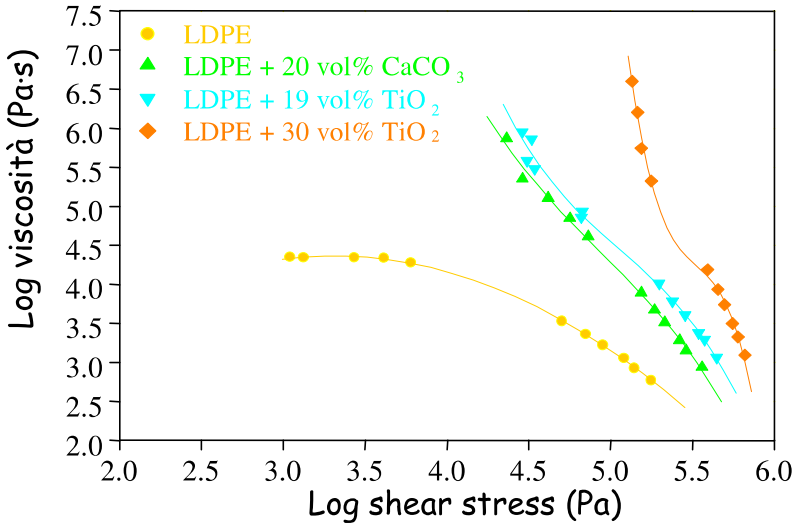
Un importante effetto della fase dispersa: lo yield stress



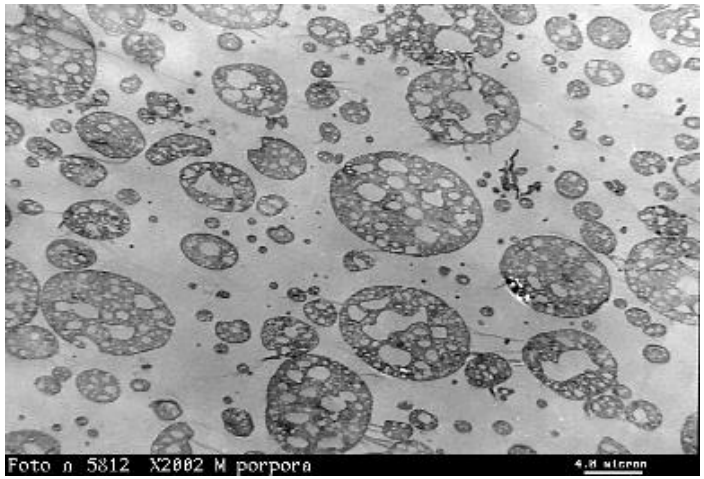
a basse shear rate scompare il plateau newtoniano

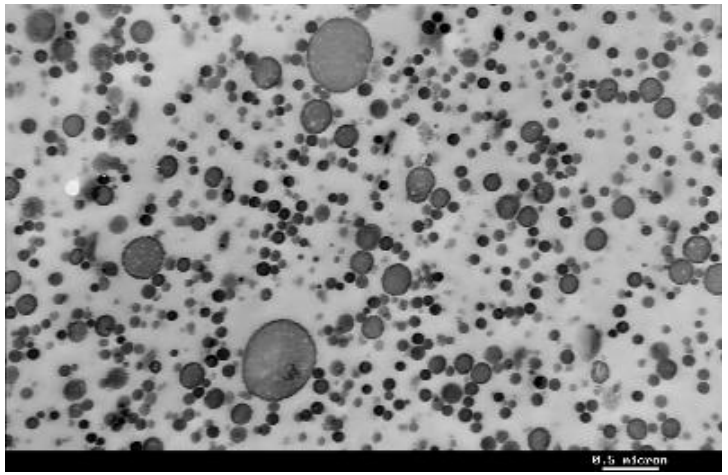
C.Y. Ma, J.L. White, F.C. Weissert, K. Min, *SPE Tech. Papers*,31 (1985)

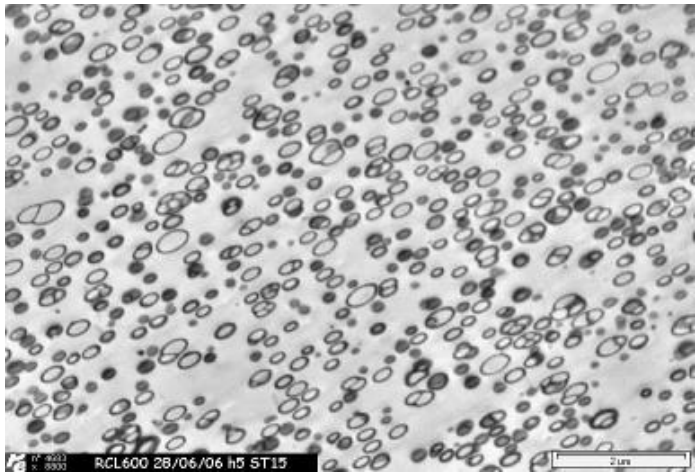
la presenza di yield stress è meglio evidenziata in un grafico viscosità-sforzo

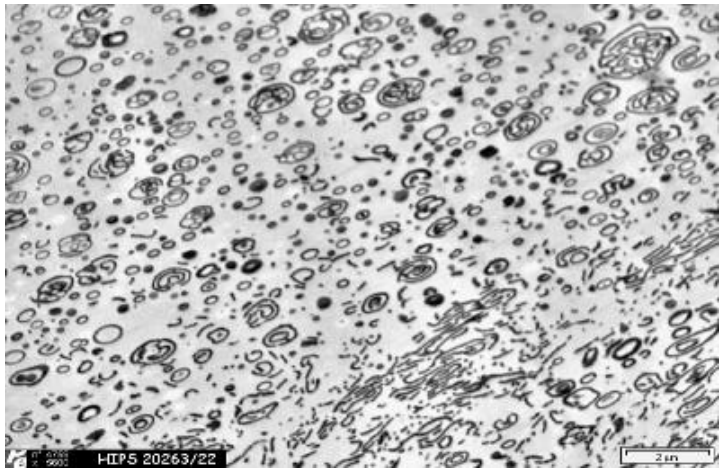


polimeri con fase gommosa (reticolata) dispersa



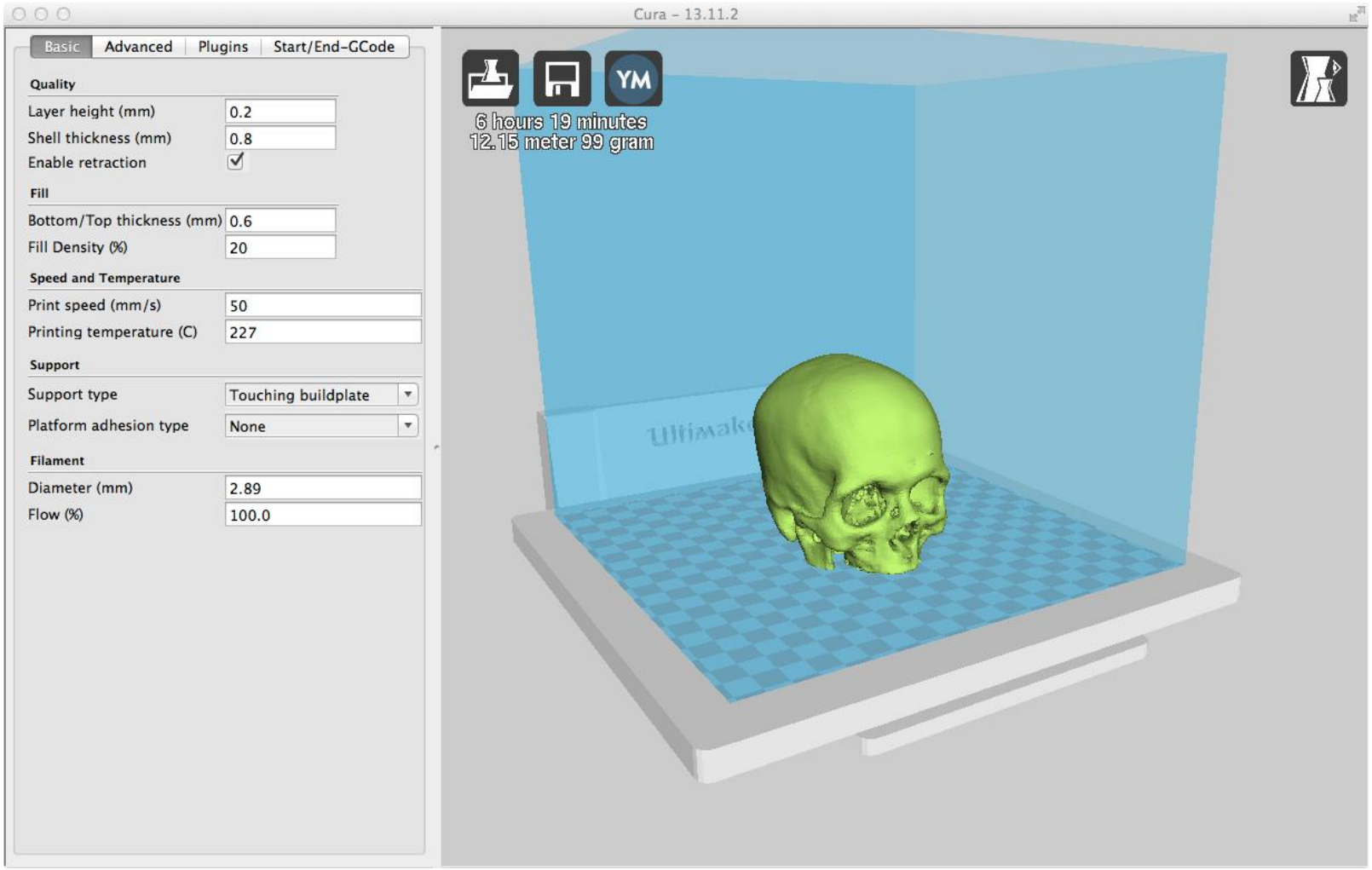






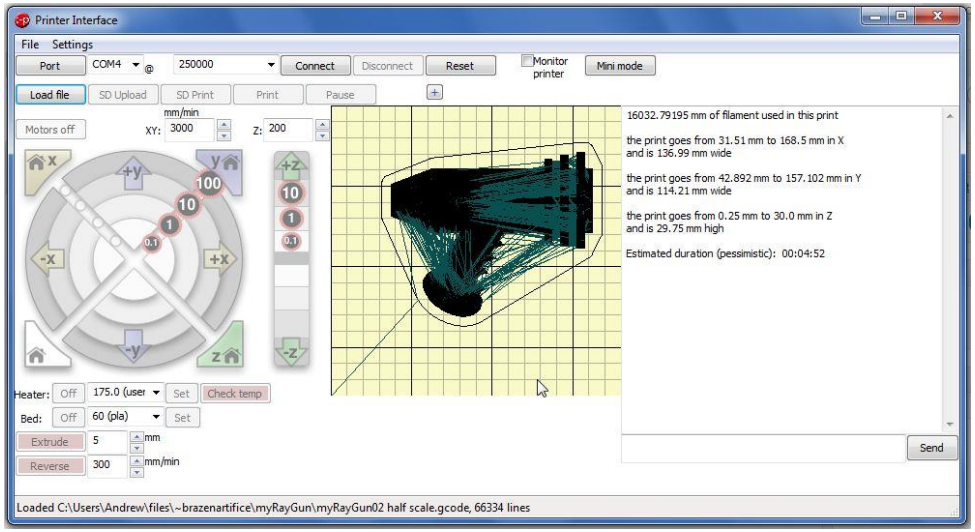
A LOOK INTO SLICING PARAMETERS

Cura

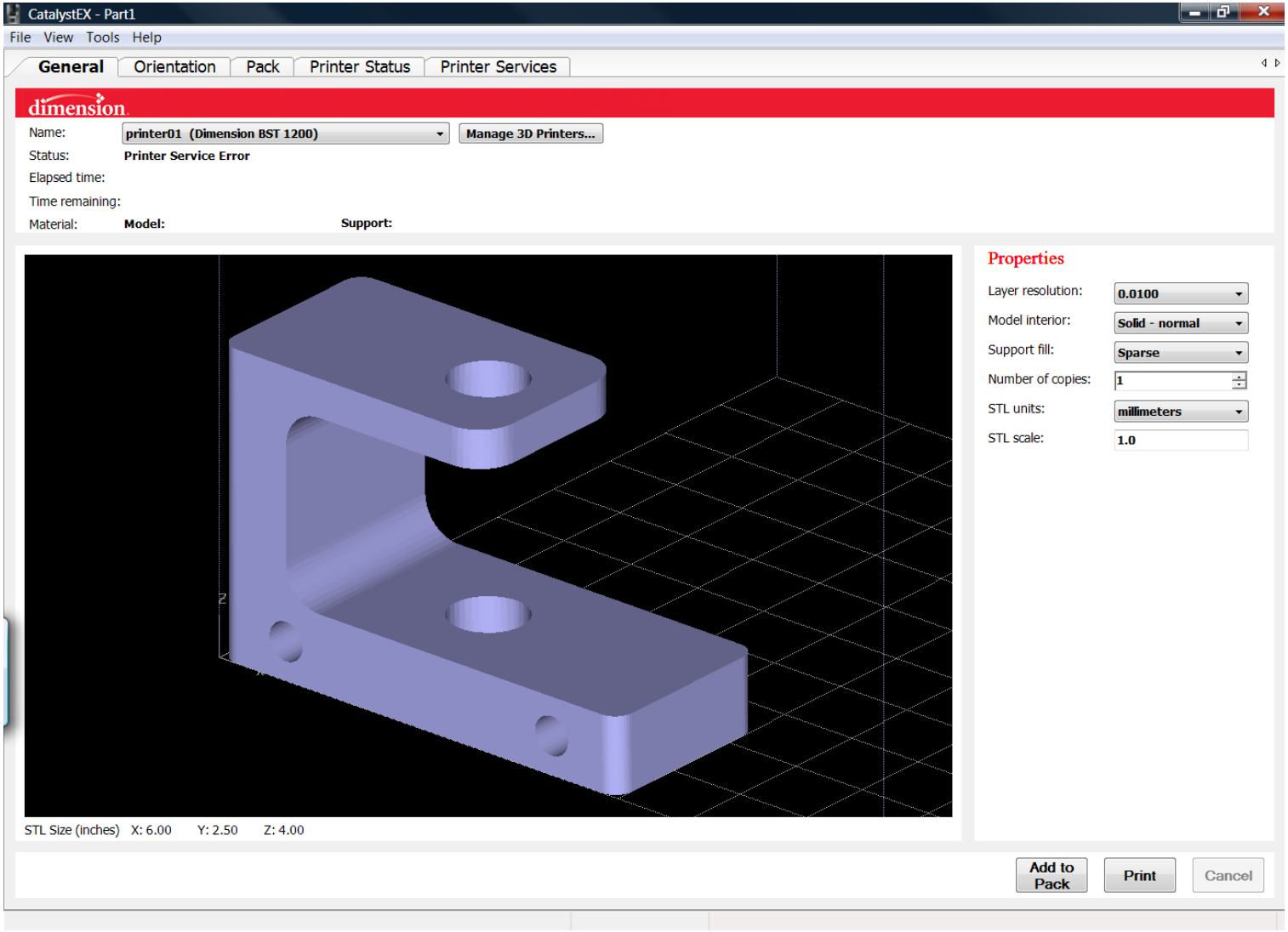

Cura - 13.11.2
Basic
Advanced
Plugins
Start/End-GCode
Quality
Layer height (mm)
0.2
Shell thickness (mm)
0.8
Enable retraction
Fill
Bottom/Top thickness (mm)
0.6
Fill Density (%)
20
Speed and Temperature
Print speed (mm/s)
50
Printing temperature (C)
227
Support
Support type
Touching buildplate
Platform adhesion type
None
Filament
Diameter (mm)
2.89
Flow (%)
100.0
YM
6 hours 19 minutes
12.15 meter 99 gram

Slic3r


Slic3r
G-code generator for 3D printers


Printer Interface
File Settings
Port COM4 @ 250000 Connect Disconnect Reset Monitor printer Mini mode
Load file SD Upload SD Print Print Pause
Motors off mm/min XY: 3000 Z: 200
16032.79195 mm of filament used in this print
the print goes from 31.51 mm to 168.5 mm in X and is 136.99 mm wide
the print goes from 42.892 mm to 157.102 mm in Y and is 114.21 mm wide
the print goes from 0.25 mm to 30.0 mm in Z and is 29.75 mm high
Estimated duration (pessimistic): 00:04:52
Heater: Off 175.0 (user Set Check temp
Bed: Off 60 (pla) Set
Extrude 5 mm
Reverse 300 mm/min
Send
Loaded C:\Users\Andrew\files\~brazenartifice\myRayGun\myRayGun02 half scale.gcode, 66334 lines

Stratasys Catalyst



Stratasys Catalyst