Enzymatic degradation of plastics waste: a geometric model

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Polyester waste: recycling by enzymatic de-polymerisation?

	PET bottle waste		96% after 24h
	PET textile waste swimwear lining		82%
	PET fiber waste automotive scrap		36%
	PET/PBT textile swimwear trunk		15%
	PBT		0%

What do enzymes need?

enzymes act only at the **surface**

they “need space” to act:

- **amorphous** substrate (avoid crystals!)
- substrate **mobility** (avoid glass!)

natural temperature range (enzymes are proteins)

- roughly $40–70°\mathrm{C}$

water

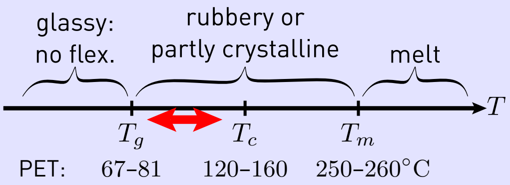
The growing crystallites are a problem!

Prepare the polyesters:

prepare:

- melt + quench
- mill + sieve: break into pieces $\sim 300\,\mu m$

de-polymerise:



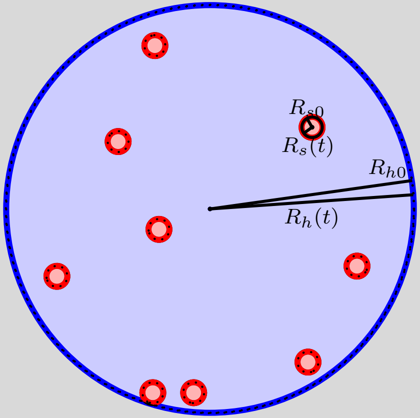
- initial crystallinity + nucleation
- **crystal growth!**

Competition: de-polymerisation vs. crystal growth

model: one shrinking sphere: amorphous material: degradable

many growing spheres: (partly) crystalline material: not degradable

so-far degraded material



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depend on material, composition, preparation, processing temperature, . . .

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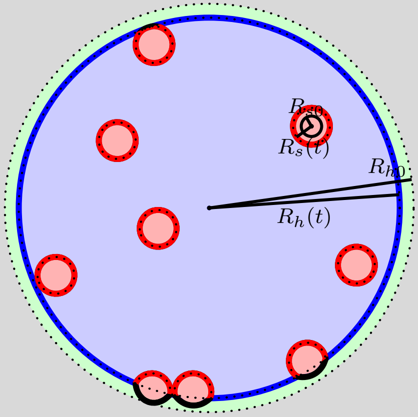

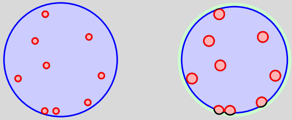

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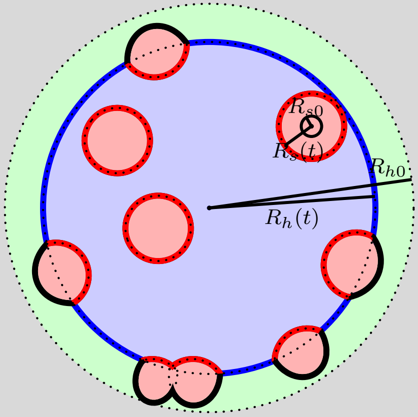

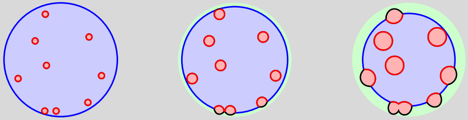

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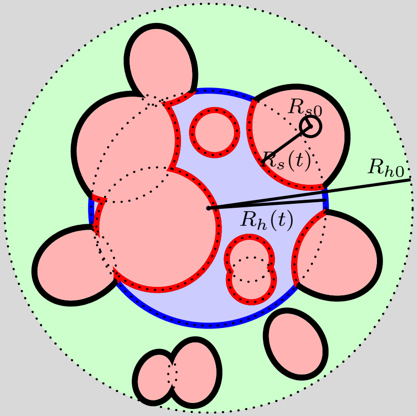

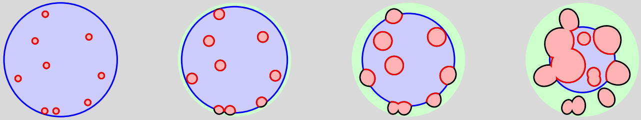

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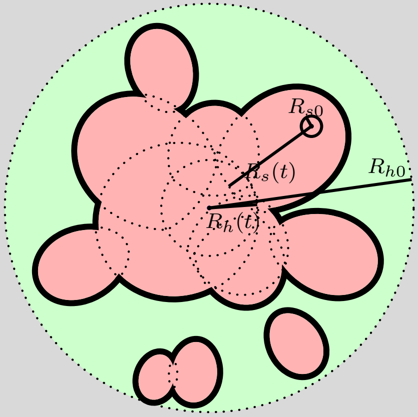

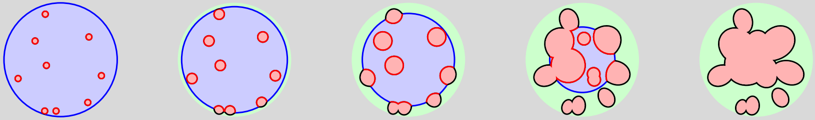

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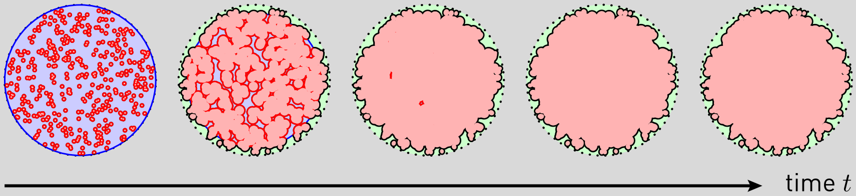
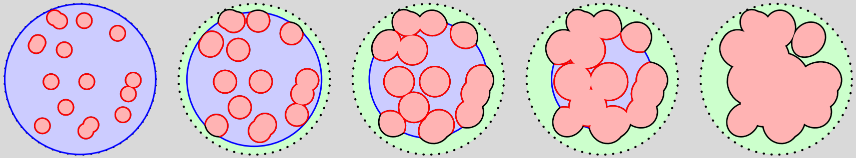
Competition: de-polymerisation vs. crystal growth

careful! there is more than just the total initial crystallinity

many small



few big (same initial volume-fraction!, same growth rate!)



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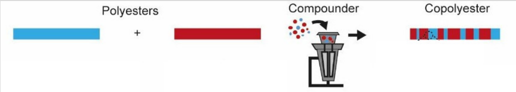
How to slow down crystallisation?

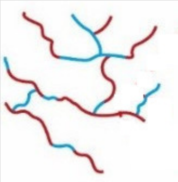
"Classic" optimisation: understand the parameters for every material
including their temperature dependence, . . .
sort materials (!?)
optimize parameter compromises
repeat the procedure also for mixtures (!?)

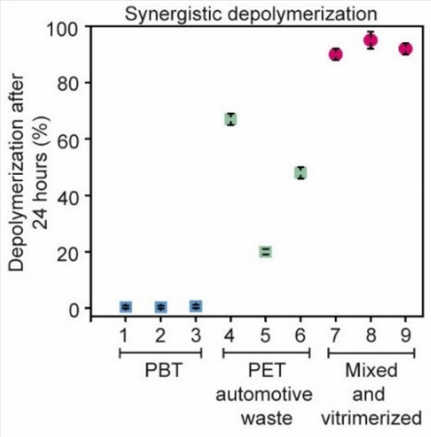
Radical new idea: **Mixing rather than sorting**

melt transesterification: increase randomness along chains
works for blends: 75%+25% of PET+PBT or of PET+PTT

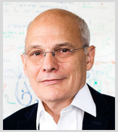


vitrimerisation:
cross-link chains to form a random network





This was really a group effort:



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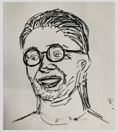

. . . and me (Gulliver lab, CNRS). . .

and Costantino Creton (SIMM lab, CNRS)

and Clément Freymond (SIMM lab, ESPCI)

and Louise Breloy (SIMM lab, ESPCI)

. . . plus industrial contacts . . .

Publication currently under review at PNAS