iFormulate

Introduces…

A Quick Guide to Adhesion Science

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An iFormulate *Skills* Formulation Training 2016 Webinar

Overview:

1. Why is Adhesion Important?
2. Traditional Theory
3. Forces Involved in Adhesion
4. App Demonstration
5. Summary and Learning More

- This webinar is being recorded and will be made available

The audience is muted and you may ask questions using the question function in GoToWebinar

This webinar will last about 30 minutes

Your Speakers

Professor Steven Abbott

Dr David Calvert
iFormulate Ltd

iFormulate Skills Formulation Training 2016

A Little About iFormulate

A company founded in 2012 by two experienced industry professionals…

Combining diverse experiences, knowledge and wide range of contacts:

…polymers, materials science, chemistry, imaging, dyes, pigments, emulsion polymerisation, biocides, anti-counterfeiting, environmental, formulation, consultancy, marketing, business development, strategy, regulatory, training, events, R&D, innovation

Complementary network of Associates

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Our Services

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Importance of Adhesion to Formulators

- Inks and Coatings
- Packaging
- Home Care Products
- Cosmetics
- Agrochemicals
- Pharmaceuticals
- Construction

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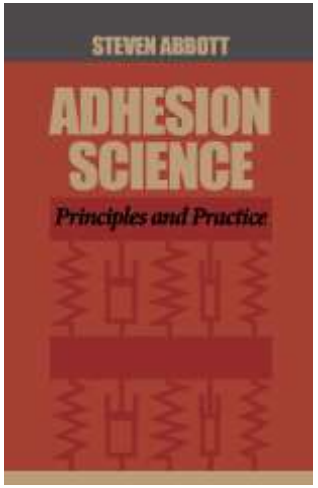
Most of what we are taught about adhesion science is *wrong*

- Sad, but true
- But the problem is easily fixed
  - Some simple proofs that the bad ideas are wrong
  - A big, app-based website with all the good ideas, www.stevenabbott.co.uk/Practical-Adhesion
  - A great book *Adhesion Science: Principles and Practice*, where all formulae and calculations are linked to the Practical-Adhesion website
  - The iFormulate Adhesion Science for Formulators 1-day course on 1 December
- But first, how stuck is stuck?



Units

- Work of adhesion, W, is the amount of work (J) to separate 1 m^2 of an adhesive joint, so is in J/m^2
- Peel is the force (N) required to separate across 1m of joint, so is in N/m
- It turns out that J/m^2 and N/m they are exactly the same!
  - Their "dimensions" are both kg/s^2
  - So a peel strength of 100N/m is the same as a work of adhesion of $100J/m^2$
- Work = Energy, so Work of Adhesion = Energy of Adhesion
- Dyne/cm = mN/m = mJ/m^2
  - So a typical surface energy of 40dyne/cm=40mN/m=$40mJ/m^2$

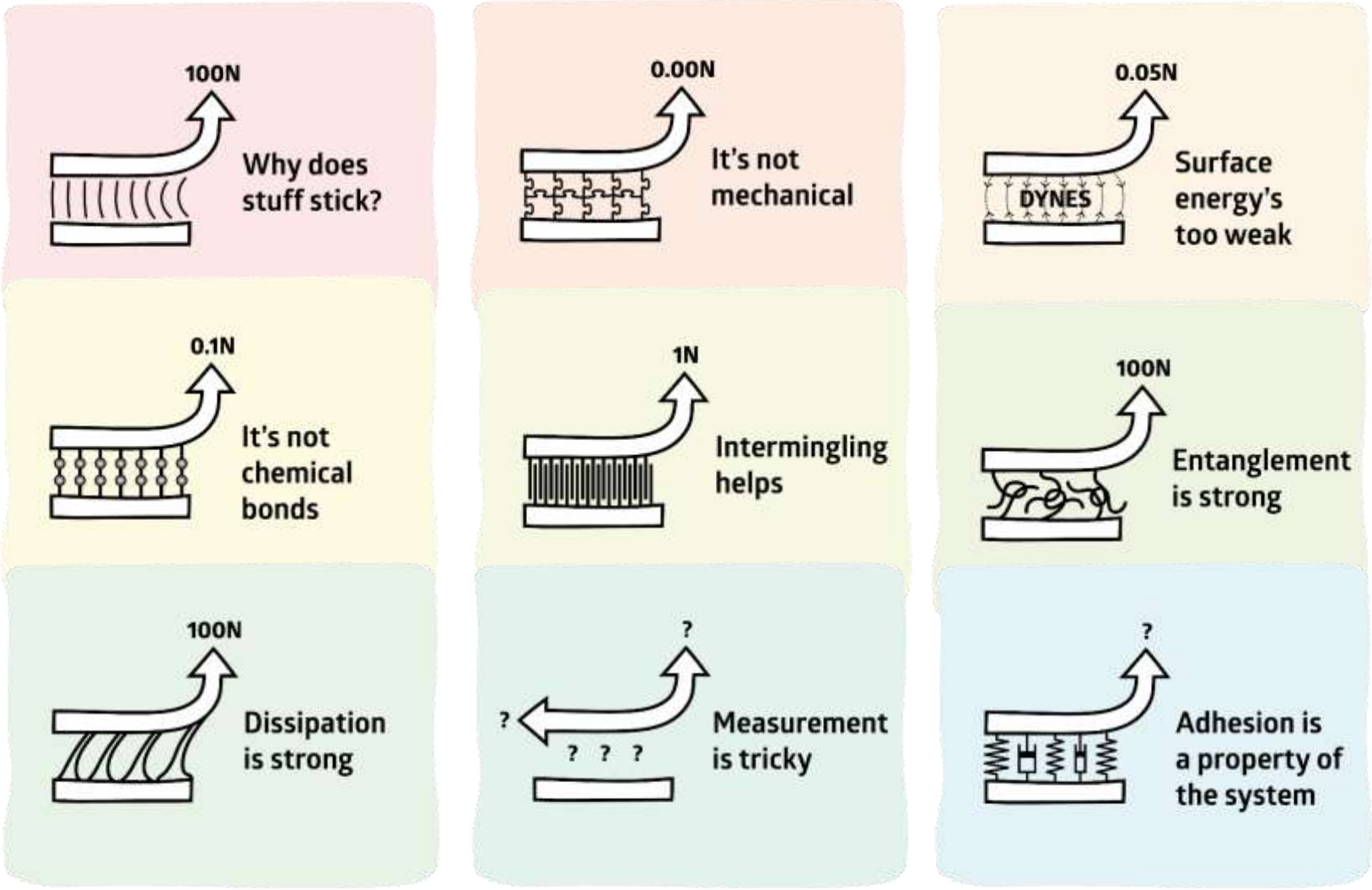
What are the relative strengths?

- Surface energy is ~40 dyne/cm, 40mJ/m², 40mN/m
- A Post-it® is something like 4N/m, 100x larger than surface energy
  - So surface energy really isn't important!
- A household adhesive tape is easily 100N/m
  - That's 2.5N/25mm in a typical peel tester
- A strong adhesive is therefore in the 400N/m, 400J/m² range
  - i.e. 10000x stronger than surface energy

Relative strengths

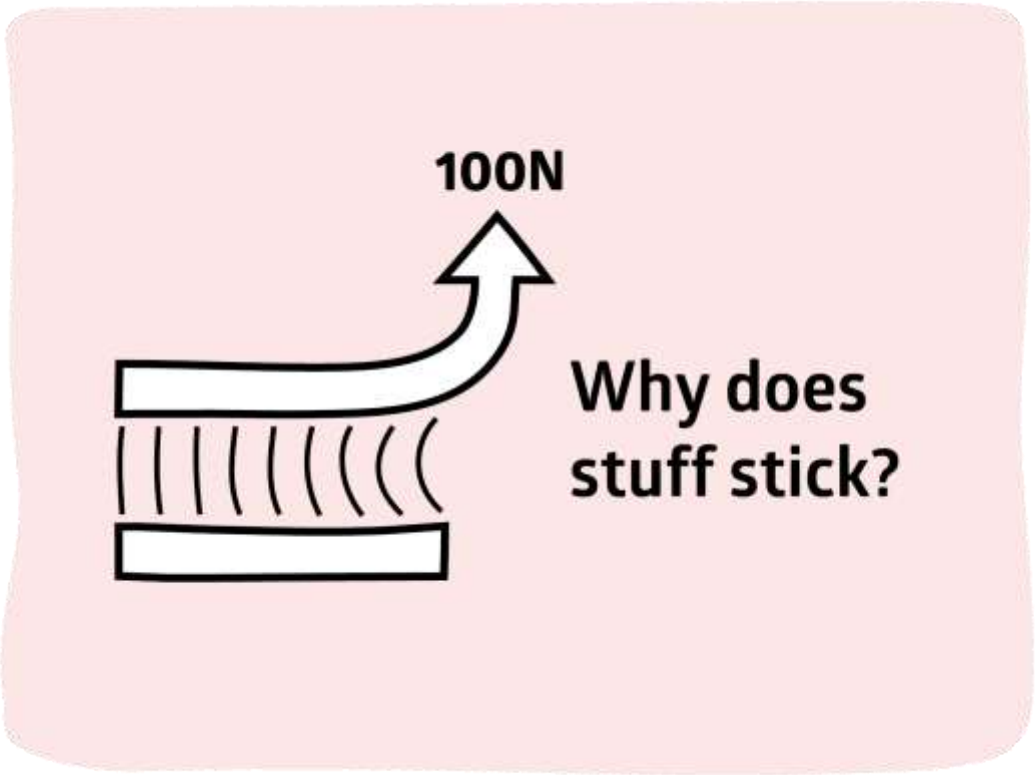
- Surface energy is about enough to support the weight of 2 paperclips across the width of a Post-it®
  - That's not a lot of stuckness
- 10N/m is a 1kg bag of sugar pulling off 2.5m of Post-it® stuck to a smooth wall
  - Noticeable, but not large
- 800N/m is my 80kg weight peeling off 1m of strong adhesive tape stuck to a smooth wall
  - Large but not unimaginable

Adhesion in 9 graphics



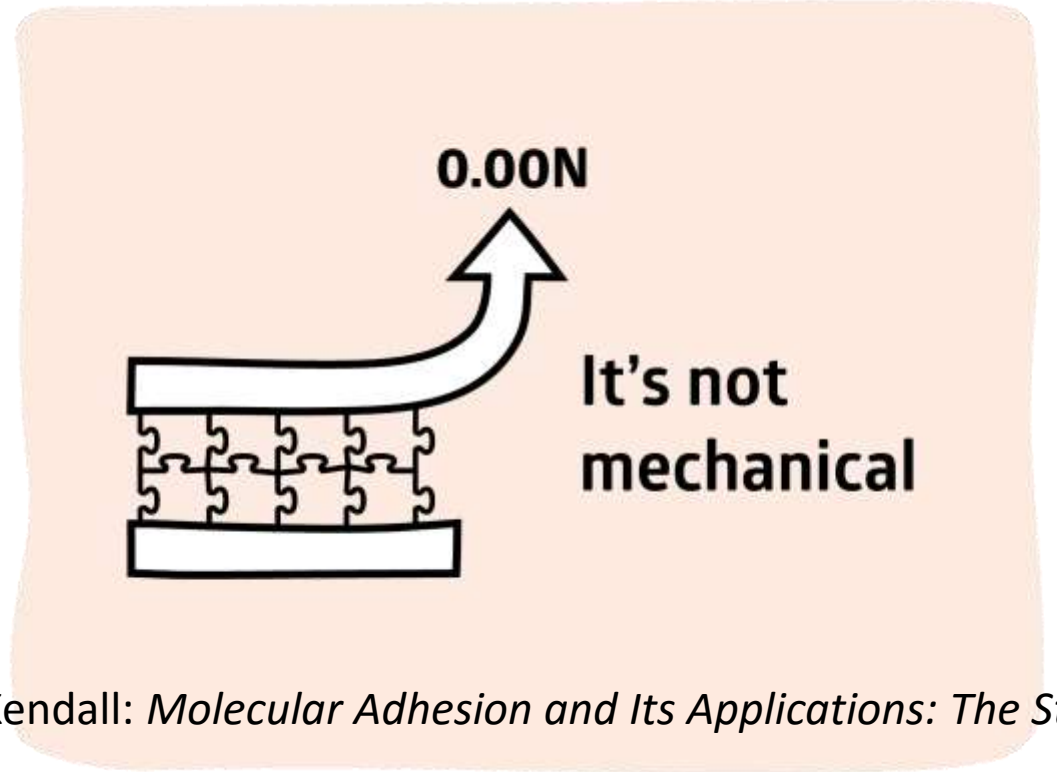
Why does stuff stick?

- Lots of bad ideas out there
- That don’t help you to formulate or solve problems



It’s not mechanical

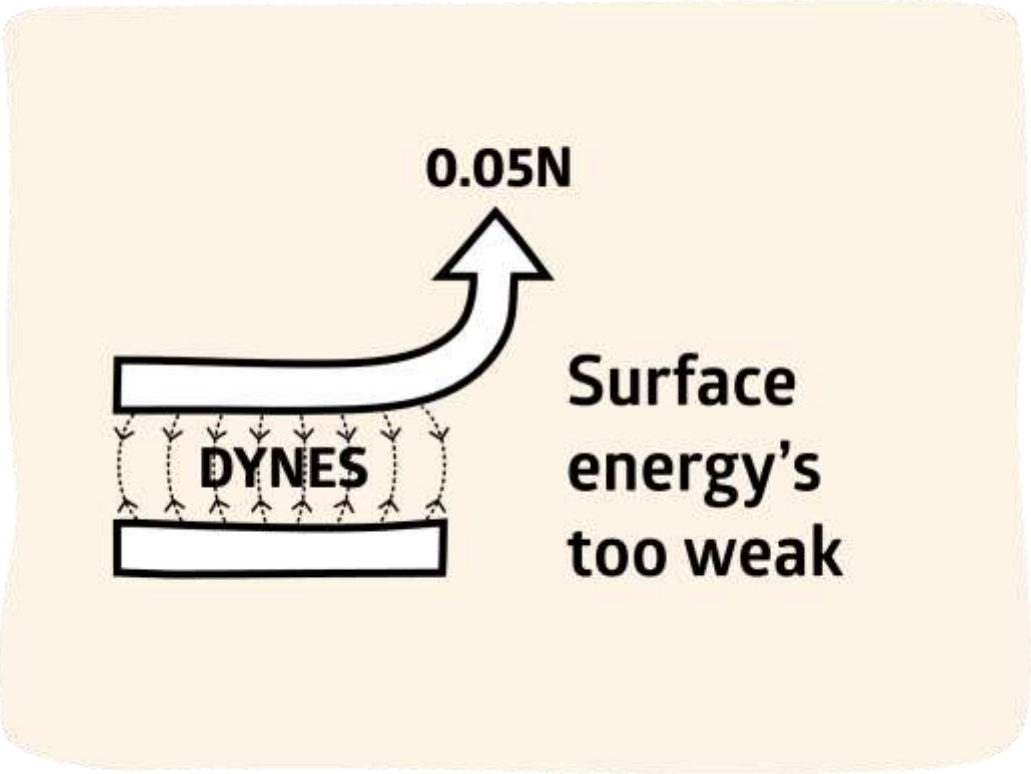
- People often talk about “mechanical interlocking”. It’s simply false*, impossible except for adhesives into paper, board and non-wovens



*Prof Kevin Kendall: *Molecular Adhesion and Its Applications: The Sticky Universe*

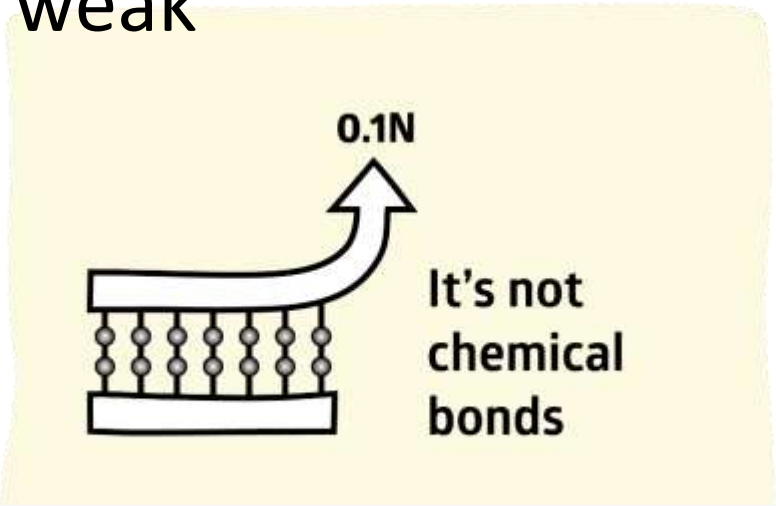
Surface energy's too weak

- We all know that surface energies are around 40dyne/cm=40mN/m=40mJ/m2 and that strong adhesion is more than 40N/m. So surface energy is 1000x too small



It’s not chemical bonds

- Even 100% chemical bonds across an interface give <1N/m so typical chemical bonding is much too weak



Chemical

Bonds/10nm^2 1

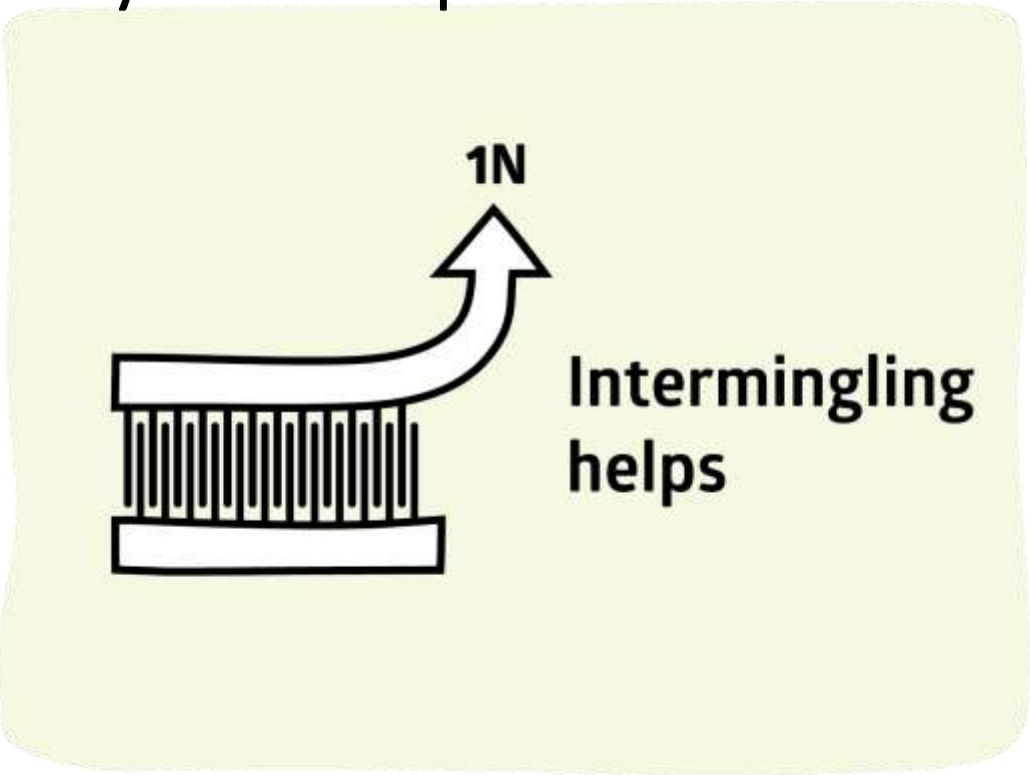
U kJ/mole 350

W J/m^2 0.058

www.stevenabbott.co.uk/practical-adhesion/chemical.php

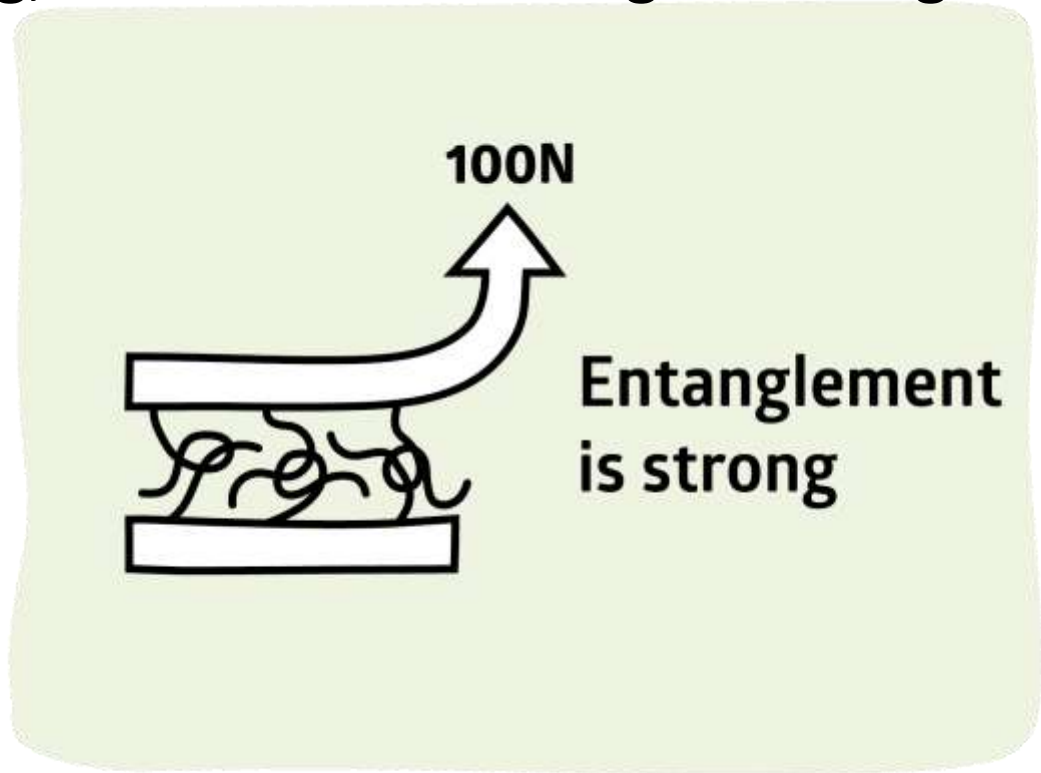
Intermingling helps

- Getting some polymer chains across an interface can start to give some reasonable adhesion – so we'd better work out how to do this directly or with primers



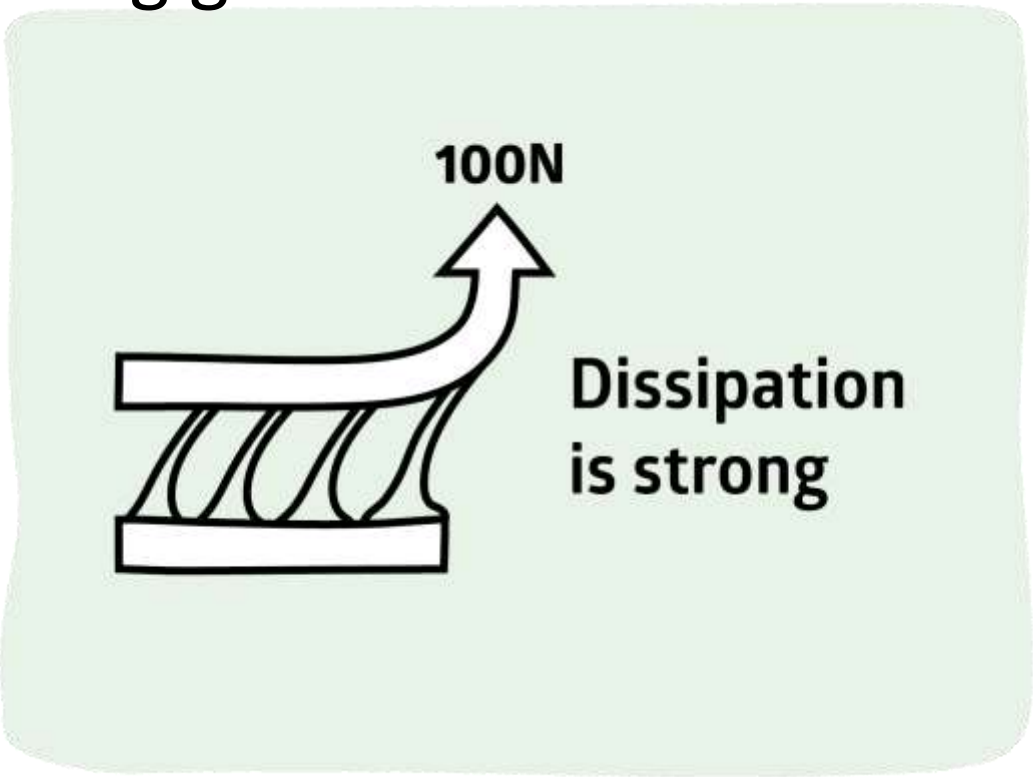
Entanglement is strong

- Getting polymer chains entangled physically or via cross-links gives strong adhesion
  - Chemical bonds that give cross-links *can* be strong, but too much of a good thing is a bad thing



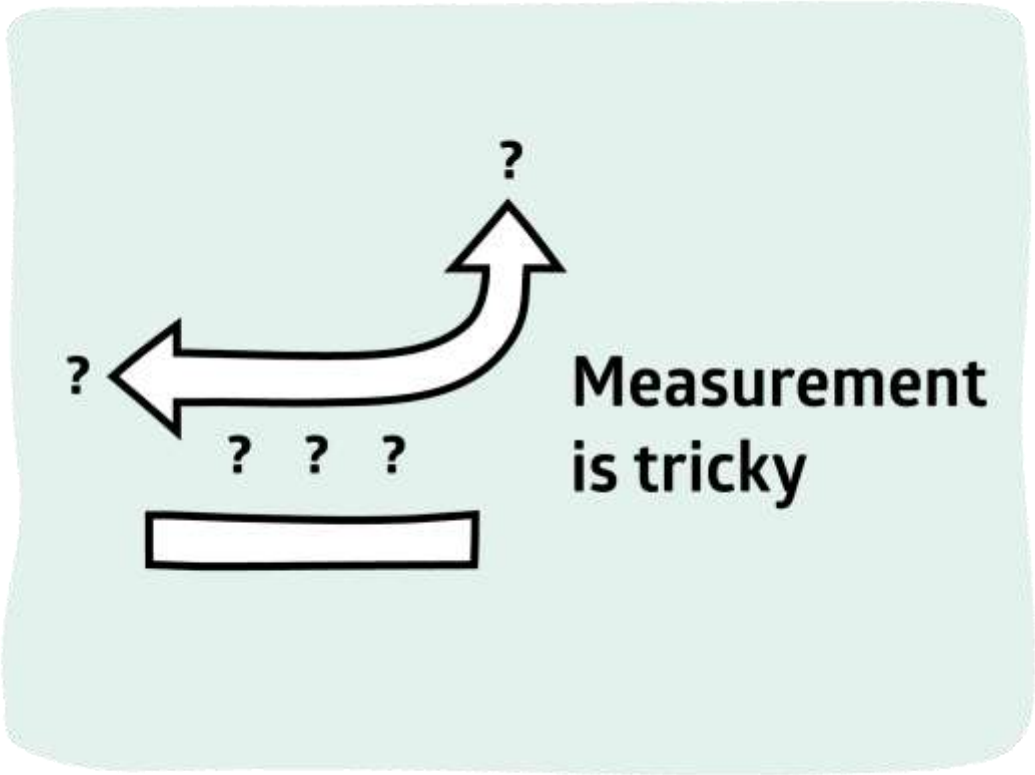
Dissipation is strong

- Intermingling, entanglement and the right sort of “weak” polymer (a PSA) allow strong adhesion via dissipation – absorbing energy like chewing gum



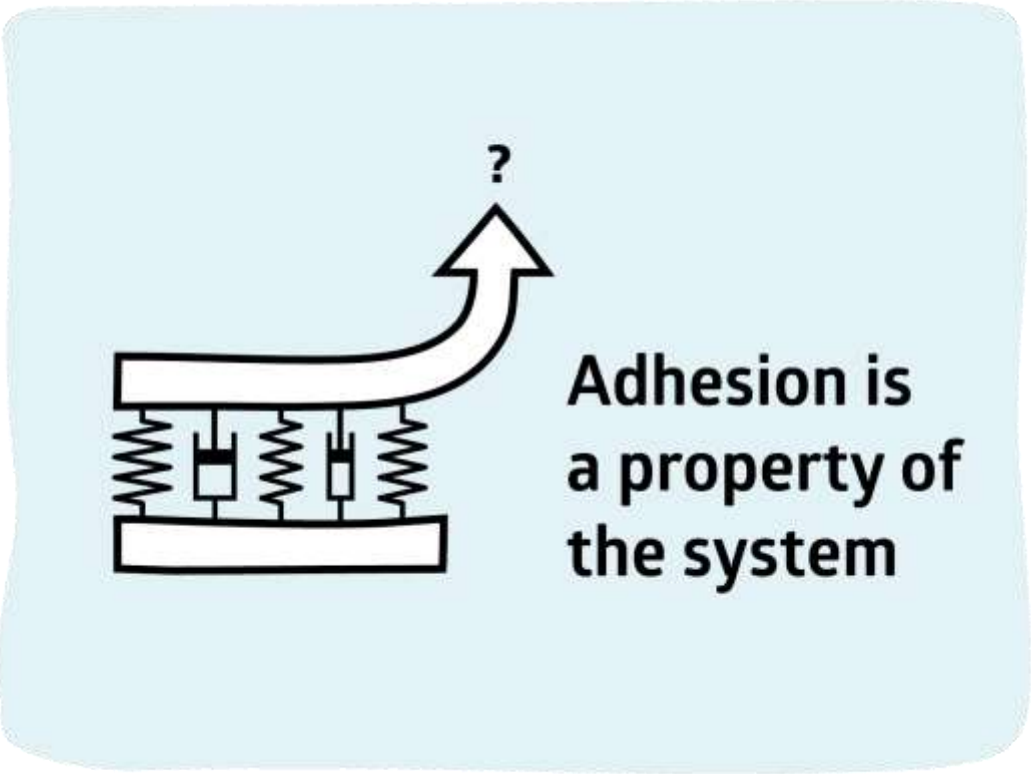
Measurement is tricky

- We'd all love a simple, objective test of our adhesion. It doesn't exist! All tests are indirect.
  - Emphasised in the Testing episodes



Adhesion is a property of the system

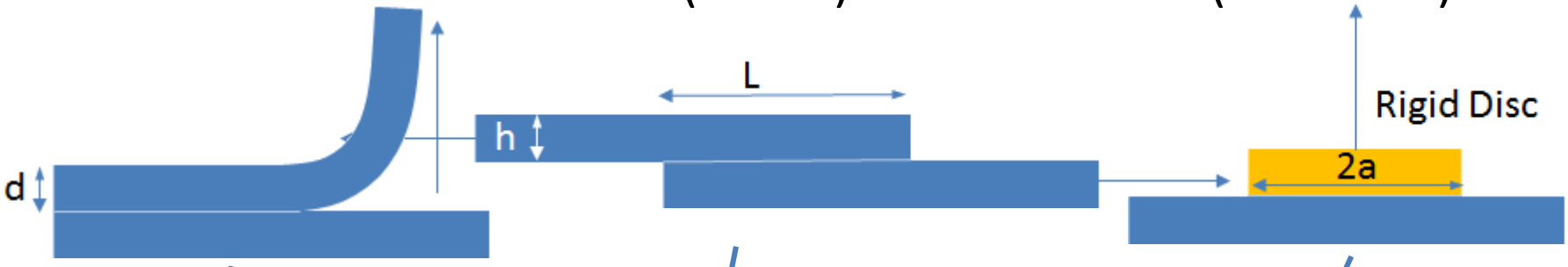
- You must always think of the whole system to know if you have strong-enough adhesion



Let's see that with an app

Same material in 3 joints ~ same size
Work of adhesion=W, width=b, Modulus=E
Force to break the joint=F

$F=W.b$ $F=b(2WEh)^{½}$ $F=(10\pi WEa^{3})^{½}.$



Weak & Strong

W J/m^2 0.04

b mm 25

E GPa 3.76

h µm 100

F_{Peel} N 1.00e-3

F_{Lap} N 4.34e+0

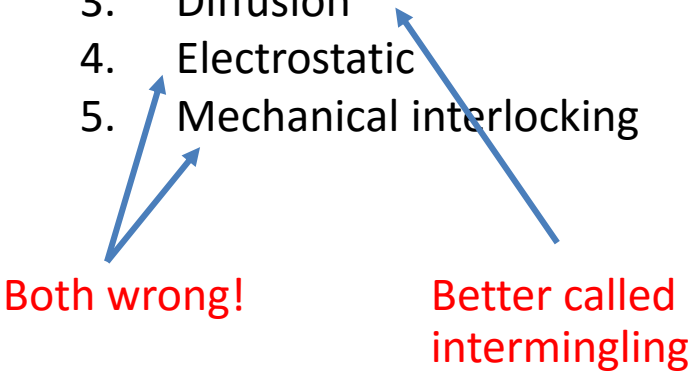
F_{Butt} N 9.61e+1

www.stevenabbott.co.uk/practical-adhesion/weak-strong.php

Adhesion Modes

Classic list

1. Physical adsorption (Surface energy)
2. Chemical bonding
3. Diffusion
4. Electrostatic
5. Mechanical interlocking



This list doesn't help formulate good adhesives or troubleshoot problems

Correct list

1. Surface energy. Weak and useless except for geckos.
2. Chemical bonds. Surprisingly weak and often useless or worse.
3. Intermingling/Entanglement. Most of strong adhesion, with chemical crosslinks equivalent to entanglement.
4. Dissipation. A large element of much of strong adhesion and most of PSA.
5. The above should only be applied in the context of the system

This list is helpful for formulation and for troubleshooting

You are all adhesion experts now

- Just these principles will get you a long way!
  - Surface energy is 1000x too weak to be relevant
  - Mechanical interlocking is non-existent
  - Chemical bonding, on its own, is surprisingly weak
    - And trying too hard makes things worse
  - We need entanglement and dissipation for real strength
  - Adhesion is a property of the system
- But a day spent on the Adhesion Science for Formulators course will give you a deeper, fuller understanding
  - See you on 1 December!

Learning More: Practical Adhesion Science for Formulators

One-day Training Workshop:

1st December 2016, The Source, Meadowhall, Sheffield, UK.

See: http://iformulate.biz/training-and-events/practical-adhesion-science-for-formulators/

Back by popular demand in 2016, and featuring Professor Steven Abbott, the workshop will enable you to:

– Quash popular myths of adhesion

– Better understand the real science that underpins adhesion

– How to apply principles to real-life problems

– Use free apps (Practical Adhesion)

– Become better formulators of “sticky” AND “non-sticky” products

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Any Questions?

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