Closed Loop Emotionally Valuable E-waste Recovery

Janet L. Scott, University of Bath

With some confidential data redacted

Context

A lot of the context for this project will be presented in the following presentation, so to avoid repeating things, I refer you to the next speaker who will be able to talk authoritatively on the topic!

http://whatsinmystuff.org/
Sheffield Hallam University
Engineering for Life research network project

Context summary

- There are lots of valuable materials and elements in our E-waste, including in small electronic devices such as mobile phones, tablets etc.
- These small devices, however, are often poorly recycled as they are not returned to the recovery / remanufacture / recycle stream

Closed Loop Emotionally Valuable E-waste Recovery

The people stuff!

How to keep personal electronic devices in the loop?

Why do we often retain devices even when we recycle other things?

What would drive consumers to return their devices?

Is there a better business model?

What does “emotional attachment” mean in this context?

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The technical stuff!

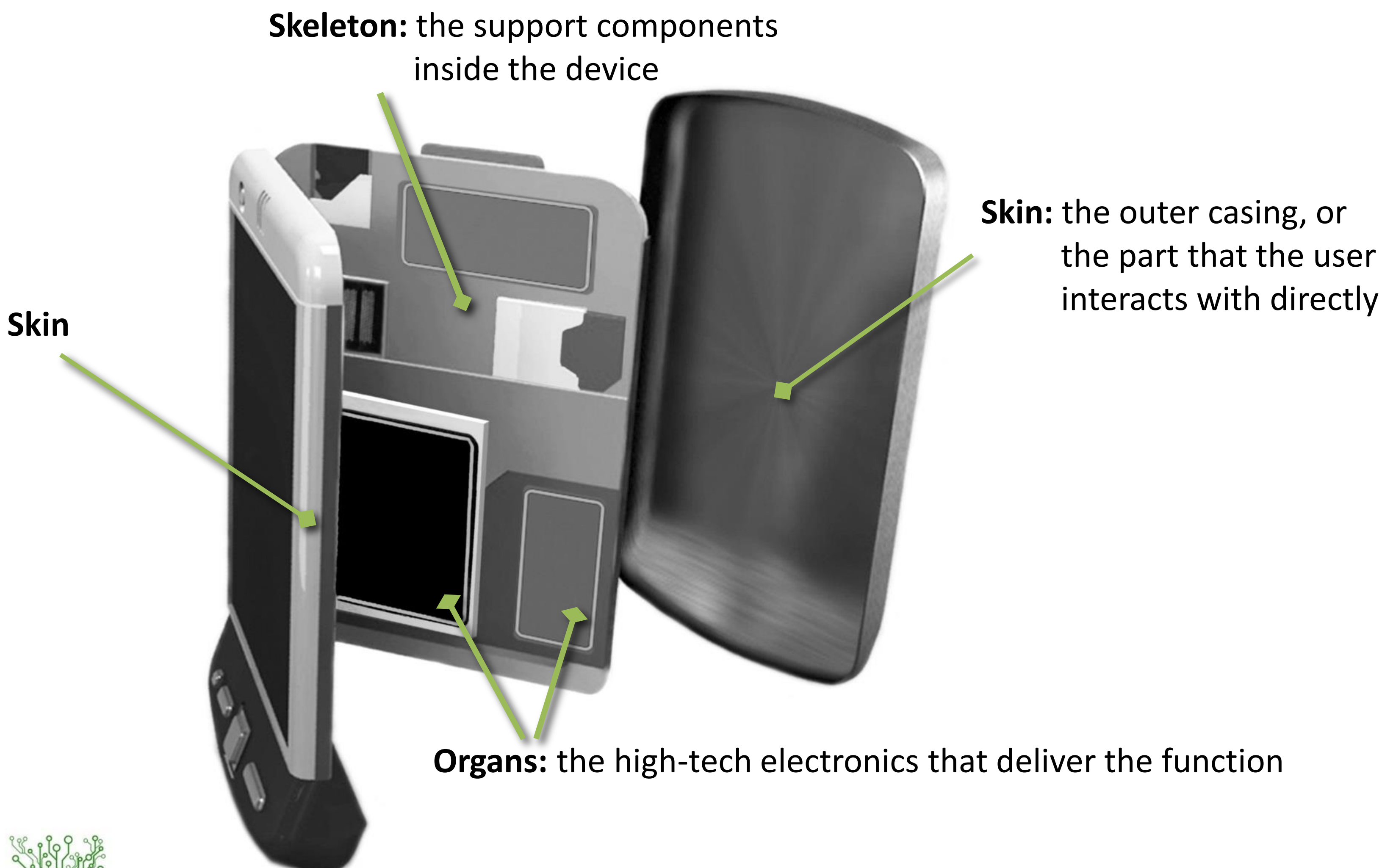
How to enable recovery of valuable metals for retention in the manufacturing loop?

Where are the pinch points in recovery of metals?

Can materials be designed to overcome these?

Many possible approaches

- ***Social Values***
  Fairphone: “A smartphone with social values … From conflict-free minerals to fair factory wages, we’re making improvements one step at a time.”
- ***Modularity***
  Phonebloks: “… a vision for a phone worth keeping. We want a modular phone that can reduce waste, is built on an open platform and made for the entire world.”
- ***Customisable phones***
  Project ARA: “Lego phones” - Started at Motorola, Project ARA is now part of Google’s top-secret Advanced Technology and Projects (ATAP) division.



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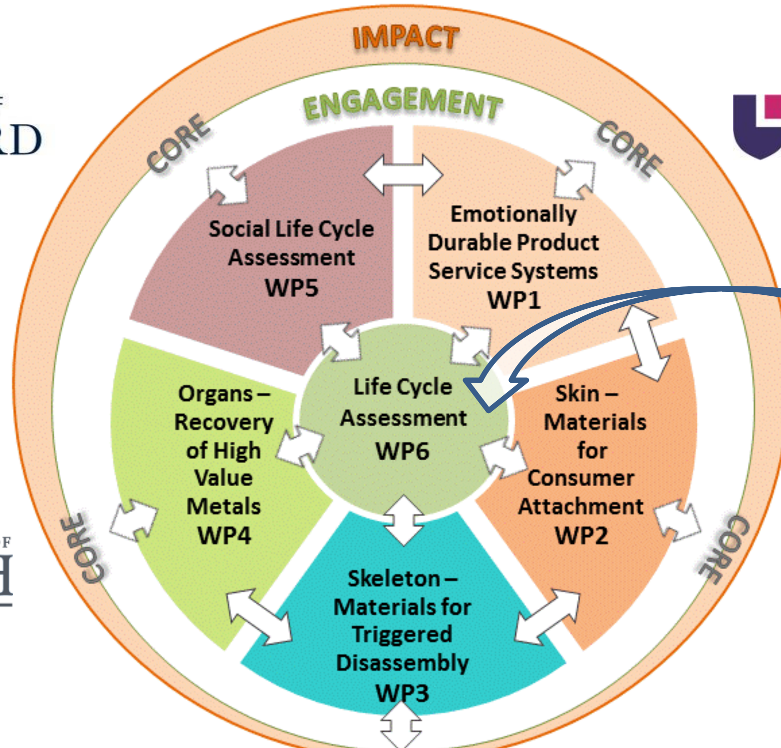
Engineering and Physical Sciences Research Council

Closed Loop Emotionally Valuable E-waste Recovery (CLEVER)



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WP1: Emotionally Durable Product-Service System

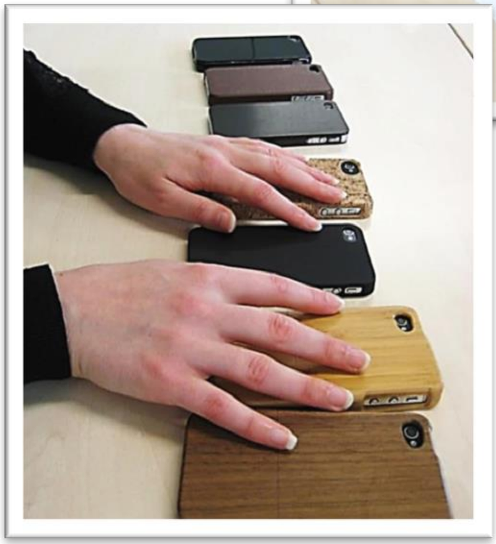
Dr Debra Lilley, Dr Grace Smalley, Richard Mawle and Alan Manley

Understand consumer attitudes and establish the wide ranging reasons that products are discarded prior to failure

Explore the factors that contribute to emotional attachment users feel towards materials and objects

Identify and employ emotional durability strategies to extend product lifetime

Design and Evaluate a Product-Service System that incorporates materials and processes developed in other workpackages



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WP2: Skin – novel materials for consumer attachment

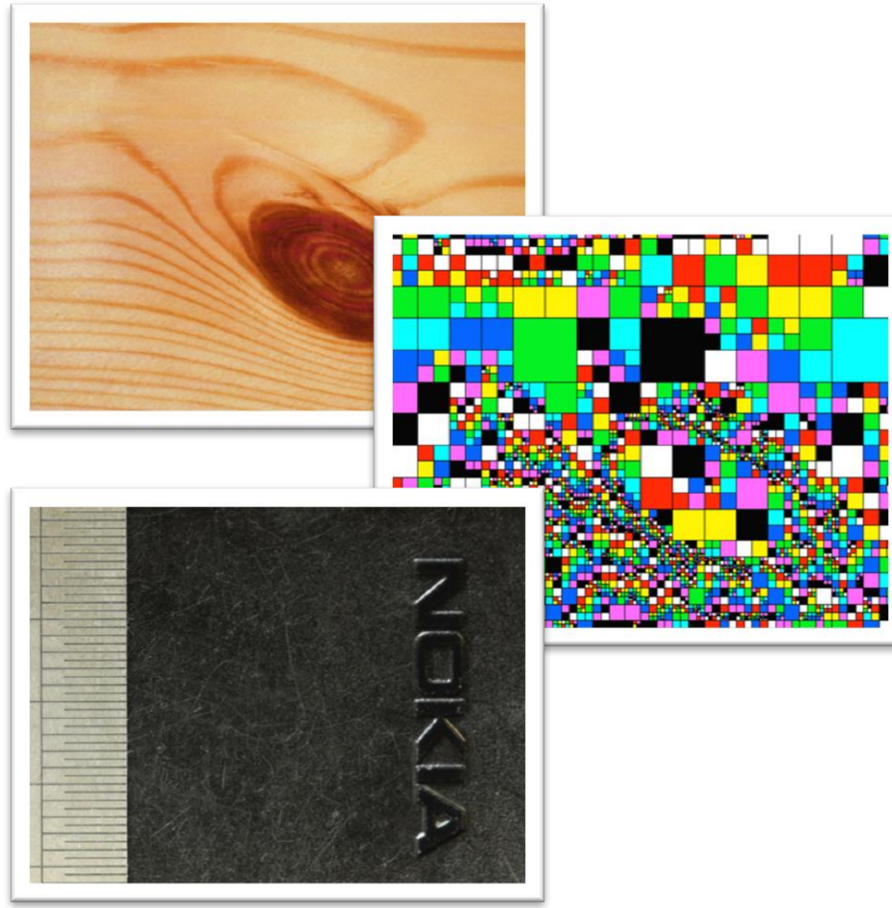
Dr Ben Bridgens and Dr Keerthika Balasundaram

Develop test methods for accelerated ageing of consumer electronics

Analyse surface complexity, variability, tactile qualities and response to wear and ageing of natural and man-made materials

Identify design requirements for ‘heirloom’ materials that increase in ‘value’ with use

Manufacture prototype materials and **evaluate** through user testing (working closely with WP1)



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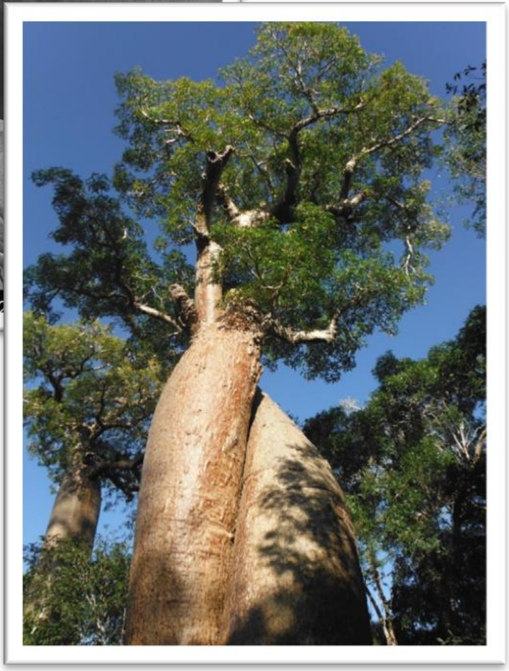
WP3: Skeleton - Materials for Triggered Disassembly

Dr Janet L. Scott and Dr Saravanan Chandrasekaran, Centre for Sustainable Chemical Technologies

Develop novel biopolymer based composite materials for the “skeletal” components of consumer electronics, e.g. circuit boards and flexible circuits.

Ensure that these materials meet the criteria required for the next generation of printed circuits (not current epoxy based materials, where etching is used, but genuinely *printed* electronics).

Require novel blends of flame retardants, hydrophobizing agents and low dielectric constant fillers.



WP4: Organs – Recovery of High Value Metals

Dr Janet L. Scott and Research Associate 2, Centre for Sustainable Chemical Technologies

Explore triggered degradation of materials prepared in WP3. Use of biopolymers allows enzymatic degradation under mild conditions.

Develop a strategy for metal recovery, including well developed methods such as density separation to achieve “enriched” fractions.

Apply novel selective metal recovery strategies, including selective dissolution in ionic liquids and selective recovery (e.g. electroplating).

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WP4: Social Life Cycle Assessment

Dr Kersty Hobson and Dr Hee Sun Choi, School of Geography and the Environment

Examine the governance and ethical imperative behind the recent interest in SCLA

Explore and contribute to debates about the methodological challenges of SCLA

Collect primary data on SCLA for the CLEVER PSS

Stakeholder categories	Impact categories	Sub-categories	Inventory indicators	Inventory data
Workers	Human rights			
Local community	Working conditions			
Society	Health & Safety			
Consumers	Cultural heritage			
Value chain actors	Governance			
	Socio-economic repercussions			

Redrawn after Benoit *et al*.

WP6: Environmental life cycle assessment

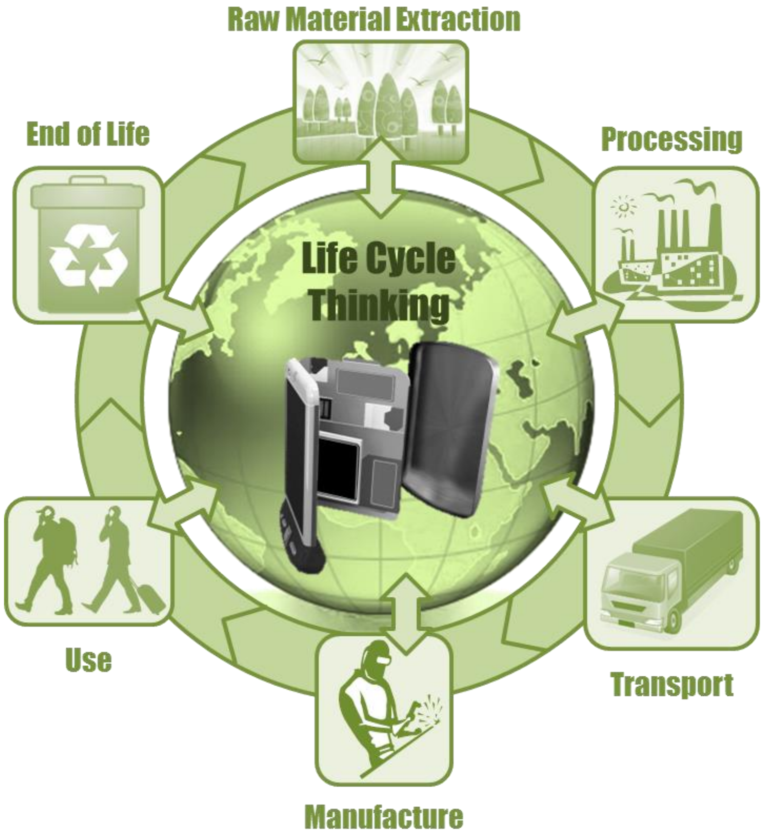
Dr Jacquetta Lee and Dr James Suckling, Centre for Environmental Strategy

Determine appropriate boundaries for environmental analysis of the product

Identify relevant environmental issues

Quantify appropriate impact categories which 'feed' into the identified issues

Provide environmental guidance on appropriate choice of materials and processes to support design decisions



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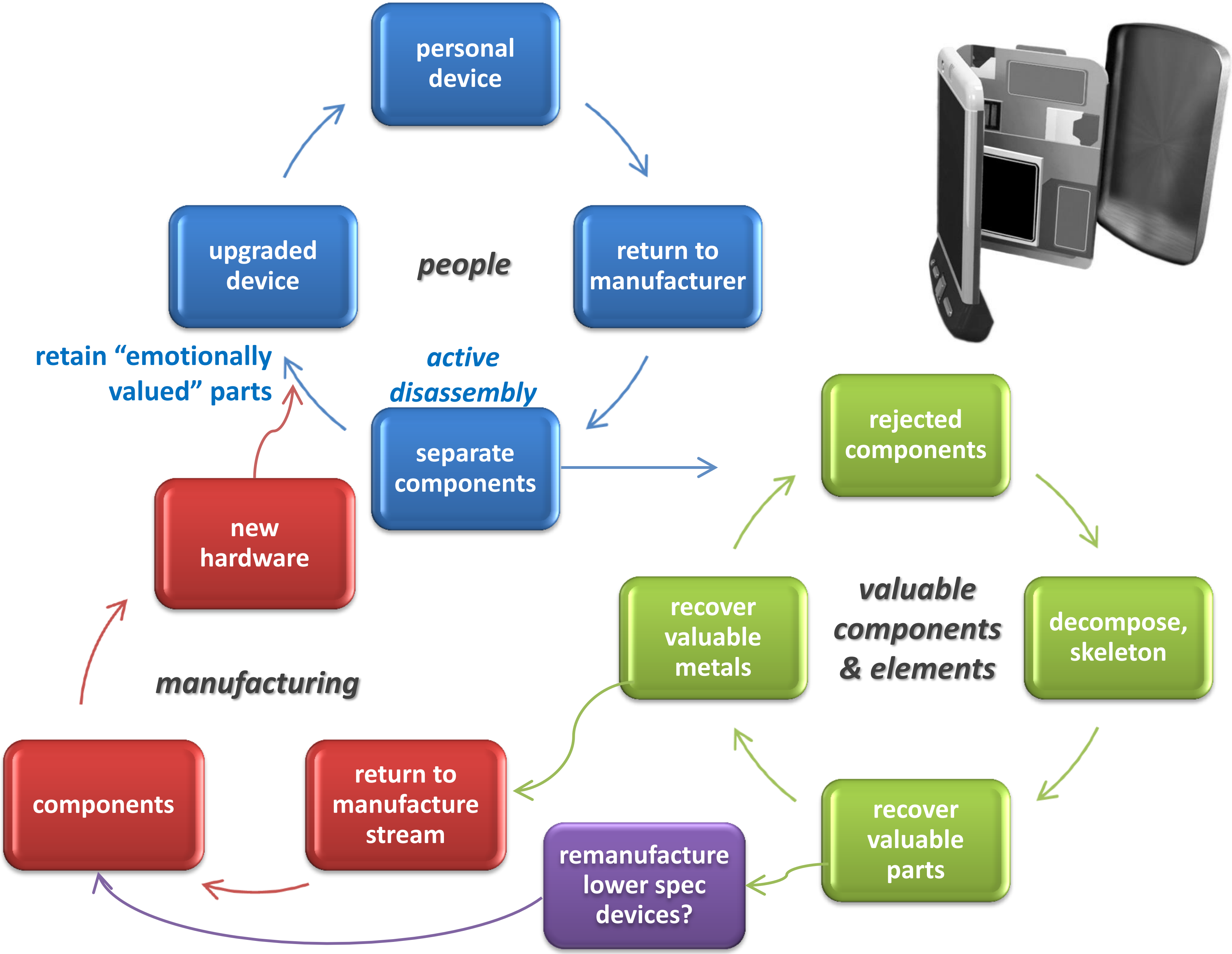
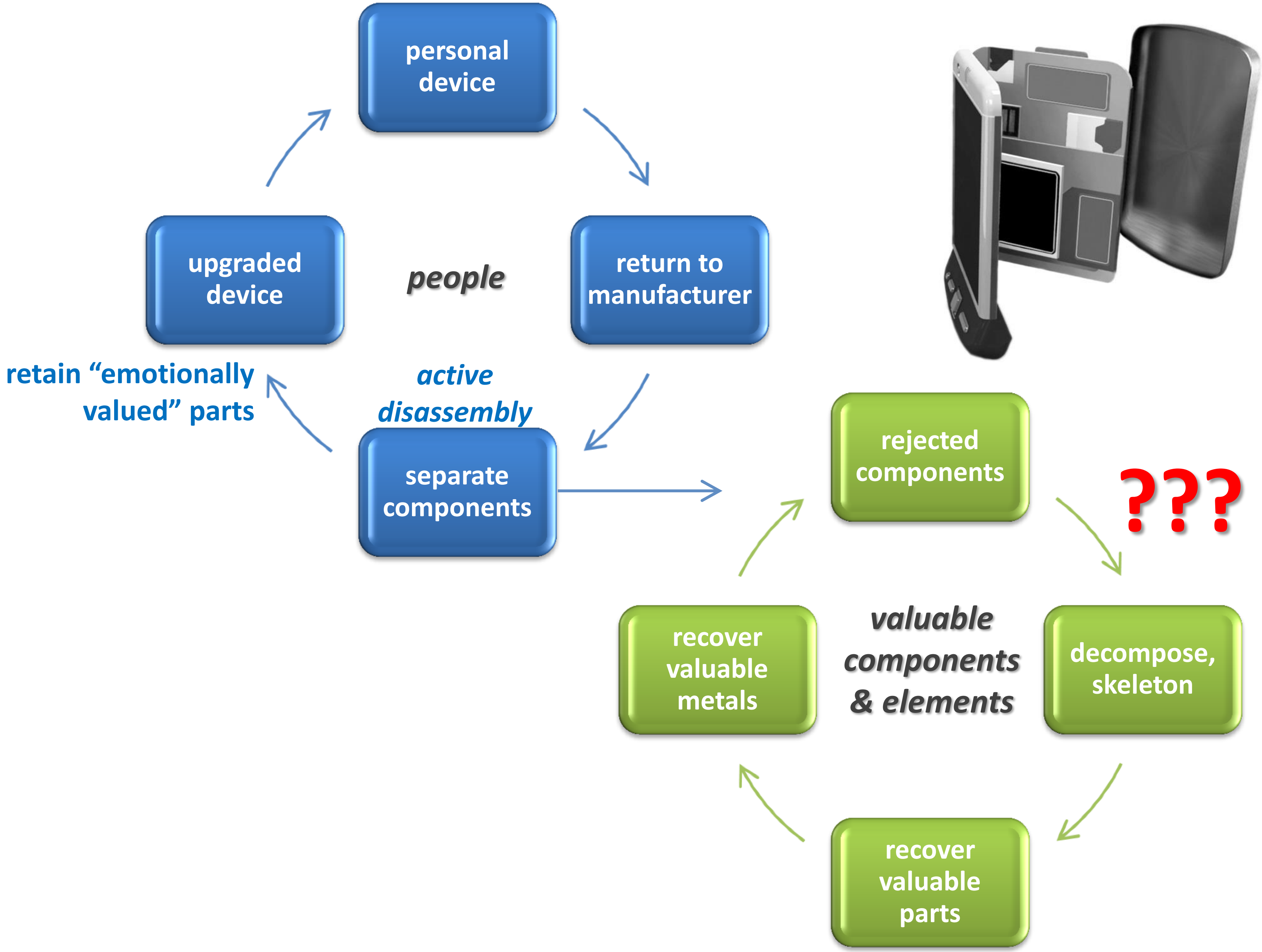

personal device
return to manufacturer
separate components
upgraded device
people
active disassembly
retain "emotionally valued" parts
new hardware
manufacturing
components
return to manufacture stream
remanufacture lower spec devices?
rejected components
decompose, skeleton
recover valuable parts
recover valuable metals
valuable components & elements


personal device
return to manufacturer
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upgraded device
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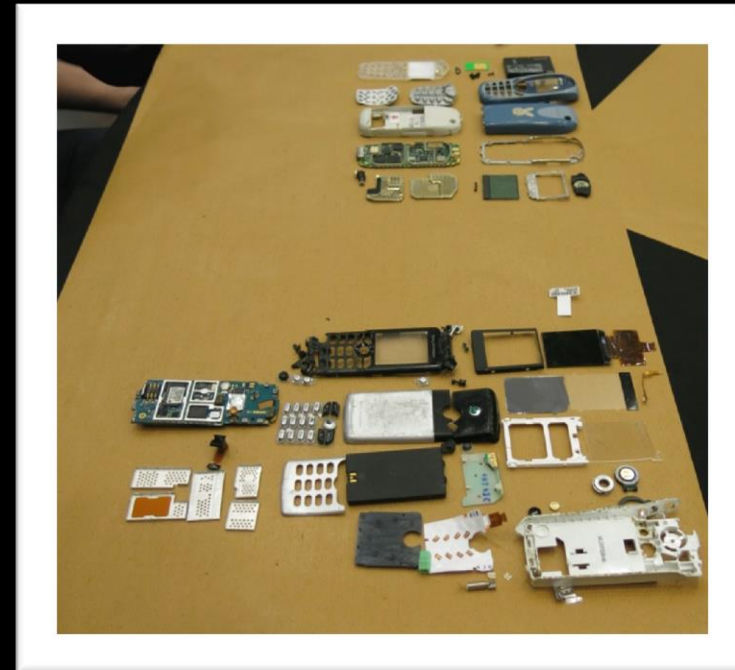
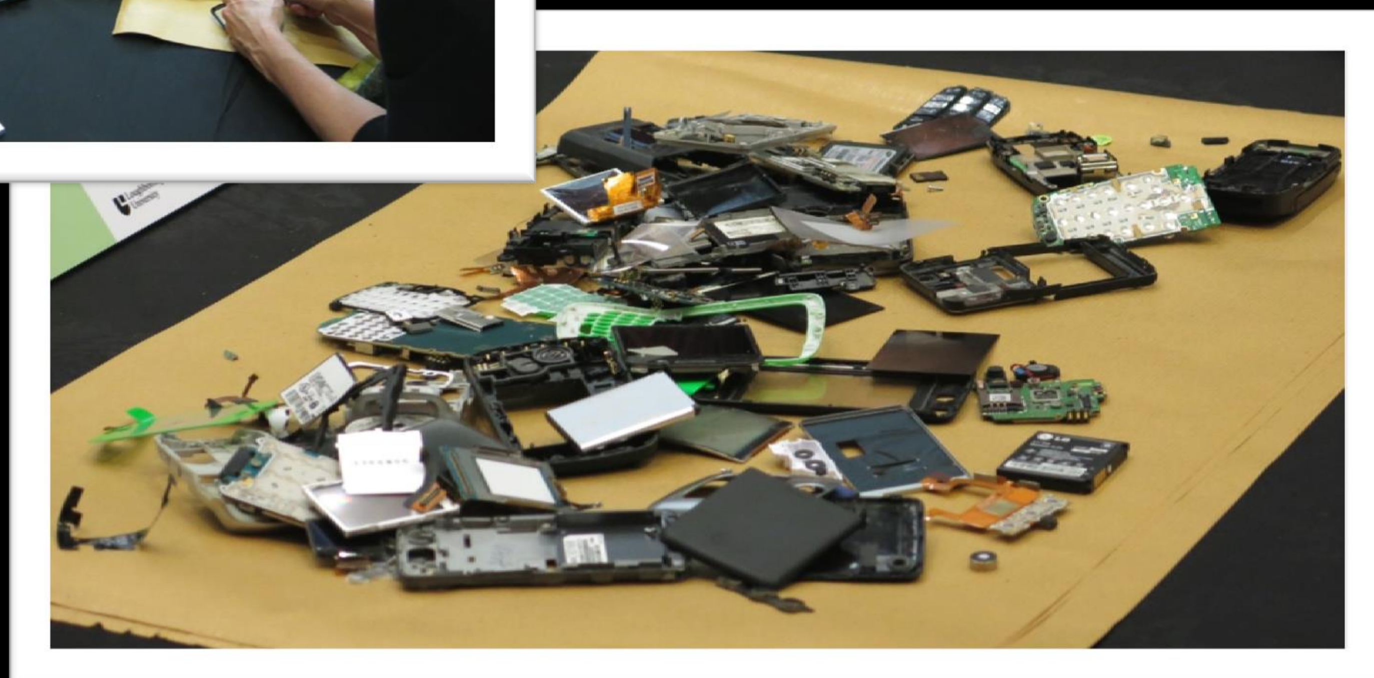
active disassembly
separate components
rejected components
???
decompose, skeleton
valuable components & elements
recover valuable metals
recover valuable parts





Required: a way to separate the “organs” from the “skeleton”

Some possibilities:

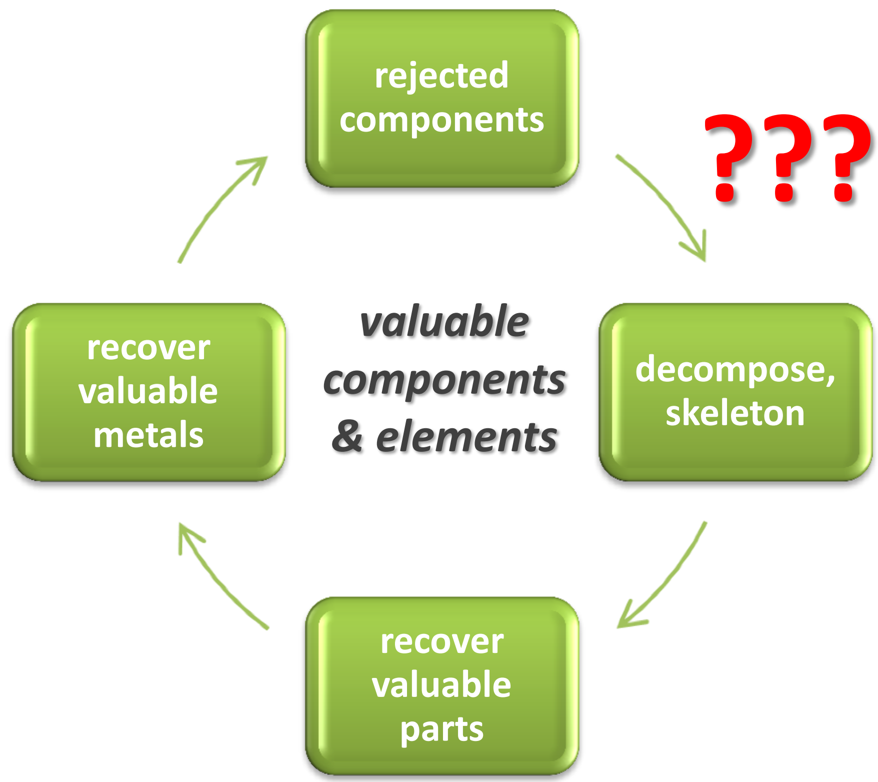
National Physics Laboratory: dissolving circuit board … “just add hot water”, 2012

Transient Silicon Electronics, S-W. Hwang *et al.,* Science, 2012, **337**, 1640-1644.

Support requirements

- Robust
- Rigid / flexible
- Non-conductive
- Non-flammable
- Smooth
- Printable
- Processible
- Degradable (triggered)

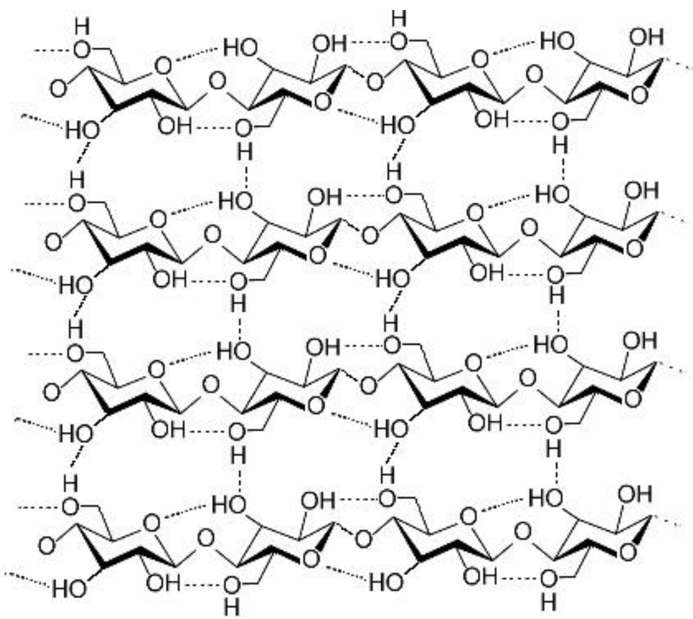
… CHEAP!



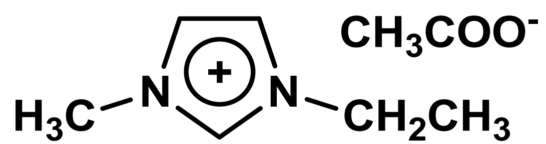
Required: supports that are robust in use, but degrade when triggered

CELLULOSE
total volume: 7×10^{11} *t*
renewed annually: 4×10^{10} *t*
feedstock use p.a.: 1×10^{8} *t*

Cellulose processing



crystalline / hydrogen-bonded
insoluble

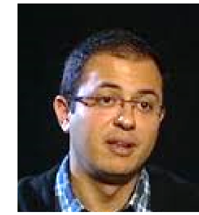


ionic liquids may be used
to dissolve cellulose

Highly desirable properties, but difficult to process

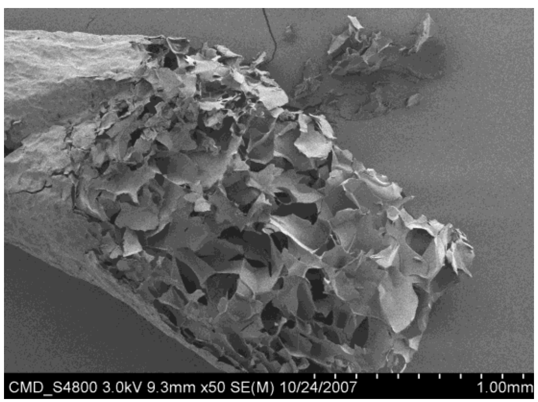
Cellulose processing using ionic liquids

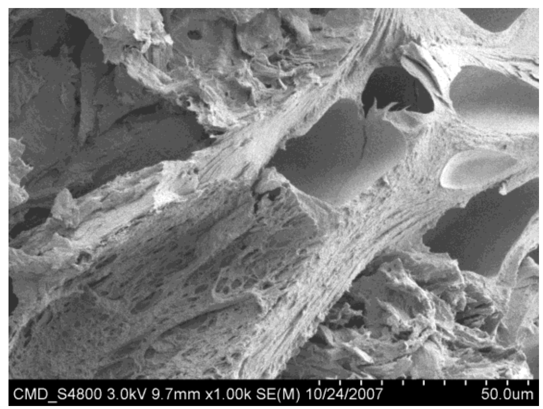
Rinaldi: instant dissolution of cellulose in organic electrolyte solutions[3]

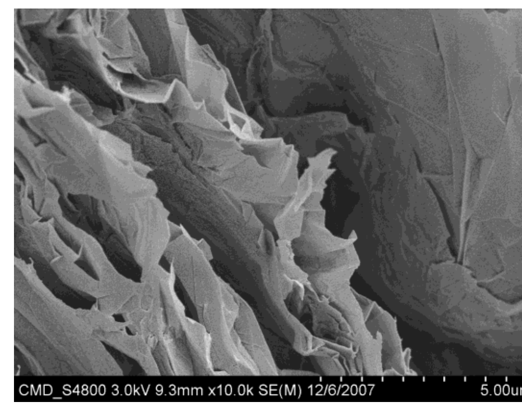


Rogers: dissolution of cellulose in ionic liquids[1,2]

Scott *et al*.: traceless ionic liquid foaming agents and cellulose composites[4]

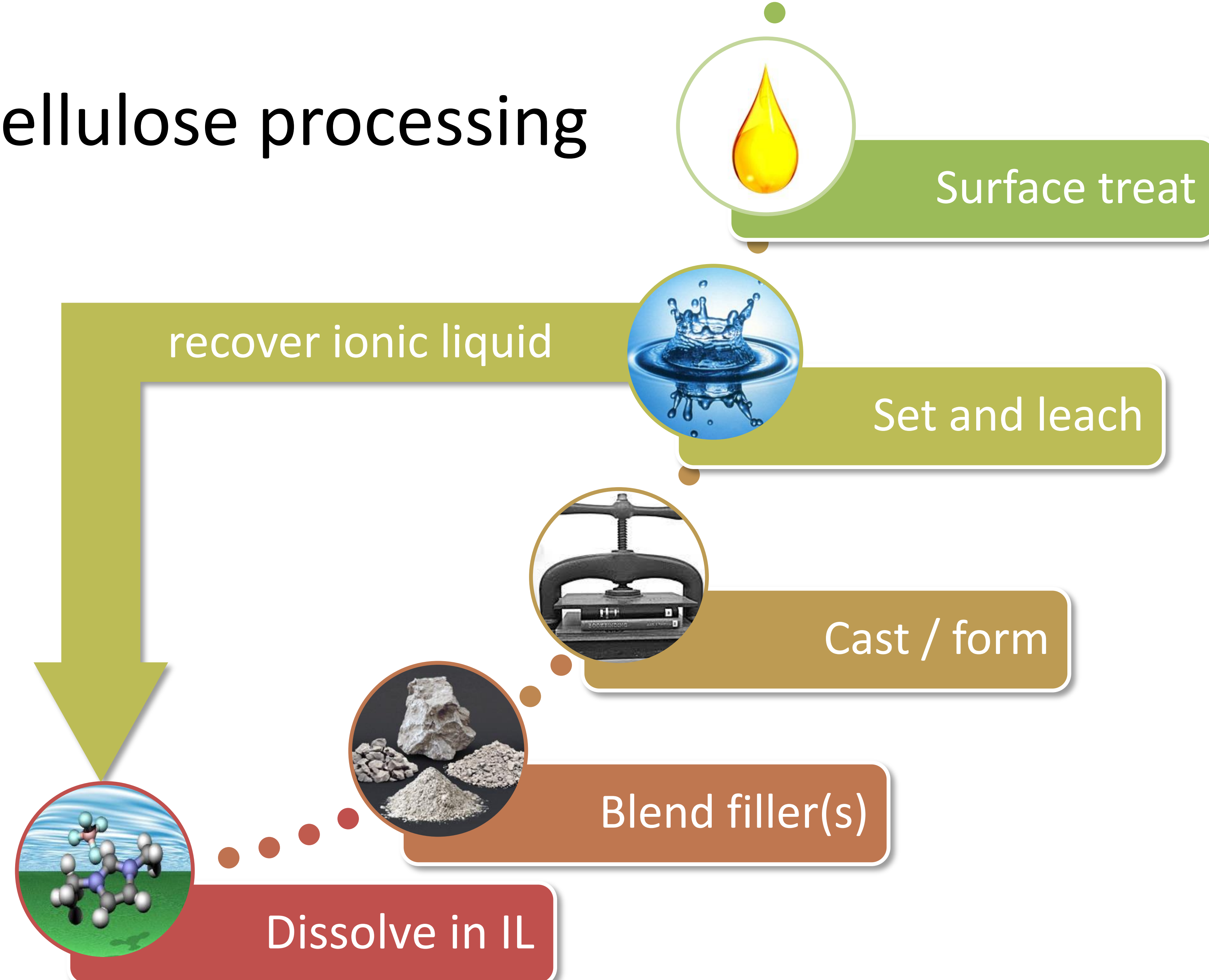




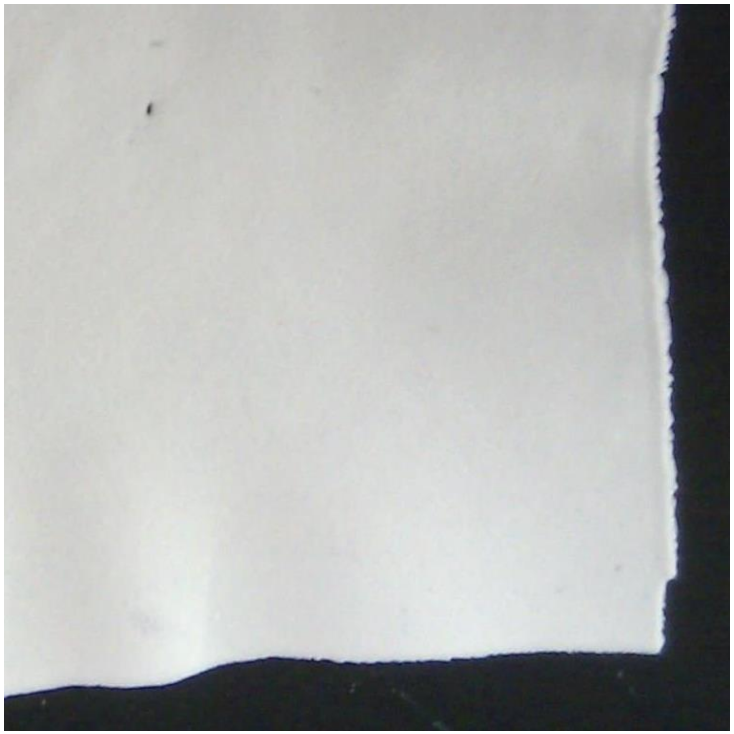


1. R. P. Swatloski, R. D. Rogers, J. D. Holbrey, WO03029329, 2003; US6824599, 2004
2. R. P. Swatloski, S. K. Spear, J. D. Holbrey, R. D. Rogers, *J. Am. Chem. Soc*., 2002, **124**, 4974-4975.
3. R. Rinaldi, *Chem. Commun*., 2011, **47**, 511-513.
4. J. L. Scott, G. Unali, A. Perosa, *Chem. Commun*., 2011, **47**, 2970-2972.

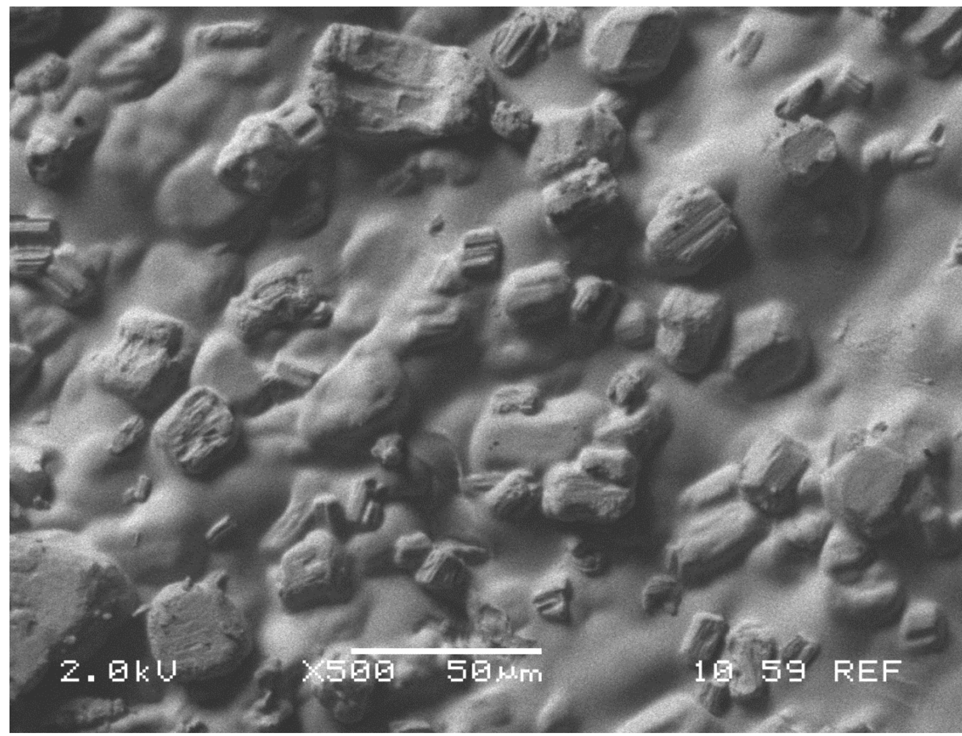
Cellulose processing



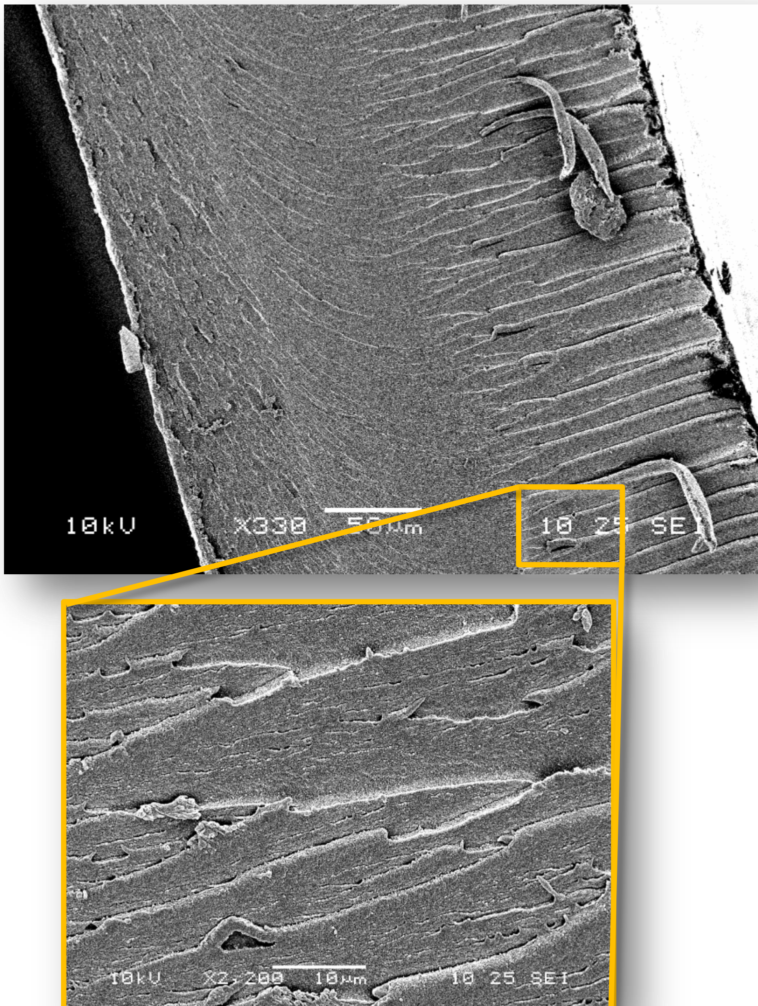
Cellulose films - fire retardant fillers



Cellulose based film containing an inorganic filler (1:1 cellulose: filler) cast from an ionic liquid/solvent solution

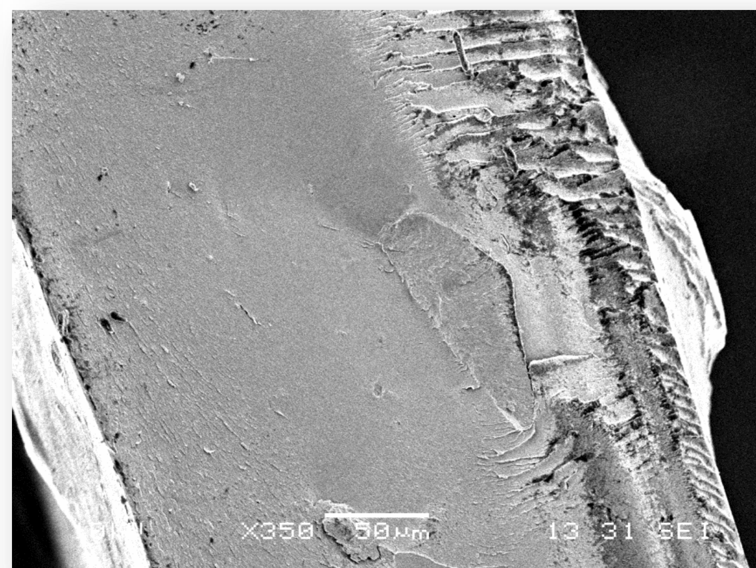


Cellulose films - fire retardant fillers

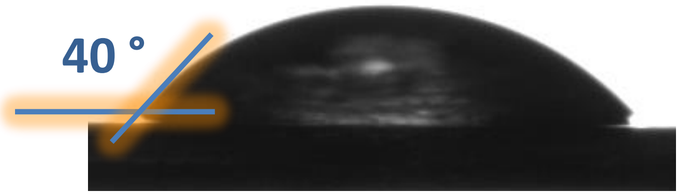


Cellulose film from 15 wt % solution in ionic liquid (cross section)

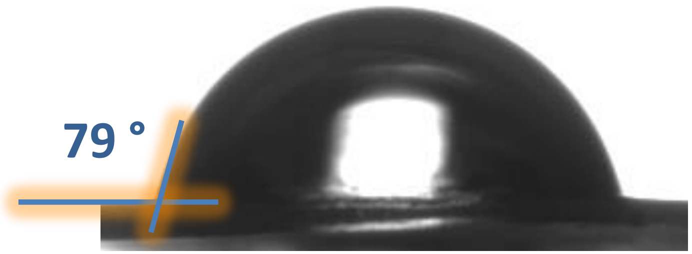
Cellulose film with 15 % filler from 15 wt % solution in ionic liquid (cross section)



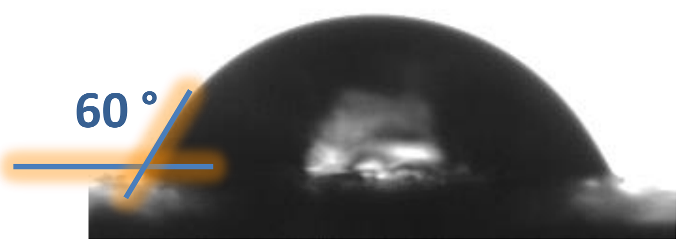
Cellulose films – interaction with H_2O



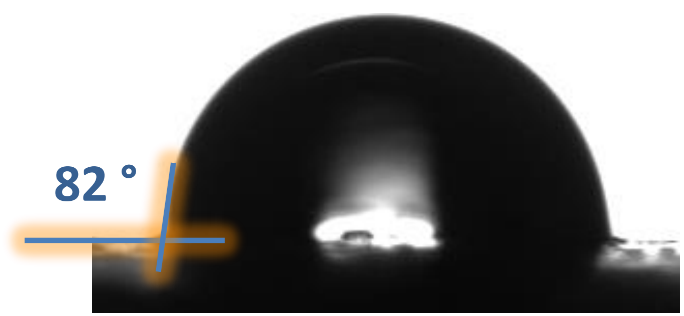
Cellulose film



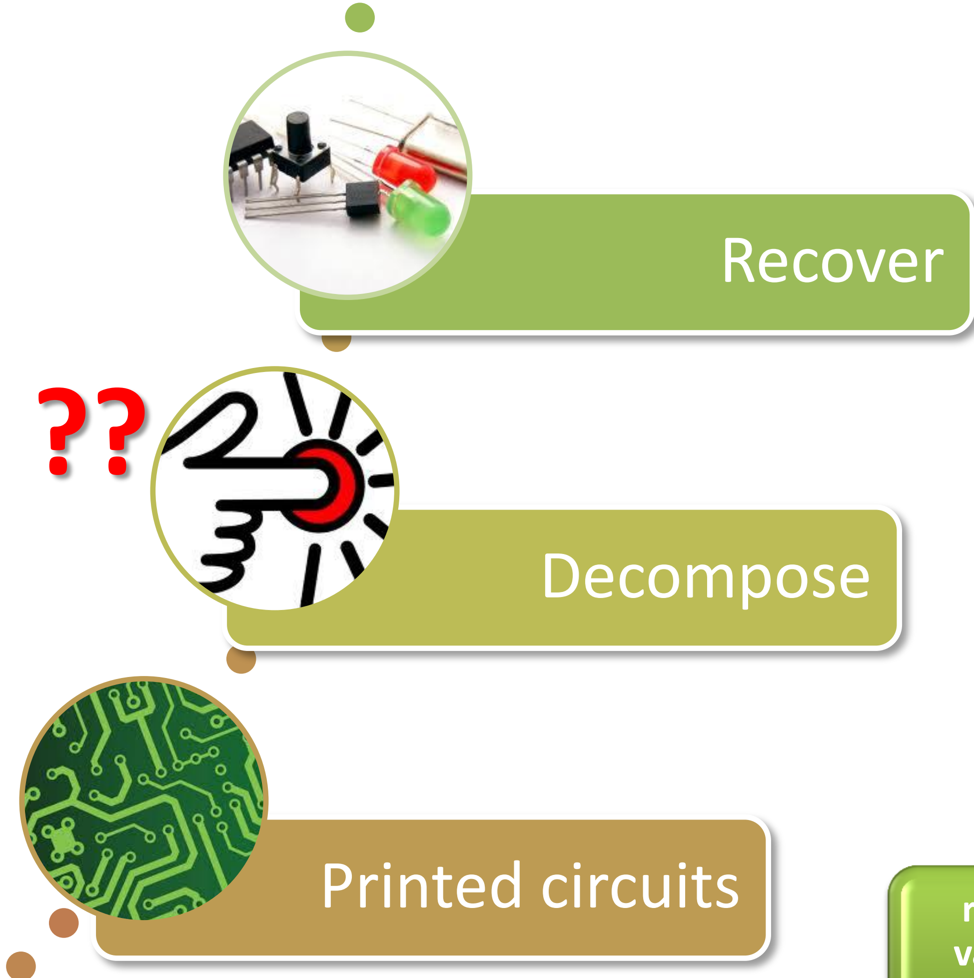
Cellulose film
coated with hydrophobising agent

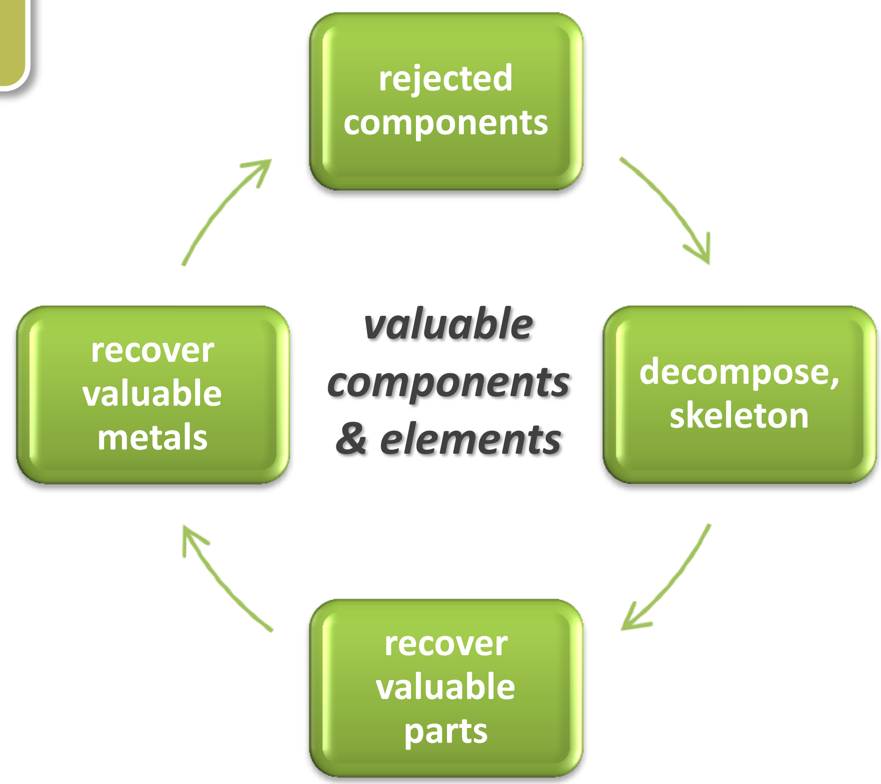


Cellulose film
+ 10 wt % filler



Cellulose film
+ 10 wt % filler
coated with hydrophobising agent


Recover
??
Decompose
Printed circuits


rejected components
decompose, skeleton
recover valuable parts
recover valuable metals
valuable components & elements

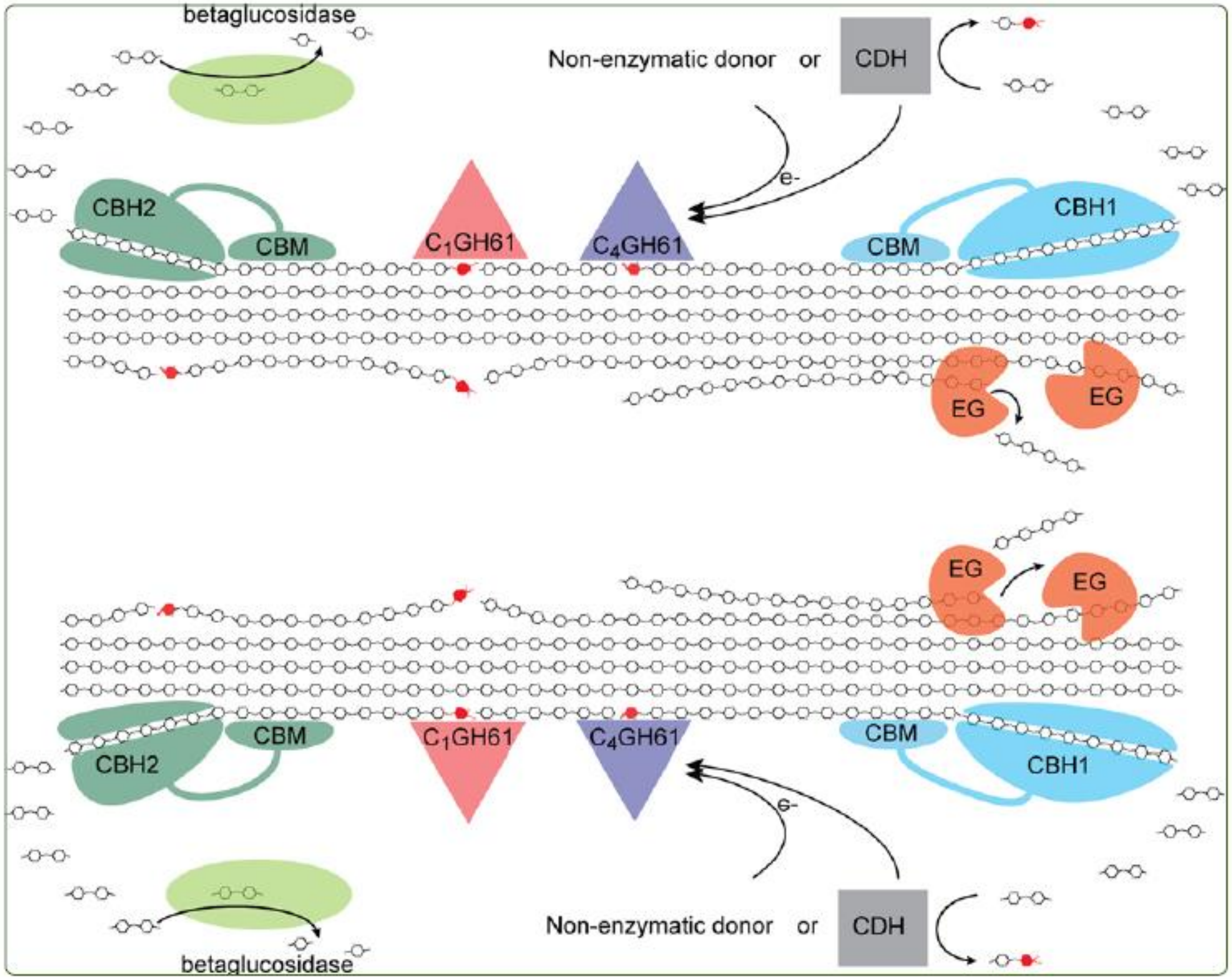
Enzymes as the trigger

- 2^{nd} Generation biofuel development is driving discovery and development of enzymes and enzyme combinations for saccharification of cellulose
- Even enzyme cocktails that do not effectively produce simple sugars may be useful for triggered degradation of materials

Do not reinvent the wheel, but use it!

Novel enzymes for the degradation of cellulose[1]

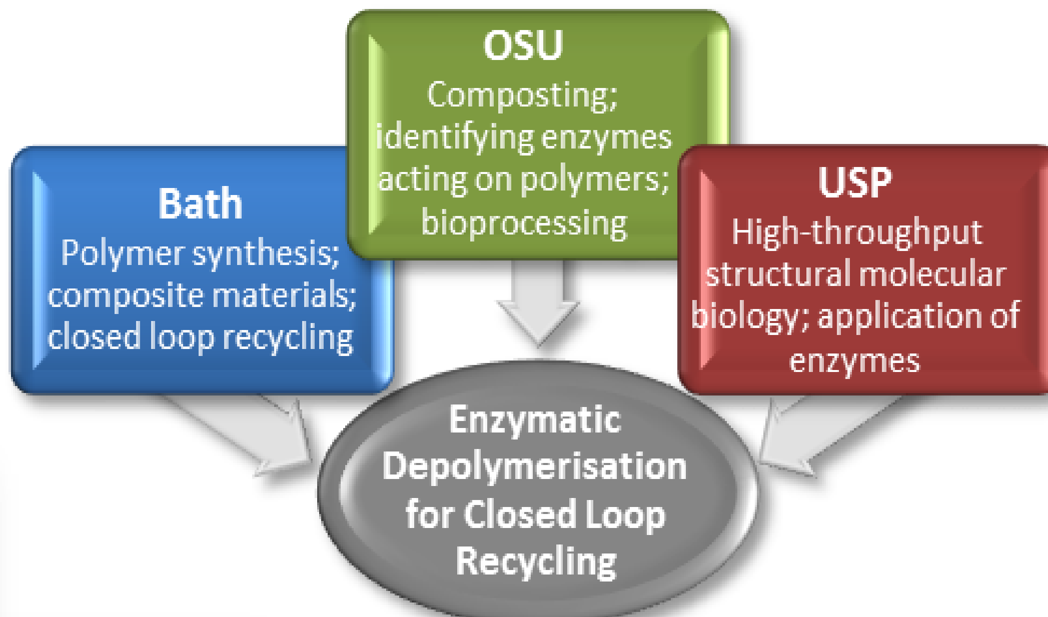
Biotechnology for Biofuels



1. S. J. Horn, G. Vaaje-Kolstad, B. Westereng, Bjorge; V. G. H. Eijsink, *Biotechnol. for Biofuels*, 2012, **5**, 1-12; http://www.biotechnologyforbiofuels.com/content/5/1/45

Global Innovation Initiative

Transatlantic discovery, characterisation and application of enzymes for the recycling of polymers and composites



CLEVER Team

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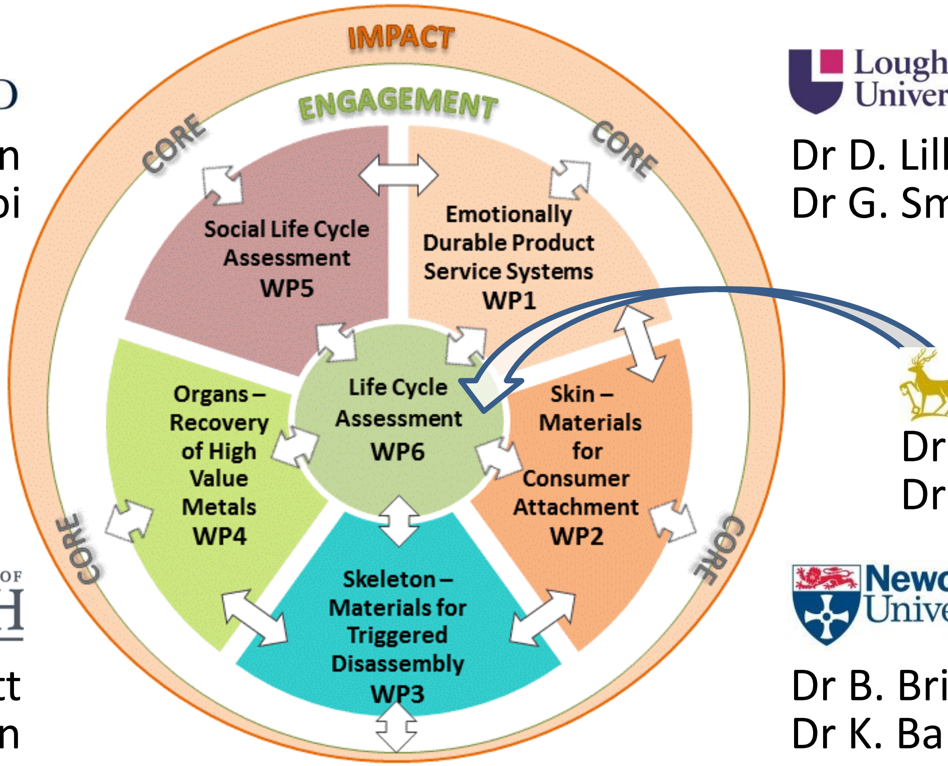
Dr S. Choi



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