



The need for design-for-recycling of paper-based printed electronics – a prospective comparison with printed circuit boards

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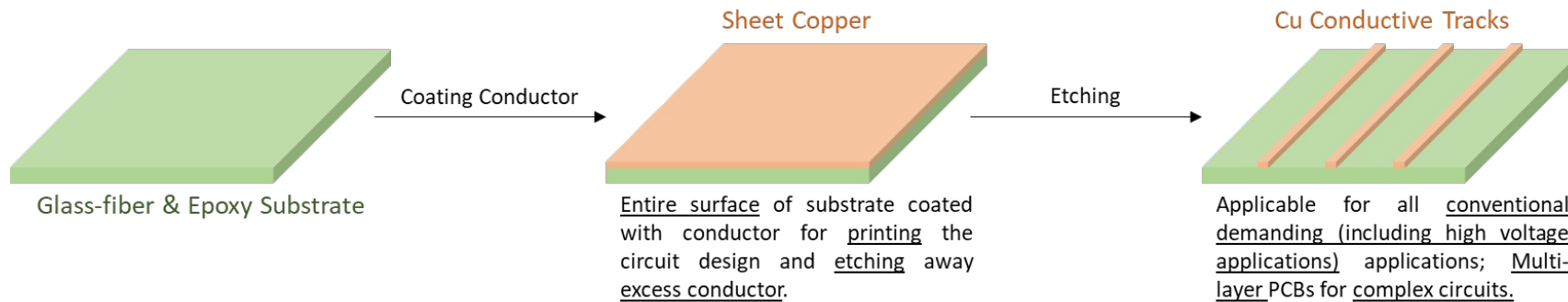
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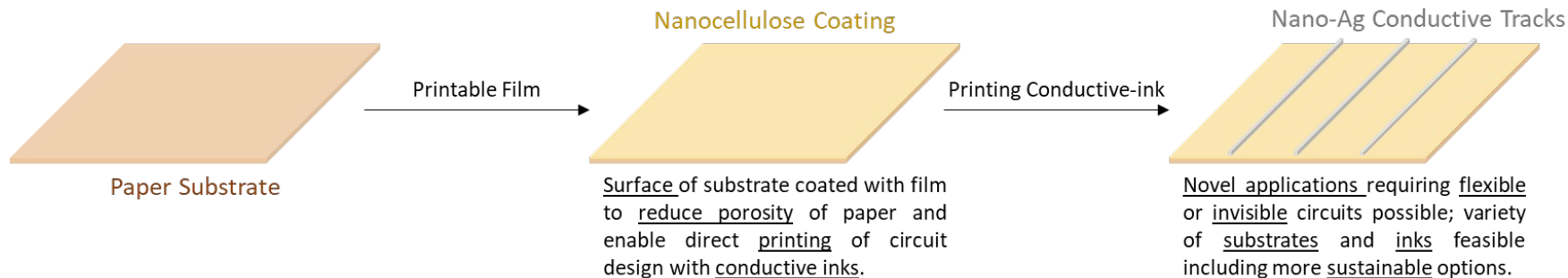
Paradigm Shift in Electronics

Novel Printed Electronics

• **Subtractive** Circuit Manufacturing of Conventional **PCBs**



• **Additive** Circuit Manufacturing of Novel **PEs**



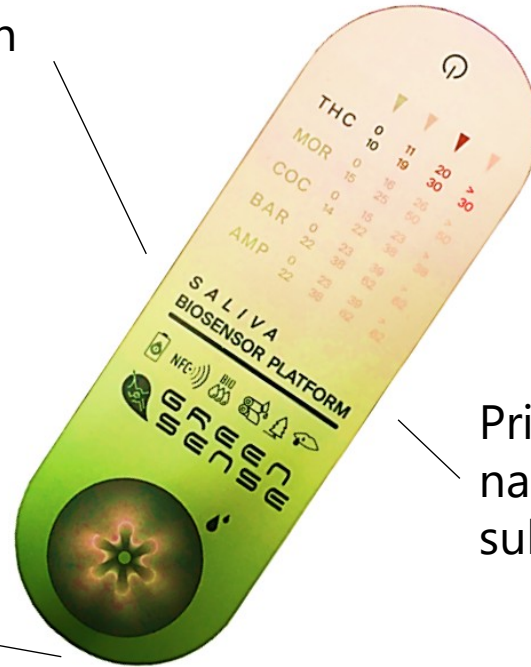
• **Benefits:**

- Material efficiency during manufacturing
- Elimination of chemical etching
- Flexibility in substrate selection (biodegradable and bio-based)
- Monolithic integration of components
- Elimination of BFRs

Envisioned Applications

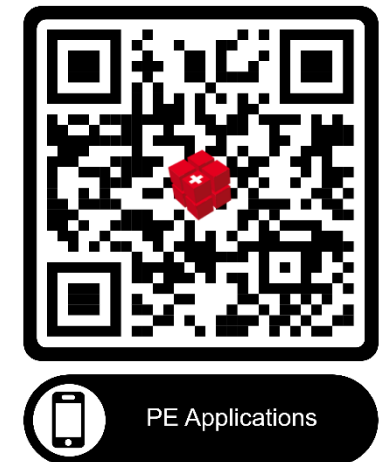
GREENSENSE

Quantitative drug-detection system



Biofluids (saliva) for biosensing

Printed electronic system with nanocellulose coated paper as substrate

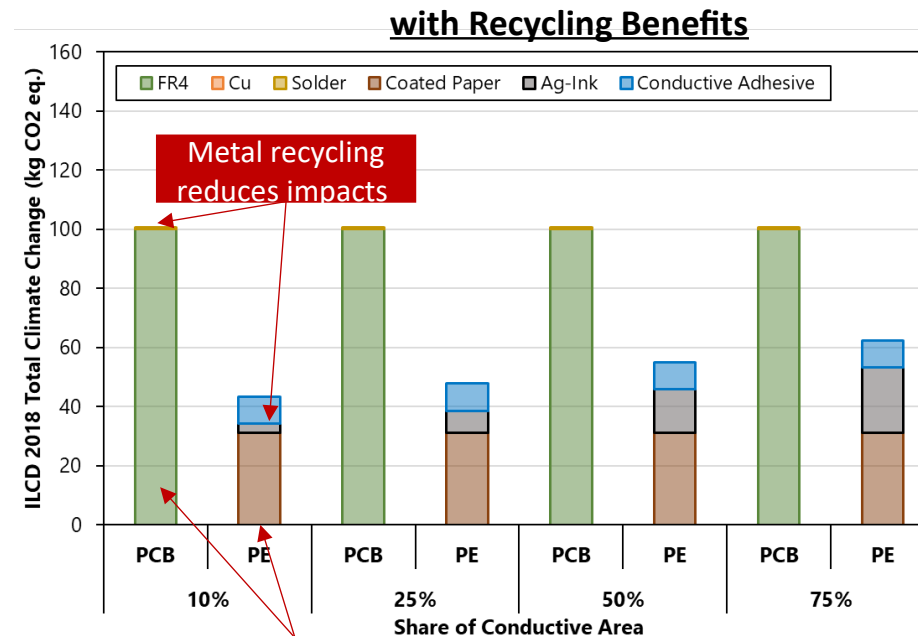
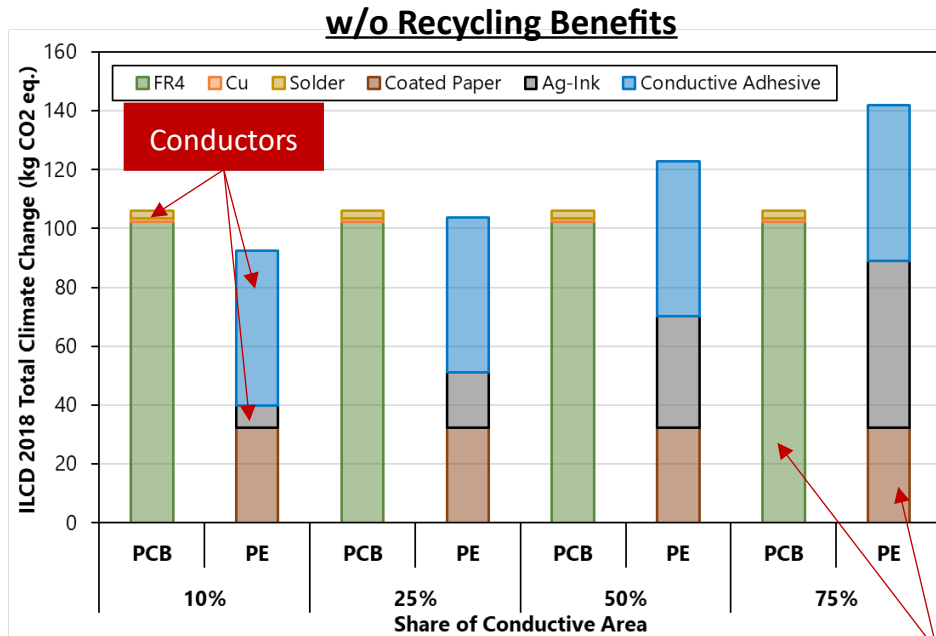
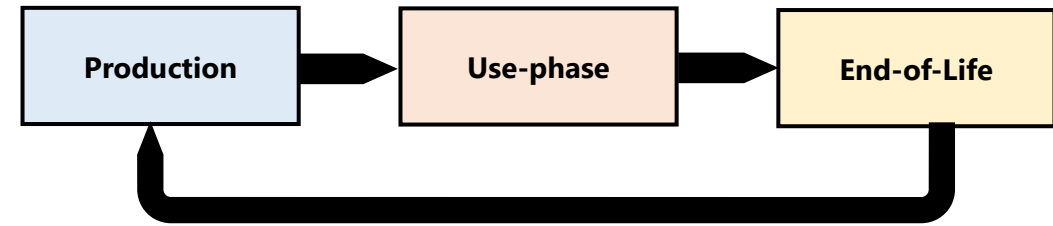


General Applications: low voltage applications in environments with lower humidity (clocks, radios, computer mice, keyboards, etc.)

Environmental Impacts

PE vs. PCBs

- Cradle-to-grave (and cradle assessment)
- Metals (Cu, Ag) recycled in a closed-loop and benefits from recycling included



- Use of recycled metals in the production or ensuring that the materials are recycled
- Consistent sustainability advantage
- Design-for-recycling should be emphasized because of Ag dependence = no composting



- No advantage after conductive area exceeds 25%

Substrates
Substrates impacts unchanged as not recyclable

Conclusion

Takeaways

- Biodegradable and biobased PEs developed to tackle problem of persistent WEEE
- Replacement of glass-fiber and epoxy substrate sensible where feasible
- Mismanagement of waste PEs detrimental to their (relative) environmental performance
- E-waste recycling systems should be considered during development of novel electronics



Thank You

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