The 3 D's for recycling of flexible packaging films – Deinking, Dissolution & Delamination

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Technological impediments for recycling of flexible packaging

- Mechanical recycling predominant method for recycling of post-consumer flexible packaging (others - incineration, fuel in cement kilns & steel mills, waste to energy, pyrolysis)
- Output --- substantially downcycled material not re-usable in flexible packaging

Limitations of mechanical recycling for flexible packaging films

- Unable to handle multilayer films with different polymers / materials in each layer

  Different polymers not compatible (melting points) ---- poor mechanical properties
- Unable to process printed films ---- Residual ink causes discoloration, VOCs (odours), pigments cause oxidation & degradation products (not fit for food contact applications)
- Contamination (label, paper, metal, microbial) --- batch to batch variability
- Repeated thermal cycles (extrusion) --- degradation of polymer mechanical properties
- Buildup of additives (antioxidants, heat & light stabilizers, UV absorber, O_2 scavengers), Non-Intentionally Added Substances increases with each cycle

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Possible Technical Solutions

- Hybrid Mechanical – Chemical Recycling
- The Three D's (De-inking, De-lamination, Dissolution)
- These are practical, do-able solutions with available technologies
- **De-inking** - removal of surface printing using hot friction washing using specialized surfactants. Highly promising for surface printed mono-materials (example & success story are Milk Pouch & Bread Bags; > 95% removal of surface printing)
- De-inking is a norm in the paper recycling industry (aim for plastic ind. to emulate)
- Milk Pouch & Bread Bags are the largest source of food grade LDPE / LLDPE post-consumer waste in India
- Domestic Milk production 230.58 million tons in 2022 – 23
- Domestic sliced bread production 9.56 million tons in 2022
- Successfully used for Non-food surface printed mono materials waste --- printed PP raffia bags, FIBCs, printed PP non-woven carry bags etc.

- Targeted Dissolution of polyolefins in solvent to extract relatively pure polymer. Highly promising for multilayer films like PET / PE, Paper / AL / PE, barrier films like PE / PA / PE (where the polyolefin – PE can be targeted & dissolved)
- Solvent extraction of edible oils (preferential dissolution of oils from oilseeds using solvents like n-hexane ---- 310 plants in India)
- Consider a common flexible packaging --- PET + PE: solvent will selectively dissolve PE layer, and the PET fraction is filtered out. PE is precipitated by anti-solvent / cooling / supercritical CO_2. PE fraction is filtered off and the solvents are recovered for further use by distillation.
- Solvents are handled by domestic chemical industry in thousands of tons daily.
- Delamination: Mechanism: weak alkali / acid diffusion through polymer layers leading to partial dissolution of adhesives followed by mechanical friction to physically separate them.
- Organic solvents --- swelling of tie layers --- mechanical friction --- separation
- Micro-perforations improve delamination rates by decreasing the time for process to occur. Promising for structures like PET + AL + PE, MET PET + PE etc.