Supplementary material

S1 Highlights

In general, the SME is the comparison of the dimension between 'shaper I' and 'shape 1'. The technique that is mostly used for the manufacturing of the 3D structures is FDM. This technique is cost-efficient, easy to process, easy to fabricate, and also provides fewer materials wastage.

Hence, the literature survey revealed that PLA is one of the most used thermo-responsive materials in different applications (actuator, biomimetic tissue engineering, and smart textiles) by 4D printing. Also, ABS is one of the most used materials in FFF-based 3D printing processes. Most of the previous studies for ABS-PLA composite with mechanical, thermal, chemical, and morphological properties investigations. But hitherto, very fewer studies have been reported for the ABS-PLA combination as the thermoresponsive materials to be used by 4D printing in self-assembly applications. In this study, the PLA has incorporated in ABS matrix from 5 to 25% (weight %), and composites were made by extrusion in form of cylindrical filaments for 4D printing. The tensile, and shape memory properties of ABS-PLA composites were investigated for the selection of the best combination.

Usually, 3D printing is one of the plastic recycling processes which delivers the mechanically sustainable product and may be used for 4D printing applications such as; self-assembly, sensors, actuators, and other engineering applications. The better success and implementation of the 4D printing is dependent upon the tendency of the shape memory with the action of external stimuli such as; heat, force, fields, light, pH, etc. Acrylonitrile butadiene styrene (ABS) is one of the most common materials for fused filaments fabrication (FFF) based on 3D printing. However, low shape memory tendency on heating, weaker and less rigidity of ABS limits the applications domains. Polylactic acid (PLA) is an excellent responsive behavior on the action of heat which has high stiffness. The incorporation of PLA in ABS is one of the solutions to tune the shape memory effect for better applicability in the 4D printing domain. In this study, the primary recycled PLA has incorporated in the primary recycled ABS matrix from 5 to 25% (weight %), and composites were made by extrusion in form of cylindrical filaments for 4D printing. The tensile, and shape memory properties of recycled ABS-PLA composites were investigated for the selection of the best combination. The results of the study are supported by fracture analysis by scanning electron microscopy (SEM) and optical microscopy. This study revealed that prepared ABS-PLA-based composites have the potential to be applied in self-assembly applications.

Therefore, results revealed that increasing the amount of the primary recycled PLA in the primary recycled ABS matrix leads to an increase in the MFI of the ABS-PLA composite matrix. Thus, the addition of the PLA in the ABS matrix has increased the acceptability of the composite feedstock filaments. The MFI of ABS-40%PLA (31.48 $g \cdot min^{-1}$) was observed highest among composites. Above loading of 20% (by weight %) primary recycled PLA in ABS, the tensile strength was started decreasing as reinforcement of PLA was increased. This trend in reduction of tensile strength was followed up by a 40% loading of PLA in ABS. In the case of 25% loading of PLA in ABS (ABS-25%PLA), the percentage elongation was observed highest among all. The results of the tensile properties were obtained inline and comparable with the tensile properties reported in previous studies. Most importantly, SME of the ABS-20%PLA and ABS-25% PLA were obtained almost similar to primary recycled PLA. However, the elongation properties of ABS-25%PLA are better than primary recycled ABS, so it may be useful for extended applications.