This research utilizes self-similar microstructures of chaotic mixing to obtain unusual morphological forms in the blending of miscible and immiscible polymers and polymers with micro- and nanoscopic fillers.

In our research chaotic mixing is produced by application of piecewise shear flows. Nevertheless, the overall mixing progresses at exponential rates, reminiscent of unbounded extensional flows. The repeated stretching and folding of material interfaces and alignment of material interfaces along the direction of local stretching are responsible for such exponentially rapid mixing. Other unique features of chaotic mixing are self-similarity of mixing microstructures which are produced and retained in the mixed materials. Many of these morphologies have not been seen previously in conventional blending in single and twin-screw extruders. Some wholesome attributes of chaotic mixing as highlighted by our work are listed below:

(1) A minor polymer component can be rendered into high aspect ratio (>1,000) fibrils by chaotic mixing (Figure 1). Such structures augment dimensional stability of the blend materials and produce electrically conductive networks by double percolation. For example, a composite of 90 parts polyamide 6 (PA6) and 10 parts polypropylene (PP) is made electrically conductive with volume electrical conductivity of $\sim 10^{-3}$ S/cm by using only 1 wt% Ketjenblack 300J carbon black (CB). Note that typically 20-30 wt% CB are needed to make PA6 electrically conductive. In this case, primary percolation of CB occurs in the PP-phase and secondary percolation is achieved due to continuous PP fibrils containing CB particles in major phase PA-6. Note, however, that such electrically conductive networks are produced only in flow direction and the blend does not conduct electricity in the thickness direction.

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(2) The fibrillar structures in Figure 1 break down by capillary instability upon further mixing and produce much smaller droplets compared to those found in conventional mixers and much smaller than those permitted by the equilibrium between interfacial and viscous forces. An analysis of flow kinematics in the chaotic mixer revealed negligible extensional flow component. Thus one would expect poor droplet deformation for polymer systems with viscosity ratio greater than ~4. However, our experiments on immiscible polymers with viscosity ratio varying between 1 and 30 show that droplet formation is possible at viscosity ratios higher than 10 due to a different pathway of breakup – lamella to fibrils to droplets. This is different from the well-studied droplet to fibrils to droplets pathway for breakup in emulsions.
Figure 1. Fibrillar morphology of PP-phase created by chaotic mixing of 10 wt% PP in PA6.

Publications:


7. Sau, M., Jana, S.C. 2003 A study on the effects of chaotic mixer design and operating conditions on the development of morphology in immiscible polymer systems. SPE ANTEC, 61, 1556-1560.


ANTEC 2002 Proceedings, 60, 1436-1440.


(3) We found that droplets are stable against coalescence in the flow field of chaotic mixers. The 
chaotic trajectories of droplets deter coalescence due to frequent reorientation of the shear 
direction. Thus finer droplet morphologies generated by chaotic mixing are further stabilized 
against coarsening and coalescence due to the chaotic trajectories of the droplets. This attributes 
can be used in injection molding with the aid of chaos screws.

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AIChE J., 51(10), 2675-2685.
flows on coalescence in blends of polypropylene and polystyrene. SPE ANTEC 62, 2819- 
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