



**Figure 5.4** Schematics of hydrodynamically stable flow patterns of a gas (white color) and liquid (darker color) mixture in a horizontal round tubing. The notations and images of the flow were based on Ullmann and Brauner<sup>15</sup> and Jiang *et al.*<sup>2</sup> The air and liquid in slug flow can swap places depending on the affinity of the liquid for the material on the inner surface of the tube, *e.g.*, a water slug with a strongly hydrophobic surface would appear as shown, with convex/roundish water slugs moving through the tube. For a strongly hydrophilic surface with water as the liquid, the air slugs would be convex. Regardless of surface affinities, the slugs become asymmetric at sufficiently high velocities. Stratified flow regimes are not shown due to their absence for  $U_{LS} > 0.01$  when  $D \leq 0.004$  m.

### 5.2.2 Hydrodynamically Stable Regime Analysis for Slug Flow

Among the stable hydrodynamic regimes identified for gas–liquid flow (Figure 5.4), two suitable for crystal growth are the short-bubble slug flow (SB-slug) regime and the elongated-bubble slug flow (EB-slug) regime, and it is possible to operate in either. In mapping out the hydro-dynamically stable regions, experimentalists have made numerous observations at various values of  $U_{GS}$  and  $U_{LS}$ , the superficial velocities of the gas and liquid phases, respectively (the superficial velocity is the volumetric flow rate divided by the total cross-sectional area in the tube). Figure 5.5 gives a flow region map for an air–water mixture flowing through a 0.0031 m i.d. tube. The transition boundaries dividing up the map were generated by using relations advocated by Ullmann and Brauner.<sup>15</sup> The work by Ullmann and Brauner was a follow-up to that started by Taitel and Dukler,<sup>16</sup>