Supplementary materials

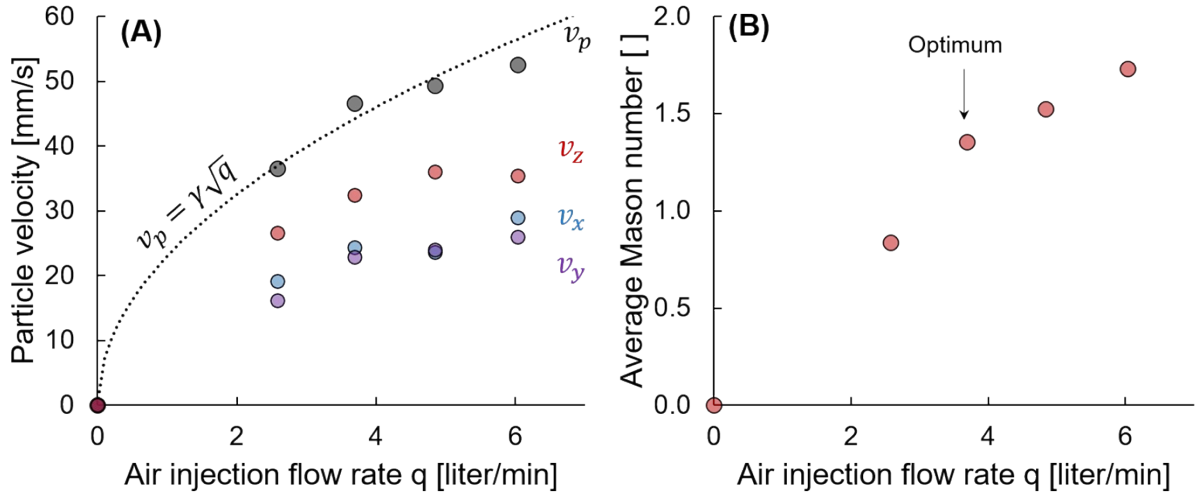


Fig. S1 Particle dynamics: **(A)** average particle velocity v_p in the large bubble-column reactor determined using particle image velocimetry $v_p = \sqrt{v_x^2 + v_y^2 + v_z^2}$. Dashed line: $v_p = \gamma\sqrt{q}$. **(B)** Average Mason number $Mn = \frac{F_D}{F_M}$ as a function of air injection flow rate q, where $F_D = \frac{1}{2} C_D (v_{rel})^2 \rho_f A$ and F_m [N] is measured experimentally to be 0.0053(x/mm)$^{-3}$, where x is the separation distance between the two magnets. The dipole-dipole interaction force F_m in the figure was calculated based on a separation distance of one rod particle thickness (x=6mm). The drag coefficient is C_D=0.82 and the rod cross-sectional area is A=6mm x 6mm. We assume that the particle relative velocity v_{rel} is equal to the average particle velocity v_p.

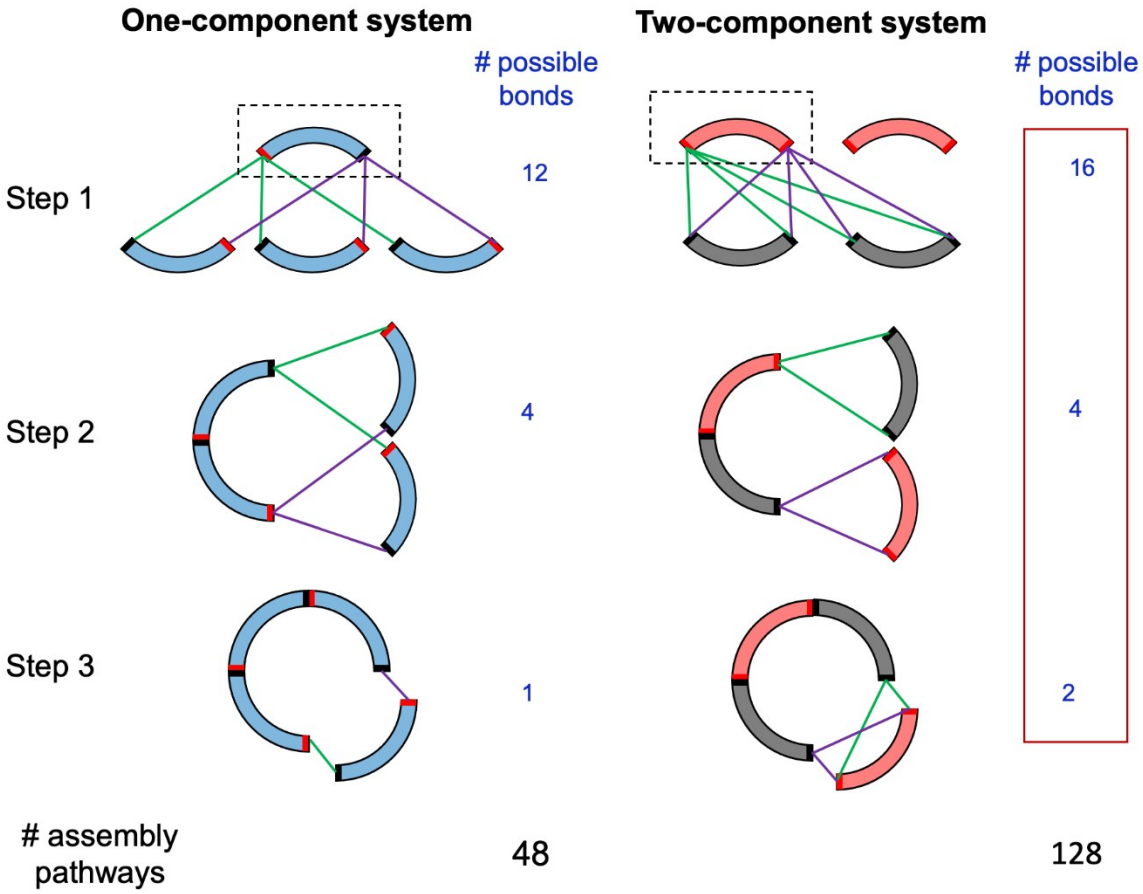
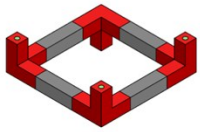
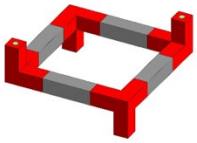
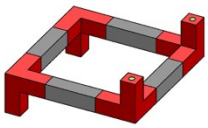
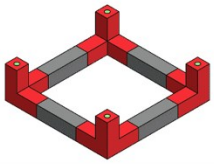


Fig. S2: Assembly pathways for one and two-component circles. Red and black poles have opposite polarities. The green and violet lines indicate possible bond pairs.

Table S1: Probability of the self-assembly of 4 tripods and 4 rods into the initial nucleation structures (Fig. 2). Each tripod can have one of two possible orientation: UP (U) or DOWN (D). There are 2^4=16 possible combinations.

Structure	**Structure 1**	**Structure 2**	**Structure 3**	**Structure 4**
Topology				
Possible combinations	DUUU UDDD UDUU DUDD UUDU DDUD UUUD DDDU	DUDU UDUD	UUDD DUUD DDUU UDDU	UUUU DDDD
Probability	8/16	2/16	4/16	2/16