Electronic Supplementary Information

The polymers in the training set were represented in terms of approximate mole fractions of the functional groups with additional architecture variables of crosslinked vs. linear, which are tabulated in Table S1. This represents the simplest approach to parametrization of composition but is a well established method.[1]

Polymer /Group	Sulfonate	Carboxylate	PEG	Alkyl	Aromatic	PEO	X-link	Linear
PC		0.5		0.5				1
Napthalene	0.5				0.5			1
LS	0.33			0.34	0.33		1	
LSPEG	0.25		0.25	0.25	0.25		1	
KL		0.33		0.34	0.33		1	
KLPEG		0.25	0.25	0.25	0.25		1	
PEO						1		1
PSS_PEGMA	0.25		0.25	0.25	0.25			1
PCE Adva		0.33	0.33	0.34				1
PSS	0.33			0.34	0.33			1

Table S1. Representation of the polymers in the training set in terms of mole fractions of functional groups.

Experimental measurement of polymer solution viscosity and osmolality were taken at concentrations up to 1%. The results were fit to Eq. S2 and S3 to calculate specific polymer contributions to each single-physics interaction. Dilute suspensions containing 10% MgO (compared to 70% for the slurries) were prepared with the dispersant concentrations up to 1%, and zeta potential and sedimentation were measured and fit to Eq. S4 and S5 to determine the specific polymer contributions to these single-physics interactions. The results of these, along with the estimate for MgO coverage θ at 1% polymer are shown in Table S2.

Polymer/ Interaction	Polymer viscosity	Polymer A2	Polymer electrosteric	Polymer zeta potential	Polymer theta
PC	5709.20	-2.81	-210.18	-36.23	0.55
Napthalene	4585.60	-0.29	-961.73	-44.93	0.10
LS	11327.17	-1.66	-10672.12	-53.97	0.13
LSPEG	3124.93	2.67	-268.17	-47.67	0.49
KL	16608.07	-5.33	-14794.64	-50.43	0.25
KLPEG	2900.21	-2.10	-1575.03	-43.00	0.21
PEG	3911.44	3.55	-262.13	-7.88	0.13
PEGMA-PSS	7169.87	-6.49	-476.01	-20.00	0.38
PCE Adva	3686.72	5.84	-2025.87	-12.13	0.21
PSS	5484.48	-1.45	-166.66	-26.00	0.65

Table S2. Specific contributions of the polymers in the training set to single-physics interactions.

Least squares estimation was performed in MATLAB to calculate the contributions per functional group on each of the specific polymer properties, and the results are tabulated in Table S3. This parametrization provided a general map between composition and single-physics interactions.

	viscosity	A2	electrosteric	zeta	theta
Sulfonate	-18572.60	26.04	13844.11	-73.49	-0.38
Carboxylate	-6106.94	12.02	678.24	-58.49	-0.67
PEG	-12063.68	7.03	12162.35	30.50	-0.05
Alkyl	15981.58	-14.29	-9074.76	22.15	1.18
Aromatic	23272.21	-28.41	-17710.33	13.32	0.21
PEO	1756.98	2.80	-1401.11	7.15	-0.07
Crosslinked	2113.08	4.45	-2640.47	-43.84	0.02
Linear	2154.47	0.75	1138.97	-15.03	0.20

Table S3. Contributions of functional groups to single-physics interactions based on mapping composition onto experimental measures of viscosity, osmolality, sedimentation, zeta potential, and adsorption.

References

1. D. W. v. Krevelen and K. t. Nijenhuis, *Properties of polymers : their correlation with chemical structure : their numerical estimation and prediction from additive group contributions*, Elsevier, Amsterdam, 4th, completely rev. edn., 2009.