Particle-specific design of a grafted copolymer enables highly-loaded ceramic inks for extrusion-based 3D printing

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There is a consensus, both from commercial suppliers and academia, on the need for precise calibration of interparticle forces to design ceramic inks for additive manufacturing. These forces determine the “printability” of the suspensions by exhibiting a direct effect on the rheological response of the system (e.g, shear thinning, fluid-to-gel transition). The current calibration of these forces relies heavily on electrostatic repulsion and achieves the desired levels by changing the pH of the medium, adding salt, and utilizing polyelectrolyte species as dispersants. Other coagulants, binders, defoamers, and organic solvents might also be present in the formulations, most of the time, in considerable amounts. However, i) organic solvents and other chemicals prevent the use of these inks in public space, ii) these solvents cannot provide the scalability and cost-effectiveness of water, iii) concurrent optimization of minimum 2 additives complicates the formulation of the ink, iv) having a high volume of additives raises questions on the precise dimensional control of the final object/feature and usually requires binder removal steps after printing, and v) current lack of systematic study for the formulation of the inks limits the type and nature of the nanoparticles that are to be used in these inks.

To design a single additive that can offer stability and viscosity-control, we utilized a grafted random copolymer by harnessing both electrostatic repulsion and steric hindrance. We systematically changed the charge, ionization capacity, and structure of poly(ethylene glycol) (PEG) grafted random copolymer of acrylic acid (AA) and 2-acrylamido-2-methylpropane sulfonic acid (AMPS), to reach almost theoretical particle loadings as calculated by Krieger-Dougherty equation. This particle-specific design of an additive enabled the realization of alumina inks with more than 80 wt. % particle loading with less than 1,25 wt.% use of a single additive. The optimization route that we report here has the potential to provide insights for the design of other ‘single additives’ and massively expand the limited portfolio and performance of ceramic inks for 3D printing.