Super-Resolution Imaging of Nanoscale Monomer Distribution in Copolymer Microgels

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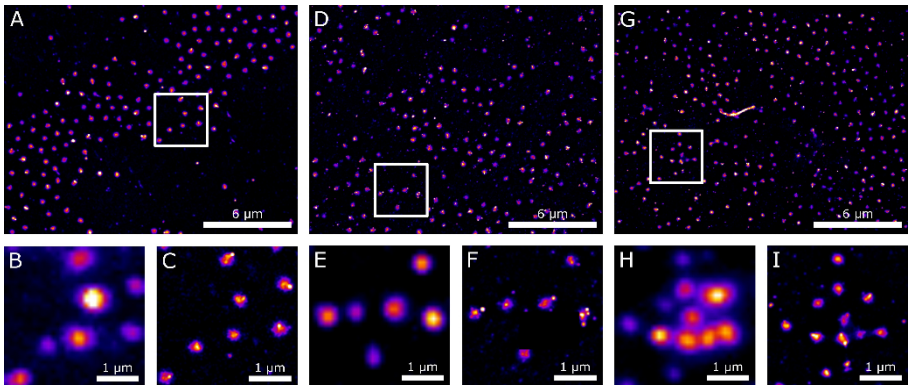
Microgels, three-dimensional polymer networks with colloidal dimensions, are promising candidates for catalysis, sensing, and drug delivery applications due to their responsive properties. Cationic copolymer microgels are particularly interesting, as they can be conjugated with biomolecules such as peptides, antibodies, or nucleic acids.[1] Poly(*N* -n-propylacrylamide-co- *N* -3-(dimethylamino)propylmethacrylamide) (Poly(NNPAM- *co* -DAPMA)) is one such microgel, exhibiting thermoresponsiveness through *N* - *n* -propylacrylamide (NNPAM) and pH responsiveness through *N*-3-(dimethylamino)propylmethacrylamide (DAPMA).[2]
In this study, the network structure of Poly(NNPAM- *co* -DAPMA) microgels was investigated using direct stochastic optical reconstruction microscopy (dSTORM), a high-resolution fluorescence technique that allows visualization of comonomer distribution at the nanoscale.[3] Microgels with varying DAPMA concentrations were synthesized and characterized for their swelling behavior using photon correlation spectroscopy (PCS), providing insight into size distribution and polydispersity. Morphological properties, including particle shape and surface topology, were examined using atomic force microscopy (AFM). Post-synthetic fluorescence labeling was performed using the anionic dye DY-654-carboxylic acid [4], which targets the cationic DAPMA units through electrostatic interactions. This specific dye-target coupling, combined with the photoswitching properties of DY-654-carboxylic acid, enabled the visualization of the internal microgel structure via dSTORM. The labeling revealed high fluorophore localization within the microgel core alongside distinct high-density domains, indicating a heterogeneous network with non-uniform comonomer distribution. These results demonstrate that the internal architecture of cationic microgels is more complex than previously assumed, and that dSTORM can provide quantitative and spatially resolved information on functional polymer networks. Such insights are crucial for the rational design of microgels in catalysis, drug delivery, or biosensing applications, where network structure strongly affects performance and interaction with biomolecules.

Keywords:
Smart Microgels, Labeling, Monomer Distribution, Fluorescence Microscopy, Super-Resolution Imaging, dSTORM, 3D Density



dSTORM of NNPAM microgels with varying DAPMA content. All microgels labeled with DY-654-carboxylic acid. (A-C) 5 mol%, (D-F) 7.5 mol%, (G-I) 10 mol% DAPMA. (A, D, G) Large dSTORM FOVs; (B, E, H) Wide-field ROIs; (C, F, I) Corresponding dSTORM ROIs showing structural heterogeneity.

References:

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