

Tuning Conjugated Polymer Nanoparticles for Fluorescence Imaging and Sensing Applications

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Recent developments in materials synthesis, bio-conjugation methods and luminescence techniques have led to a rapid proliferation of novel fluorescence-based approaches to imaging in the life sciences. However, for high-resolution or long-time duration imaging applications, molecular dyes suffer from limitations of low brightness, poor photo-stability and fluorescence intermittency (blinking).

Likewise, emissive nanoparticles, e.g., semiconductor quantum dots (Q-dots) and dye-loaded latex or silica beads, are also un-optimised. Q-dots often require an inorganic shell with a thick encapsulation layer for stability and biocompatibility, and many batches exhibit low emission rates, blinking, and significant fractions of “dark” particles. Dye-loaded beads have relatively large sizes with limited dye-loading concentrations due to problems of aggregation and self-quenching.

Consequently, we are exploring a potentially promising alternative based on highly fluorescent conjugated polymer materials which are already in use as active layers in polymer light-emitting devices, and, in conjugated polyelectrolyte form, as solar cells. Conjugated polymer materials exhibit a range of attractive properties, including high absorption cross-sections, radiative rates, and effective chromophore densities along with minimal levels of aggregation-induced fluorescence quenching. Using conjugated polymers as an emissive nanoparticle material also eliminates small dye molecules or heavy metal ions that could leach out into solution.

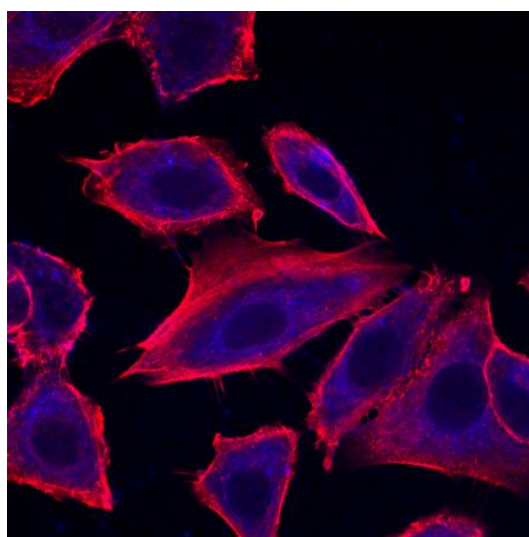


Figure 1: Polyfluorene nanoparticles (blue) in MCF-7 cells (red / phalloidin-TRITC).

We have developed a range of conjugated polymer nanoparticles based on fluorene co-polymers. These polymers are surface functionalized with different molar ratios of polyethylene glycol. By varying the preparation conditions, different sizes of nanoparticles can be prepared, resulting in smaller (20 - 50 nm) nanoparticles, produced by a reprecipitation method, and larger (90 - 110 nm) particles, produced by a solvent exchange method. These particles exhibit high absorption cross-sections (10^{-13} - 10^{-12} cm²) with high quantum yield (\approx 50 %) and well-resolved, size-independent absorption and fluorescence spectra across a broad wavelength range.

Single particle fluorescence imaging studies indicate much higher emission rates ($\approx 10^8$ s⁻¹) and little or no blinking as compared with typical results reported for single dye molecules and Q-dots. Analysis of single nanoparticle photo-bleaching trajectories for some particles indicates excellent photo-stability with almost 10^8 photons emitted per nanoparticle prior to irreversible photo-bleaching.

Also, nanoparticles were incubated with L929 murine aneuploid fibrosarcoma and MCF-7 human breast adenocarcinoma cell lines, fixed, and counter-stained with nuclear dyes. Subsequent fluorescence microscopic imaging indicated that nanoparticles are readily internalized by the cells; see Fig. 1. Further studies are in progress to understand processes of their trafficking and localization within various cell types.