Fluorescent dyes with aggregation-induced emission provide new probes for cancer diagnosis and therapy

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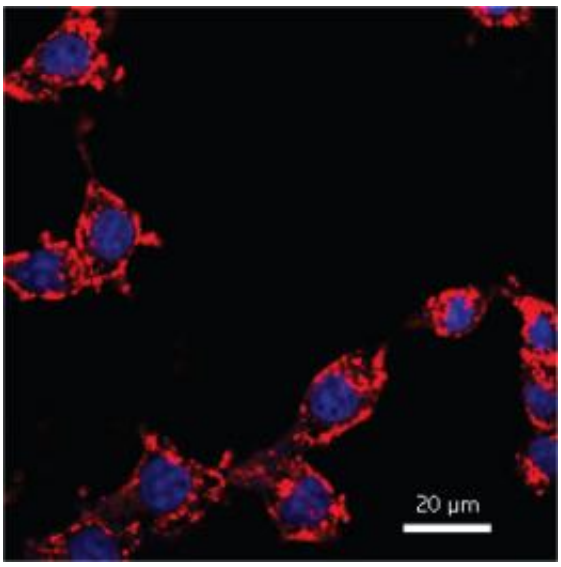

Fluorescence image of breast cancer cells incubated with dye-loaded BSA nanoparticles showing that the nanoparticles have entered the cell cytoplasms (red) but not the nuclei (blue). Credit: 2012 Wiley-VCH

Fluorescent nanoparticles loaded with organic light-emitting dyes are expected to transform live-animal imaging technologies. Compared to inorganic quantum dots, these optically stable materials are non-toxic and can easily be modified with functional groups, making them ideal when targeting specific tissues in the body. Unfortunately, traditional dyes have been known to aggregate and lose their emission intensity

when incorporated in nanoparticles at high concentration. To overcome this problem, a team of researchers led by Bin Liu and Ben Zhong Tang at the A*STAR Institute of Materials Research and Engineering have now designed a family of dyes with enhanced fluorescence upon aggregation.

At the heart of the traditional dyes is a planar chromophore called triphenylamine-modified dicyanomethylene, which emits red light in dilute solutions but fluoresces weakly when aggregated. “The close vicinity of the chromophores induces fluorescence quenching due to non-radiative pathways,” says Liu.

Liu, Tang and their team reversed this phenomenon by attaching propeller-shaped tetraphenylethene pendants to each extremity of the chromophore. Contrary to planar compounds, the shape of the propellers prevents strong stacking interactions between chromophores, blocking the aggregation-caused quenching process. In addition, the physical confinement prevents these propellers from rotating freely, enabling light emission.

The team formulated the dyes using a bovine serum albumin (BSA) matrix — a biocompatible and clinically used polymer — and evaluated their performance as probes. Experimental characterization showed that the wavelength of the emission maximum of the nanoparticles remained unchanged upon encapsulation and that the intensity of the emitted light increased with the dye loading.

Live imaging of breast cancer cells revealed that the nanoparticles displayed more intense and homogeneously distributed red fluorescence in the cytoplasms (see image) than free aggregates, suggesting that BSA boosted the cellular uptake of the dyes. The team also found that the nanoparticles were optically stable in biological media and displayed good biocompatibility.

The researchers intravenously injected the nanoparticles in liver-tumor-bearing mice for in vivo imaging studies. They found that unlike free aggregates, the nanoparticles selectively accumulated in the tumor, clearly highlighting the cancerous tissue in the animals. “This demonstration underscores new research opportunities to explore similar diagnostic probes with potential clinical applications,” says Liu.

The team is currently investigating near-infrared emissive biological probes for targeted in vivo tumor imaging applications. The nanoparticles can also be utilized to understand cancer metastasis or the fate of transplanted stem cells. “These probes are promising in multimodal imaging applications through integration with magnetic resonance imaging or nuclear imaging reagents,” says Liu.

More information: Qin, W. et al. Biocompatible nanoparticles with aggregation-induced emission characteristics as far-red/near-infrared fluorescent bioprobes for in vitro and in vivo imaging applications. Advanced Functional Materials 22, 771–779 (2012).

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