Nano-PERLs: Brilliant Tools for Biomedical Imaging and Therapy in Deep Tissues

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Persistent luminescence (PERL) materials exhibit the unique ability to emit light for extended periods after excitation has ceased. The development of efficient green-emitting bulk materials such as $SrAl_2O_4$:Eu,Dy in the 1990s marked a major milestone. In the 2010s, our work addressed the key challenge of designing PERL nanoparticles capable of near-infrared emission, a spectral window particularly relevant for biomedical applications (Figure 1)

We discovered a new PERL composition $ZnGa_2O_4:Cr^{3+}$ [1] and then developed nanoparticles via a hydrothermal synthesis route. These probes demonstrated exceptional performance as autofluorescence-free imaging agents for in vivo small animal studies, offering a markedly improved signal-to-noise ratio compared to quantum dots (Figure 2) [2]. We further uncovered a novel persistent luminescence mechanism, based on localized charge trapping around Cr^{3+} ions, which enabled optical recharging through tissue using simple white LED illumination (Figure 3). This feature allowed repeated imaging for several hours. Using this approach, we demonstrated three key applications: cellular tracking (Figure 4), tumor targeting, and monitoring nanoparticle trafficking through the gastrointestinal tract, modulated by surface functionalization. [2]

Building on these advances, we are now developing a synthesis strategy that employs mesoporous silica nanoparticles (MSNs) as nanocasting templates. This method enables precise control over morphology and mesostructure while providing a versatile platform for functionalization. Coupling $ZnGa_2O_4:Cr^{3+}$ with organic photosensitizers or therapeutic agents within MSNs opens new opportunities for advanced photodynamic therapy (PDT) against deep-seated tumors. [3]

References

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[2] T. Maldiney *et al.*, *Nature Mater*, vol. 13, nº 4, p. 418-426, avr. 2014, doi: 10.1038/nmat3908.

[3] A. Bessière, J.-O. Durand, et C. Noûs, *Nanophotonics*, vol. 10, nº 12, p. 2999-3029, sept. 2021, doi: 10.1515/nanoph-2021-0254.

Figures

Figure 1. Green PERL bulk materials in the 1990's vs Near Infrared PERL nanoparticles in the 2010's.

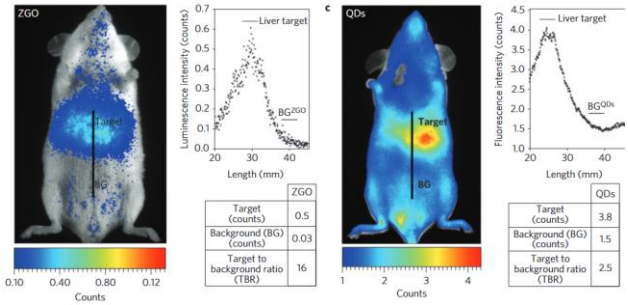

Figure 2. In vivo comparison of negatively charged QDs and PERL nanoparticles after intravenous injection in healthy mice

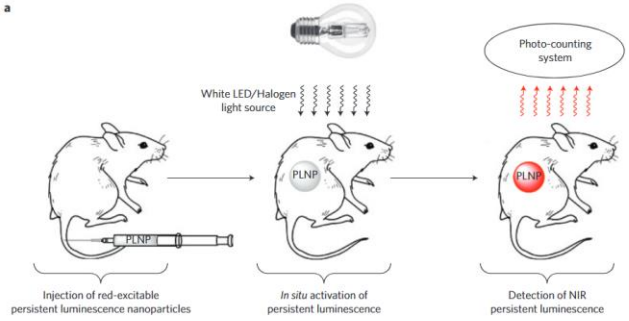

Figure 3. In vivo imaging with ZGO-based PERL nanoparticles. a, A schematic representation of in vivo imaging after in situ activation of PLNPs.

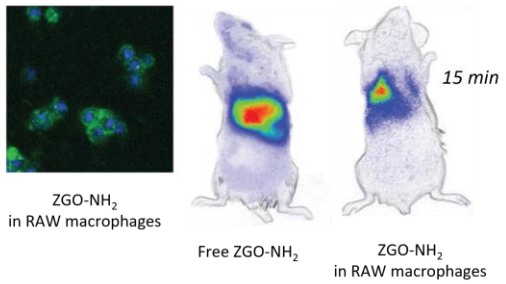

Figure 4. Cellular tracking with persistent luminescence after LED excitation. Biodistribution of ZGO-NH2 nanoparticles in healthy mouse, 15 min after systemic injection and of RAW cells tagged with ZGO-NH2 nanoparticles in healthy mouse, 15 min after systemic injection