



Zn₃Ga₂Ge₂O₁₀:Cr³⁺ Persistent Luminescent Nanoparticles for *In Vivo* Bioimaging

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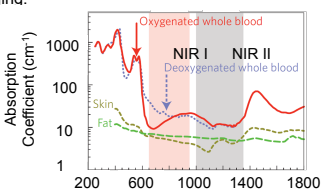


Abstract

Fluorescence imaging is becoming an important tool in biomarker-guided diagnosis, staging, typing, and prognosis of cancer. However, *in vivo* fluorescence imaging suffers from suboptimal signal-to-noise ratio and shallow detection depth, caused by the strong tissue autofluorescence under external excitation and by the scattering and absorption of short-wavelength light in tissues. In this project, we tackle these limitations by using a novel type of optical nanoprobe, Zn₃Ga₂Ge₂O₁₀:Cr³⁺ (ZGGO:Cr) nanoparticles with very-long-lasting near-infrared (NIR) persistent luminescence. This allows optical imaging to be performed in an excitation-free and hence autofluorescence-free manner. The ZGGO:Cr nanoparticles were fabricated by a solvothermal method, followed by calcination at high temperature and wet grinding. ZGGO:Cr nanoparticles pre-charged by ultraviolet light exhibited NIR persistent luminescence (emission peaking at 696 nm and 713 nm) in the first biological transparency window (650–950 nm). Our studies reveal promising potential of these ZGGO:Cr nanoparticles as nanoprobes to detect chemical or biological changes, especially in the applications of cell tracking and tumor targeting.

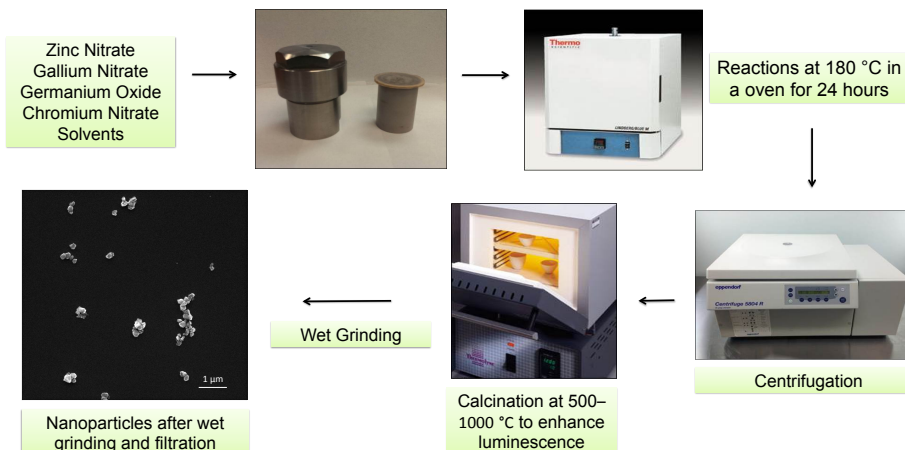
Introduction

Most optical imaging techniques work by tracing fluorescence signals from optical probes, including organic fluorescent dyes and nanoparticles. Despite its dominance in analyzing cells and tissues *in vitro*, however, fluorescence imaging technique is minimally used for *in vivo* clinical applications because of its poor signal-to-noise (S/N) ratio and general shallow detection depth (< 1 cm).¹ These drawbacks are mainly associated with tissue autofluorescence. Autofluorescence is caused by the fluorescence from tissue due to the constant external irradiation. To reduce autofluorescence, tremendous efforts have been spent on finding near-infrared (NIR) optical probes, because the window in NIR regions (NIR I: 650–950 nm; NIR II: 1000–1350 nm) has a relatively low level of tissue absorption. Another approach is using persistent luminescent nanoparticles as self-luminescing nanoprobes for *in vivo* bioimaging.³ However, the further development of the nanoparticles for bioimaging was restricted by the short persistence time (<1 h). Here we report that a novel Cr³⁺-doped zinc gallogermanate NIR persistent nanoparticles with a longer persistence time >48 h and NIR emission (peaking at 713 nm) in the first tissue transparency window for *in vivo* bioimaging.⁴⁻⁷

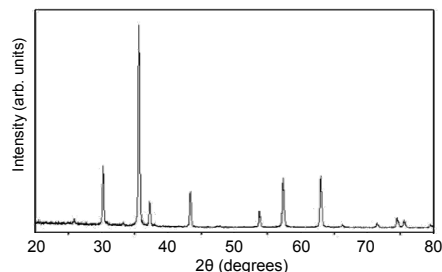


Absorption coefficients of biological components as a function of wavelengths.²

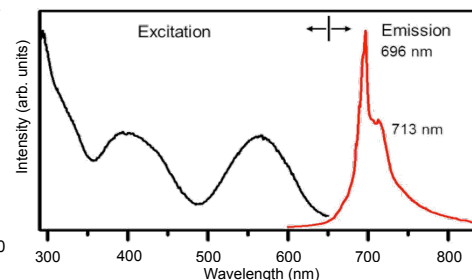
Solvothermal Synthesis of Zn₃Ga₂Ge₂O₁₀:Cr³⁺ Nanoparticles



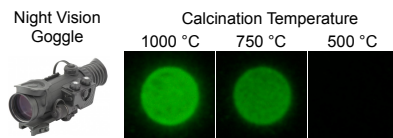
Results and Discussions



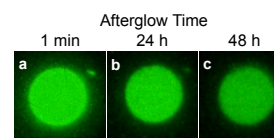
XRD pattern of ZGGO:Cr nanoparticles. The product was identified as spinel phase of ZnGa₂O₄ (PDF NO. 38-1240) and Zn₂GeO₄ (PDF NO. 25-1018).



Photoluminescence of ZGGO:Cr nanoparticles. Normalized excitation and emission spectra at room temperature. The emission spectrum is acquired under 400-nm-light excitation and the excitation spectrum is obtained by monitoring at 713 nm emission.



NIR afterglow images of ZGGO:Cr pressed discs at different calcination temperatures (500 to 1000 °C). The disc was irradiated by a 365 nm UV lamp for 5 min. The images were taken by a digital SLR camera via a PVS-14 Generation III night vision monocular in a dark room at 1 min after stoppage of UV irradiation. The imaging parameters are: manual/ISO 400/0.01 s.



NIR afterglow images of ZGGO:Cr pressed discs at different afterglow times. The disc was irradiated by a 365 nm UV lamp for 5 min. The images were taken at different afterglow times (1 min to 48 h). (The imaging parameters: a, manual/ISO 400/0.02 s; b, manual/ISO 400/8 s; c, manual/ISO 400/10 s.)

Conclusion

Zn₃Ga₂Ge₂O₁₀:Cr³⁺ (ZGGO:Cr) persistent luminescent nanoparticles with an average size 200 nm have been prepared by solvothermal synthesis. The crystalline ZGGO:Cr nanoparticles can be effectively excited by broad bands (290–650 nm) to emit NIR emission in the first biological transparency window. They also exhibit long-lasting NIR afterglow (>48 h) after stoppage of UV irradiation. The ZGGO:Cr nanoparticles may act as ideal optical nanoprobes for *in vivo* deep-tissue bioimaging.

Acknowledgments

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