Metal nanoparticles for imaging guided phototherapy

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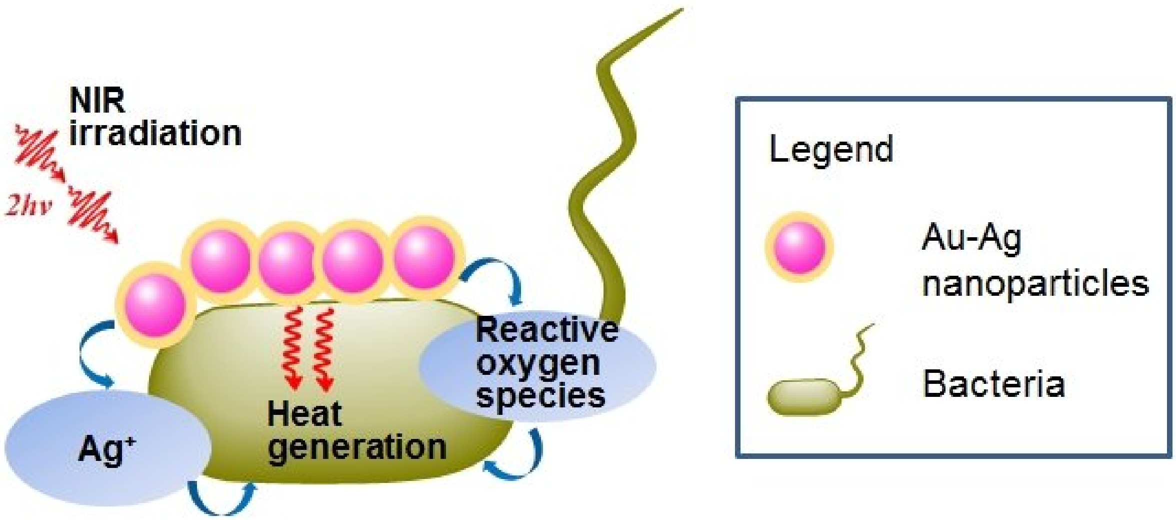

Figure describes the imaging capability and antibacterial activity of Au-Ag nanoparticles. The Au-Ag nanoparticles, which are positively charged, aggregate on negatively charged bacterial cell walls. They release silver nanoparticles and generate reactive oxygen species, which are antibacterial agents. Strong emission under NIR irradiation allows these bacteria to be easily imaged. The NIR irradiation also increases the antibacterial effect of the nanoparticles through the photo-thermal effect (heat generation using energy converted from the absorbed photons). Credit: National University of Singapore

National University of Singapore chemists have recently discovered that gold-silver (Au-Ag) nanoparticles can be used to image and provide concurrent treatment for bacterial infections.

The global spread of multidrug-resistant bacterial infections is a major threat to public health. They have resulted in significant morbidity and mortality as few antibacterial agents are effective against them. Also, biofilm-associated infections have emerged as another medical challenge due to the poor ability of antibiotics to penetrate through the slime layers (extracellular polymeric substances) enclosing the bacteria. Antibacterial agents that can overcome these drug resistance and delivery issues, as well as effectively image the severity of bacterial infections would have many applications in the biomedical field.

A research group led by Prof XU Qing-Hua from the Department of Chemistry, NUS discovered that noble metal nanoparticles emit much stronger two-photon photoluminescence (2PPL) when they aggregate together and form clusters in solution. The 2PPL process, which involves the emission of light at shorter wavelengths via the absorption of two photons at longer wavelengths, is useful for biological imaging as cellular matter generally do not absorb light at longer wavelengths (namely in the near infrared). As many biologically important species (e.g. bacteria) can cause the aggregation of metal nanoparticles, this phenomenon has important implications in two-photon sensing, imaging and phototherapy for biomedical applications.

Among the available noble metal nanoparticles, the research team found that Au-Ag nanoparticles (Au core enclosed within an Ag shell) give the largest enhancement in 2PPL of up to 800 times when they form aggregates. In comparison, the enhancement factor is about 250 times for Au nanoparticles of similar size and shape. A larger enhancement factor means that the nanoparticles are more sensitive to subtle changes in the chemical environment. Building on this discovery, the research team demonstrated that these Au-Ag nanoparticles can potentially be used effectively to image bacterial infections and provide antibacterial treatment at the same time.

Prof Xu said, "Enhanced two-photon excitation provides the Au-Ag nanoparticles with strong photo-thermal effects and superior antibacterial activity. This is in addition to their intrinsic antibacterial activity through the release of silver ions and generation of reactive oxygen species, which are further improved as a result of enhanced excitation efficiency. Due to their exceptional antibacterial activity, these nanoparticles have been shown to effectively eradiate bacteria in biofilms under near-infrared irradiation (NIR) in our experiments. The intrinsic three-dimensional selectivity of two-photon excitation allows selective killing of bacterial cells without affecting nearby healthy cells."

Future research efforts to augment these metal nanoparticles with cancer cell-specific binding groups can potentially enable them to be used as multifunctional agents for many biomedical applications.

More information: Xin Ding et al. Au-Ag core-shell nanoparticles for simultaneous bacterial imaging and synergistic antibacterial activity, *Nanomedicine: Nanotechnology, Biology and Medicine* (2016). DOI: 10.1016/j.nano.2016.09.003

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