
A Boost to the Optical Properties of Gold Nanoclusters by Designed Proteins

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A collaboration between Juan Cabanillas (IMDEA Nanociencia) and Aitziber L. Cortajarena (CIC biomaGUNE) groups explore the potential of coordination proteins in the emission properties of gold nanoclusters. The emission mechanisms are still to be explored, opening an exciting avenue towards emitting and sensing biocompatible devices.

Gold nanoclusters are groups of a few gold atoms with interesting photoluminescent properties. The features of gold nanoclusters depend not only on their structure, but their size and also by the ligands coordinated to them. These inorganic nanomaterials have been used in sensing, biomedicine and optics and their coordination with biomolecules can endow multiple capabilities in biological media. A research collaboration between the groups of Dr. Juan Cabanillas, Research Professor at [IMDEA Nanociencia](#) and Dr. Aitziber L. Cortajarena, Ikerbasque Professor and Principal Investigator at [CIC biomaGUNE](#) have explored the use of natural proteins to grow gold nanoclusters, resulting in hybrid bionanomaterials with tunable photoluminescent properties and with a plethora of potential applications.

The nanoclusters -with less than 2 nm in size- differentiate from larger nanoparticles (plasmonic) since they present discrete energy levels coupled optically. The groups of amino acids within the proteins coordinate the gold atoms and allow the groups to be arranged around the gold nanocluster, facilitating the stabilization and adding an extra level of tailoring. These nanoclusters have interesting energy harvesting features. Since the discrete energy levels are optically coupled, the absorption of a photon leads to promotion of an electron to higher levels, which can trigger a photophysical process or a photochemical reaction.



Protein engineering for the synthesis of highly photoluminescent protein-stabilized gold nanoclusters.

The results by Cabanillas and Cortajarena groups, published in [Advanced Optical Materials](#) and [Nano Letters](#), explore the origin of the photoluminescence in protein-designed gold nanoclusters and shed light into the strong influence of environmental conditions on the nature of luminescence. Nanocluster capping by two types of amino acids (histidine and cysteine) allow for changing the emission spectral range from blue to red, paving the way to tune the optical properties by an appropriate ligand choice. The nature of emission is also changed with capping, from fluorescence to phosphorescence, respectively. The synergistic protein-nanocluster effects on emission are still not clear, and the groups at IMDEA Nanociencia and CIC biomaGUNE are working to elucidate the mechanisms behind. There are potential applications for the aforementioned nanoclusters, in solid state as active medium in laser cavities. Optical gain properties from these nanoclusters are yet to be demonstrated, which could pave the way to a new generation of potentially interesting laser devices. As the combination of gold plus proteins is potentially biocompatible, many potential applications in biomedicine can also be envisaged.

A related publication of the groups in *Nano Letters* demonstrates that the insertion of tryptophans, amino acids with high electron density, in the vicinity of the nanocluster boosts its photoluminescence quantum efficiency up to 40% in some cases, values relevant for solid state light emission applications. Researchers also observed an antenna effect: the tryptophans can absorb light in a discrete manner and transfer the energy to the cluster. This effect has interest for energy harvesting and for sensing purposes as well.

The proteins through the biocapping enable the synthesis of the nanoclusters and largely improve their quantum efficiency. “The photoluminescence quantum efficiency is largely improved when using the biocapping” Dr. Cabanillas says. He believes this research work means “a new field opening for the tuning of optical properties of nanoclusters through protein engineering, and much work is ahead for the understanding of the amplification mechanism”. Dr. Cortajarena emphasizes “we have already demonstrated the great potential of engineered photoluminescent protein-nanocluster in biomedical and technological fields, and understanding the fundamental emission mechanisms is pivotal for future applications”. A variety of further applications include biosensors, as the protein admits functionalization with recognition molecules, energy harvesting, imaging and photodynamic therapies. Further work is ahead this opening avenue for photophysics research.

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