Predicting plasmonic colors to create unexpected color pigments

Gold nanoparticles are well known for their ruby-red color. Researchers have long known that this color is due to the phenomenon of plasmon resonance. But this raises questions that go beyond the scientific circle, and opens the door to applications linked to the color industry. For example, can these nanoparticles be used like ordinary pigments to create inks? Or what range of colors can be produced from gold nanoparticles? Researchers from the group Physical chemistry and Dynamics of Surfaces at INSP demonstrate how to calculate the color of nanoparticles, and shed light on the phenomenon of bichromatism.

In this study, conducted as part of the Bichromatics project (https://bichromatics.com), William Watkins, Yoann Prado and Olivier Pluchery carried out a systematic comparison of measured and calculated colors for gold nanoparticle samples. They prepared twelve samples of nanoparticles in aqueous solution, with diameters increasing from 16 to 108 nm. For each solution, they measured the transmission and diffuse reflection spectra. Based on the Mie theory for scattering, they also simulated these same spectra. The agreement is remarkable.

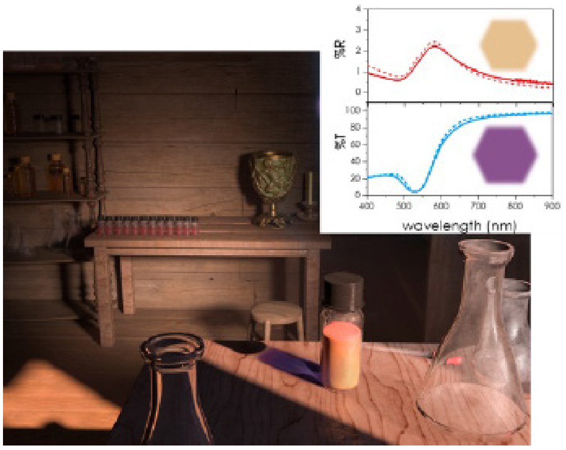


Figure 1
Imaginary representation of a chemist's laboratory. In the foreground is a vial containing bichromatic plasmonic pigments. In the background is the Lycurgus cup, and the 12 vials of gold nanoparticles used in this study. The inset shows the diffuse reflection (top) and transmission (bottom) spectra of the solution containing 85 nm nanoparticles. The colored hexagonal dots provide information on the calculated color.

The results show that gold nanoparticles between 16 and 50 nm in diameter are translucent and red in color (see Figure 2-a), with very little scattering (see Figure 2-b). For diameters greater than 50 nm, scattering phenomena become important, and the solutions show an orange/salmon color in reflection. Thus, if we consider 108 nm nanoparticles, they appear mauve in transmission, and orange in reflection/diffusion. A material that can appear with two distinct colors is said to be bichromatic. In this study, we took the analysis a step further by calculating the colors in the CIE color diagram, commonly used by color engineers. We have shown that spherical gold nanoparticles can present a beautiful bichromatic effect when their diameter is between 70 and 90 nm.

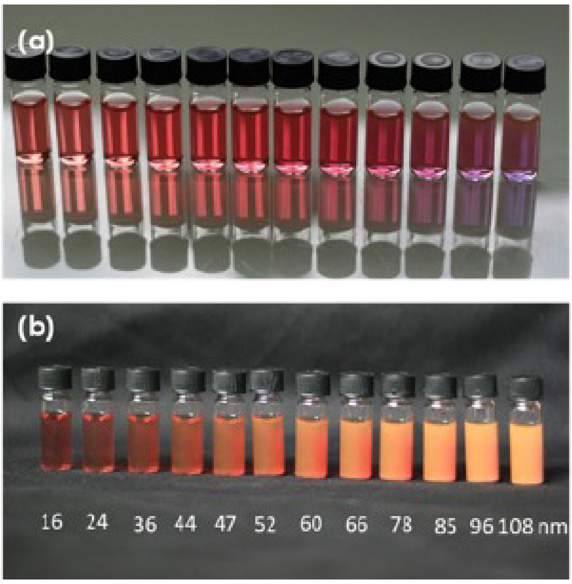
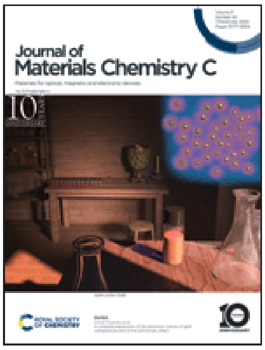


Figure 2
Photographs of the twelve samples of this study (a) in transmission and (b) in reflection. The vials contain spherical gold nanoparticles suspended in water. Their diameter increases from 16 nm to 108 nm, as shown in Fig.

These results led to the creation of plasmonic color prediction software, which is available online at https://bichromatics.com/calculator/.

This study firmly establishes the color calculation method for spherical gold nanoparticle solutions, and validates the software to achieve it. This work confirms that these solutions are essentially red or violet in transmission for all nanoparticle diameters. It is now possible to develop this approach and apply it to other forms of gold nanoparticles or other metals (silver, copper) to change the color range. This makes it possible to consider these plasmonic particles as real pigments for creating unexpected color effects.

The result is featured on the cover of the Journal of Materials Chemistry C:



Reference
"A complete explanation of the plasmonic colours of gold nanoparticles and of the bichromatic effect"
Pluchery, O; **Prado, Y**; **Watkins, W**
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