NANOSECOND LASER THERMAL DEWETTING OF THIN FILMS FOR PLASMONIC NANOPARTICLE FABRICATION AND COLOR ENGINEERING

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Laser-induced dewetting of thin metal films is an efficient and versatile method for generating plasmonic nanoparticles directly on glass substrates. The technique is based on localized thermal heating of continuous thin metal films using nanosecond pulsed laser irradiation, which induces film breakup and self-organization into nanoparticles without the need for chemical reagents. This approach enables clean, scalable, and spatially controlled fabrication of plasmonic nanostructures with tunable optical properties.

In bimetallic Au–Ag systems, laser-induced dewetting allows precise control over nanoparticle composition, morphology, and size distribution by adjusting the initial film thicknesses and stacking order. As a result, localized surface plasmon resonance (LSPR) peaks can be tuned across a broad visible spectral range from 400 nm to 530 nm, with resonance widths varying between 40 nm and 130 nm. The obtained hybrid nanoparticles demonstrate strong surface-enhanced Raman scattering (SERS) performance, achieving enhancement factors exceeding 10^5 at a 532 nm excitation wavelength. The absence of chemical contaminants makes these laser-fabricated substrates particularly attractive for sensitive molecular detection and sensing applications.

Beyond noble bimetallic systems, the laser-induced dewetting method can be further optimized through substrate and interlayer engineering. Introducing a thin titanium adhesion layer beneath gold films significantly influences the dewetting dynamics, promoting the formation of smaller and more uniformly distributed nanoparticles. This morphological modification broadens the achievable plasmonic color palette beyond the intrinsic limitations of gold thin films [1], enabling vivid, tunable colors with improved film adhesion and durability [2]. By varying laser parameters such as pulse energy, scanning speed, repetition rate, and hatch spacing, high-resolution plasmonic color beyond the limited palette of gold thin films can be produced in a controlled and reproducible manner.

Overall, nanosecond laser-induced thermal dewetting of thin metal and multilayer films represents a robust, environmentally friendly, and cost-effective platform for fabricating plasmonic nanoparticles. The demonstrated versatility of this method opens pathways toward large-area SERS substrates [3,4], plasmonic color printing, anti-counterfeiting technologies [5], photonic devices, and other advanced optical applications [6].

Keywords: gold, silver, nanoparticles, laser, LSPR, dewetting

[1] N. Li, P. Zhao, and D. Astruc, "Anisotropic gold nanoparticles: synthesis, properties, applications, and toxicity," Angewandte Chemie International Edition, vol. 53, pp. 1756-1789, 2014.
[2] R. Liudvinavičius, A. Selskis, and E. Stankevičius, "Titanium adhesion layer influence on the formation of hybrid lattice plasmon structures via laser-direct writing," Optics & Laser Technology, vol. 175, p. 110807, 2024.
[3] P. Mulvaney, M. Giersig, and A. Henglein, "Electrochemistry of multilayer colloids: preparation and absorption spectrum of gold-coated silver particles," The Journal of Physical Chemistry, vol. 97, pp. 7061-7064, 1993.
[4] A. G. Da Silva, T. S. Rodrigues, T. J. Slater, E. A. Lewis, R. S. Alves, H. V. Fajardo, et al., "Controlling size, morphology, and surface composition of AgAu nanodendrites in 15 s for improved environmental catalysis under low metal loadings," ACS Applied Materials & Interfaces, vol. 7, pp. 25624-25632, 2015.
[5] V. Caligiuri, A. Patra, M. P. De Santo, A. Forestiero, G. Papuzzo, D. M. Aceti, et al., "Hybrid Plasmonic/Photonic Nanoscale Strategy for Multilevel Anticounterfeit Labels," ACS Applied Materials & Interfaces, vol. 13, pp. 49172-49183, 2021/10/20 2021.
[6] M. Song, D. Wang, S. Peana, S. Choudhury, P. Nyga, Z. A. Kudyshev, et al., "Colors with plasmonic nanostructures: A full-spectrum review," Applied physics reviews, vol. 6, 2019.