Hybrid platform for significant SERS enhancement of methylene blue by adopting core-shell PtAu NPs and 2D MoS_2 nanoplatelets

Shusen Lin[1], Rutuja Mandavkar[1], Rakesh Kulkarni[1], Sanchaya Pandit[1], Shalmali Burse[1], Md Ahasan Habib[1], Sundar Kunwar[2], and Jihoon Lee[1]**

[1] Department of Electronic Engineering, College of Electronics and Information, Kwangwoon University, Nowon-gu, Seoul, 01897, Republic of Korea.

[2] Center for Integrated Nanotechnologies (CINT), Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

ABSTRACT

SERS is an effective technique that has the potential to detect the molecules at ultra-low concentrations and enhance the weak Raman signals [1][2]. Herein, a hybrid template of core-shell PtAu hybrid nanoparticles (HNPs) and 2D MoS_2 nanoplatelets are adopted for the significant enhancement in the SERS signals of methylene blue (MB) [4]. The development of a unique platform of MoS_2 nanoplatelets and MB on the PtAu HNPs template offers significant improvement in the Raman vibrations as compared to the general SERS [3][4]. Depending on the development dynamics in a two-step solid-state dewetting (SSD) technique, either bimetallic core-shell hybrid or completely alloyed PtAu nanoparticles (NPs) can be synthesized, as shown in Figs. 1(a) - 1(b). As shown in Fig. 1(a), the unique structure of PtAu core-shell HNPs can provide the PtAu core–shelled configuration in addition to the high-density background Au NPs. MoS2 nanoparticles and the MB molecules mixed and deposited on the PtAu core-shell HNPs are shown in Fig. 1(c). High-density hot spots and strong LSPR can be influenced by the PtAu core-shell HNPs can be seen in Fig. 1(d). The formed core-shell PtAu HNPs and a large number of Au NPs formed in the background lead to the enhancement by the localized surface plasmon resonance (LSPR) property and by the electromagnetic hot-spots on the edges of NPs. At the same time, the 2D layered transition metal dichalcogenide (TMD) MoS_2 nanoplatelets can induce significant charge transfer towards MB. The combined effect of the electromagnetic mechanism (EM) and the chemical mechanism (CM) plays crucial roles in the SERS signal improvement [5][6]. Enhanced local e-field distributions and increased maximum local e-field intensity of the core-shell PtAu HNPs by the combination of 2D MoS2 nanoplatelets/core-shell PtAu HNPs are demonstrated by the finite-different time-domain

(FDTD) simulation [4]. As compared to simple Pt NPs, the core-shell PtAu HNPs exhibit much improved hot spots and greater maximum local e-field intensity, making them ideal for SERS applications. As illustrated in Fig. 1(e), a synergistic impact of CM and EM is adapted with this hybrid SERS platform. The SERS signal improves significantly, as demonstrated in Fig. 1(f).

Keywords: Core-shell PtAu, MB/MoS_2/PtAu NPs Hybrid mixture approach, Plasmonic nanoparticles, solid-state dewetting technique.

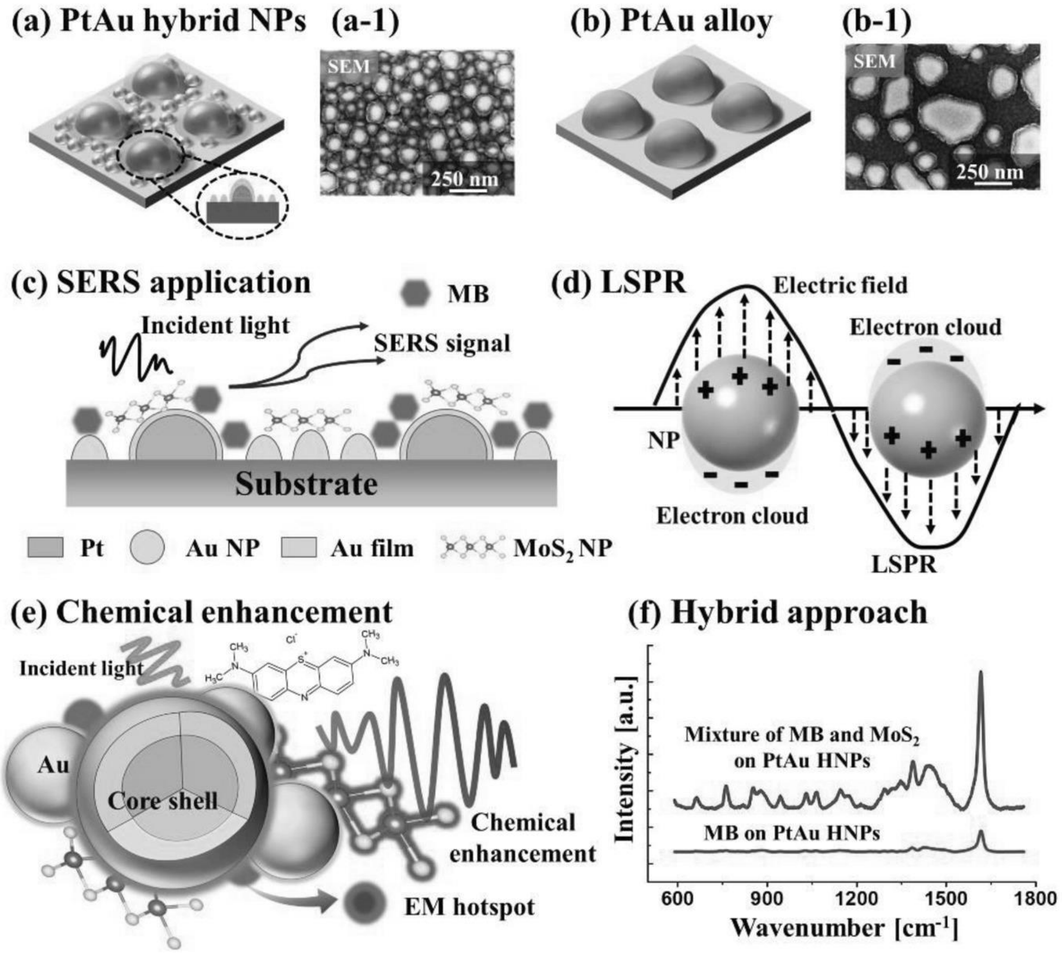

Fig. 1. The fabrication of bimetallic core-shell hybrid and fully alloyed PtAu nanoparticles (NPs) and their application towards methylene blue (MB) surface-enhanced Raman spectroscopy (SERS). (a–b) Schematic representations of core-shell PtAu hybrid NPs (HNPs) and completely alloyed bimetallic PtAu NPs after the second step of solid-state dewetting (SSD) at 800 °C with varying Au coating thicknesses. (a-1–b-1) SEM images. (c) Schematic of a combined SERS technique for detecting MB that includes the integration of MoS_2 nanoplatelets on PtAu hybrid NPs. (d) Localized Surface plasmonic resonance (LSPR) in PtAu core-shell HNPs. (e) EM and CM enhancements with MoS2 nanoplatelets on PtAu HNPs are depicted schematically. (f) SERS signals of methylene blue (MB) by the combined approach as compared to the typical NP approach [4].

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