Large-area self-assembly of anisotropic Palladium nanostructures for SERS applications

Mohammad Navvabpour[1], Pierre Michel Adam[2], Safi Jradi[3] , Suzanna Akil[4]

[321]Light, nanomaterials, nanotechnology (L2N - CNRS-EMR 7004), University of Technology of Troyes, Troyes, France
[4]Institute Chemistry Physical and Materials, LCP-A2MC, University of Lorraine, Metz, France
*corresponding author, E-mail: suzanna.akil@univ-lorraine.fr

Abstract

Here, we report for the first time a facile one-step fabrication route of anisotropic palladium nanoparticles (Pd NPs) with high SERS performance by polymer self-assembly.

1. Introduction

Recently Akil et .al have reported ring like structure and also nano cube particles for gold/silver nano particles obtained by a self-assembly shape-controlled technique, simple, fast and independent of reducing agent in two different researches. In this technique, MNPs are formed in a “one step” upon spin coating, on conductor or n doped semi-conductor substrate, of a dispersion of homopolymer (Polymethyl methacrylate) and metallic salt as precursor. There is neither reducing agent or copolymer nor preliminary functionalization of the surface in this fabrication method. In this project we aim to extend this synthesis way to Pd nanomaterials due to the potential of Pd in photocatalysis and the difficulty to produce anisotropic Pd nanoparticles by simple synthesis methods [1-5].

2. Discussion

Anisotropic Pd NPs are spontaneously formed upon the spin coating of Pd precursor-PMMA (polymethyl methacrylate) dispersion on N-doped silicon wafer/ITO due to a rapid evaporation of the volatile solvents from PMMA. Precisely, the spin coating leads first to a self-assembly of PMMA into micelles containing Pd^{2+}, and then the solvents’ evaporation leads to the formation of nano porous PMMA film, where Pd NPs are localized inside holes. The substrate conductivity plays a major role in the synthesis mechanism since it allows a spontaneous reduction of the Pd precursor into Pd nanoparticles. The repulsive interaction force between the couple (hydrophilic Pd phase /hydrophobic PMMA phase) and the substrate allows us to control the final size and morphology of the produced nanostructures. In addition, the number of Pd NPs can also be modulated by adjusting the synthesis parameters such as precursor concentration and PMMA solution. A high number of NPs (Figure 1) separated by small gaps was obtained at high Pd precursor concentration and led to high SERS performance substrate despite the weak plasmonic properties of Pd.

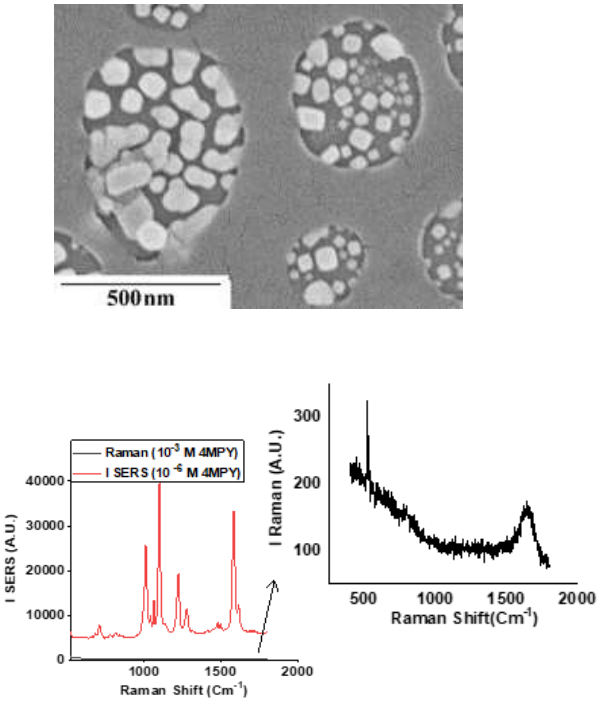

Figure 1. a) SEM images of high-density substrate of closely separated anisotropic Pd NPs. b) SERS of 4-Mercaptopyridine 10-6 M and average Raman spectra of 4-Mercaptopyridine 10-3 M obtained with self-assembly synthesis.

3. Conclusions

In summary, Mono-dispersed anisotropic Pd nano particles has been synthesized using a simple one-step method without any surfactant or reducing agent. With adjusting of synthesis parameters, different morphologies with high SERS performance were obtained.

References

[1] I. Shahine, N. Beydoun., J. J. Gaumet, E. E. Bendeif, H. Magri and S. Akil "Pure, size tunable ZnO nanocrystals assembled into large area PMMA layer as efficient catalyst," Catalysts, Vol. 9, No. 2, 162-186, 2019.

[2] R. Omar, A. E. Naciri and S. Jradi, "One-step synthesis of a monolayer of monodisperse gold nanocubes for SERS substrates." J. Mater. Chem, vol. 5, No. 41, 10813-10821, 2017.

[3] M. Khanafer, A. Issa., S. Akil., T. Hamieh., P. M. Adam and S. Jradi, "A general strategy to incorporate a wide range of salts into ring-like organized nanostructures via polymer self-assembly," RSC Adv, No. 105, Vol. 6, 102843-102852, 2016.

[4] A. Fahes, A. E. Naciri, M. Navvabpour, S. Jradi and S. Akil, "Self-assembled Ag nanocomposites into ultra-sensitive and reproducible large-area SERS-Active opaque substrates," Nanomaterials, No. 8, Vol. 11, 2055-2076, 2021.

[5] S. Akil, R. Omar, D. Kuznetsov, V. Shur, A. E. Naciri and S. Jradi "Advanced large-scale nanofabrication route for ultrasensitive SERS platforms based on precisely shaped gold nanostructures," Nanomaterials, No. 7, Vol. 11, 1806-1824, 2021.