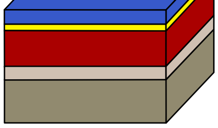
Fabrication of Hollow-Core Nanoparticles for Drug Delivery and Imaging

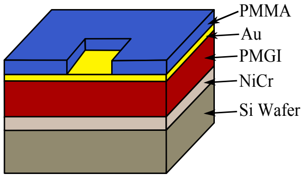
David Shakarisaz[1], Chulsoon Park[2], T. Randall Lee[2], and Paul Ruchhoeft[1]
[1]Department of Electrical and Computer Engineering, [2]Department of Chemistry,
University of Houston, Houston, TX 77204

For this work, we are developing a process for forming gold nanoparticles with a hollow core that can contain a payload for drug delivery or imaging. Figure 1 shows a schematic of the process, where a wafer is coated with 100 nm of nickel chromium 300 nm of PMGI, 30 nm of gold, and 80 nm of PMMA by a combination of spin-casting and thermal evaporation. The PMMA is then patterned using helium atom beam lithography and the pattern is transferred into the gold layer by ion milling. The gold acts as a hard mask during the oxygen reactive ion etch that transfers the pattern through the PMGI with a specific undercut.

The particles are then formed in the openings through three consecutive thermal evaporation steps. First, gold is deposited with normal incidence to form the base of the particle. Next, a copper wedge shape is formed by tilting the wafer and continuously changing the angle of evaporation from 16° to 8°. Next, a 50 nm gold evaporation at normal incidence forms the top of the particle. The surrounding bulk metal is then removed by a lift-off step using a 2.3 % TMAH solution in water. The copper layer is then dissolved in a citric acid solution and the particles can be separated by dissolving the nichrome sacrificial layer in nitric acid.

In this process, it is critical to form a wedge-shaped edge to the copper coating to ensure that the seam between the two gold layers is continuous. Also, we have successfully formed particles without the gold hard mask and by using a wet-etch for the PMGI layer, but have found that this approach is not very reproducible. Figure 2(a) shows a scanning electron micrograph (SEM) of the frontside of gold hollow-core particle with a 75 nm tall cavity. The rough edges are likely due to poor collimation during the thermal evaporation step and this effect could be lessened by reducing the top gold layer thickness. Figure 2(b) shows the opposite side of the particle that reveals both the wedge shape of the copper cavity and seam that connects the top and bottom gold layers. To encapsulate a payload, the particles need to be coated to seal the cavity. We are developing a thermally responsive poly(N-isopropylacrylamide) coating that, at low temperatures, swells to seal the cavity opening and, at high temperatures, collapses to expose the content of the cavity to the solution. Figure 3 shows an SEM of particles coated with the polymer after they were dried on a silicon wafer sample. Our next steps are to characterize the diffusion through the polymer at temperatures below and above the transition temperature and to characterize the extinction properties of the particles.

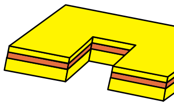


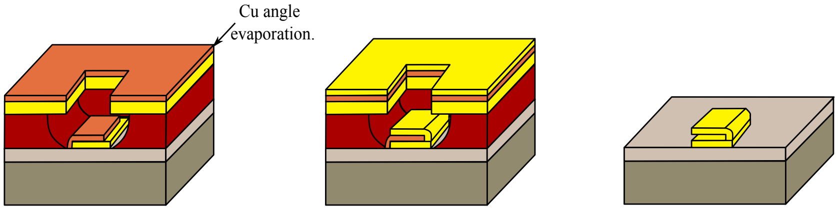


(a) Deposit NiCr, PMGI, Au, PMMA and pattern PMMA

(b) RIE pattern transfer

(c) Evaporate Au top-down





(e) Angle-evaporate Cu

(f) Evaporate Au top-down

(g) Wet etch PMGI layer, followed by citric acid etch of copper cavity

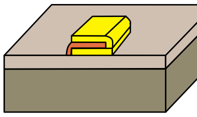
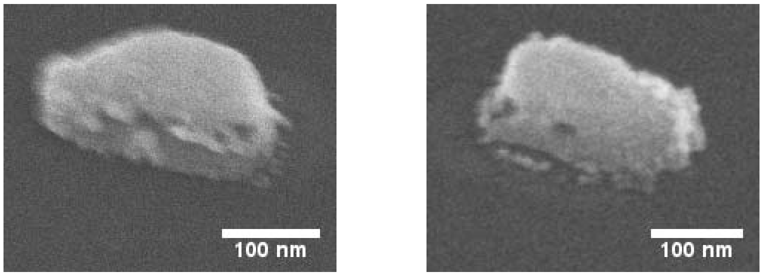


Figure 1: A schematic of the process flow for hollow-core, gold nanoparticle fabrication.



(a) **(b)**

Figure 2: SEM image of gold hollow-core particle, where (a) shows the side containing the cavity opening and (b) shows the opposite side, where a seam bridges the top and bottom gold layers.

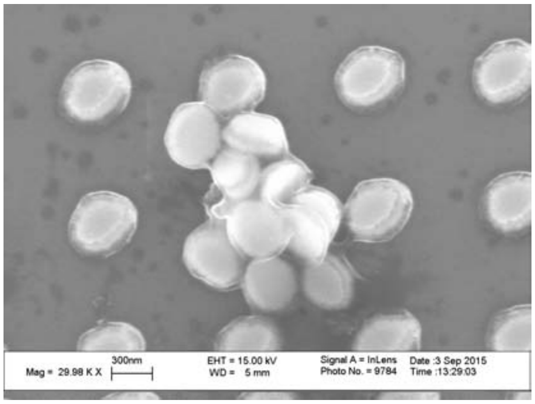


Figure 3: An SEM image of the gold particles coated with a poly(N-isopropylacrylamide).