Laser- Drawn Features on Nanoparticle Films

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Introduction:

The present work explores the silver (Ag) nanoparticles film-Laser interaction based applications in the field of printed electronics, sensors, anti-counterfeiting, optical grating. Ag having the highest conductivity among metals makes it most sought after material for providing conductivity in electronics and even its oxide form is also conductive. Ag in nanoparticle size range show interesting optical, physical and electronic properties like melting point depression (Buffat & Borel, 1976), large absorption and scattering cross section when compared to bulk silver, have a color that depends upon the size and the shape of the particle, high surface to volume ratio, tunable surface Plasmon resonance (SPR) peak wavelength, metal enhanced fluorescence (MEF) (Geddes *et al.*, 2003), surface enhanced Raman scattering (SERM) (Li & Peng, 2010) antibacterial application, diagnostic application, enhanced thermal and conductivity application. In the present work we fabricated three dimensional features on Ag nanoparticles film using laser, these structure showed interesting fluorescent properties. We are also looking into fabricating structure on polymer-Ag nanoparticles films and characterize them for the conductivity, optical, fluorescence properties. These structures might serve as conductive path on polymer-nanoparticle film, paving way for alternative way of fabricating printed circuits.

[1] Unpublished. ISCST shall not be responsible for statements or opinions contained in papers or printed in its publications.

2. Materials and Methods:

2.1. Synthesis:

Silver nanospheres were made using single-pot redox chemical techniques according to published material (Turkevich et al., 1951; Pillai and Kamat, 2004). In this we make use of a soluble metal salt (silver nitrate), a reducing agent (sodium citrate) and a stabilizing agent (excess sodium citrate). Synthesis starts with nucleation step, followed by nanoparticle growth and the stabilizing agent caps the particle leaving a negatively charged surface helping to avoid aggregation (Rivas *et al*., 2001). We start with cleaning all the glass wears with concentrated nitric acid, 600mg of sodium citrate dissolved in 160 ml of 18MΩ pure water in a 500 ml round bottom flask. This was then brought to a temperature of 95°C in an oil immersion bath. Simultaneously, 40mg of silver nitrate was dissolved in 40 ml of 18MΩ ultrapure water in a glass beaker. This was then added to the round bottom flask containing sodium citrate solution and heated to the same temperature (95°C) under constant stirring. The temperature was maintained until the reaction was complete, usually less than 1 h. The heating, stirring is stopped and solution is allowed to cool to room temperature. To impart electrostatic stability to nanoparticles, excess of stabilizing agent was added. The size of the nanoparticles is measured using Dynamic light scattering technique (Malvern, Zetasizer Nano-ZS) and also using Transmission electron microscope and UV-Vis Spectroscopy. Fig. 1A shows a transmission electron micrograph (TEM) image of the as-prepared silver nanoparticles prior to use. From the image data the average diameter was estimated to be approximately 100 nm.

2.2. Nanoparticles Film Making

Nanoparticles solution synthesized using above described method is very dilute in nature. To increase the number density of particles, the solution was subjected to rotation vaporization using Rotary Evaporator (Rotovap) instrument (BUCHI Rotavapour R-205). The solution was concentrated from 0.013wt% to 0.102wt%; the solution was then characterized using DLS and UV-Vis spectroscopy. 100µl of this solution was drop casted on 22x22mm cover slip and allowed it to air dry.

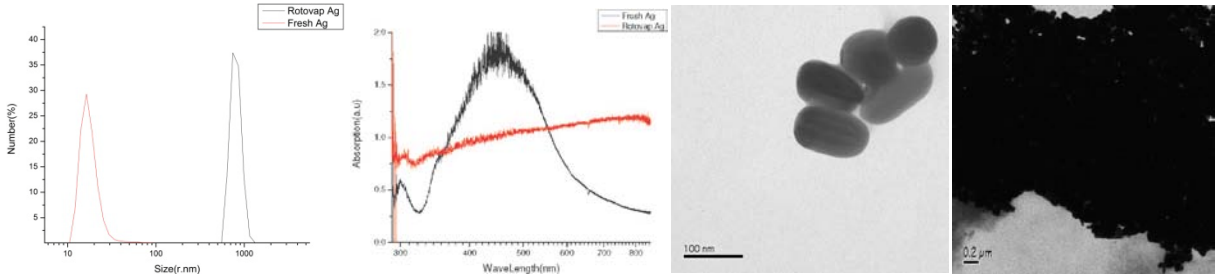
2.3. Exposing film to laser and characterization them:

The drop casted film was then subjected to 532nm continuous wave laser, the film was scanned under laser in raster pattern using an x-y scanning stage and the scan stage was controlled using LabVIEW software. Laser exposed films were characterized using optical microscope, CLSM (Confocal Laser Scanning Microscope), SEM (Scanning Electron Microscope), AFM (Atomic Force Microscope), XRD (X-ray Diffraction), EDAX (Energy-dispersive X-ray spectroscopy).

3. Results

3.1. Characterization of particles:

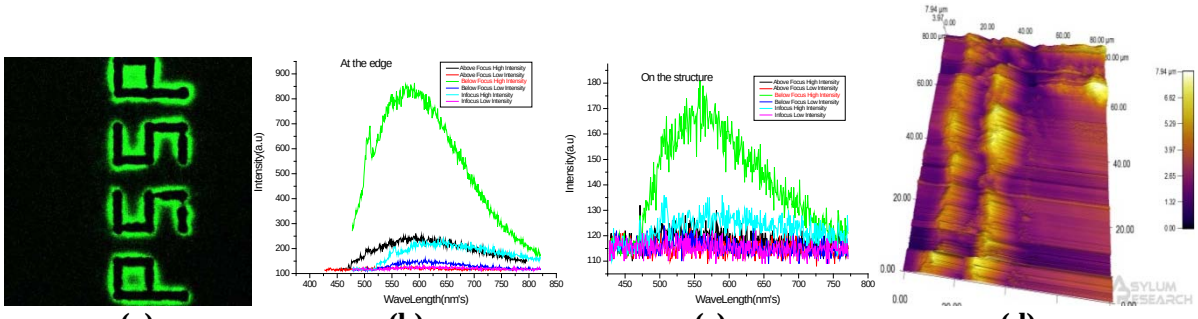
Nanoparticle solution was characterized using DLS, UV-Vis spectroscopy and TEM.



(a) **(b)** **(c)** **(d)**

Figure1: DLS (a), UV-Vis spectrum (b), TEM image of freshly made silver (c), TEM image of Rotovap concentrated silver.

The DLS graph shows that the freshly made Ag particles are around 50nm in radius and rotovap concenrated are around a micron. Theses numbers are complemented by TEM images and they also tel us about the shape of the particles. In UV-Vis graph the flat red cuve shows the aggregation effect of particles and black curve is the typical UV-Vis curve of 100nm Ag particles.



(a) **(b)** **(c)** **(d)**

Figure2: Confocal Image (a), Fluorescence spectrum at the edge of the laser drawn structure (b), on the surface of laser drawn structure (c), AFM of letter ‘P’ (d).

Confocal imaging (Figure2 (a)) of the laser drawn structure showed strong fluorescence emission from the edges of the structures. The emission was quantified by measuring the fluorescence spectrum of the signal and was compared with signal from the edges (Figure2 (b)) to signal from the surface of the structure (Figure2 (c)). The fluorescence spectrum also shows that the emission is coming from below the structure at the edges (different curves in the spectrum represents different level along the z-axis of the structure) and the broad emission wavelength range. This fluorescent nature of the structures shows there potential in Anti-Counterfeiting application, effective marketing techniques for products.AFM image (Figure2 (d)) of tail of letter 'P' quantified that the structures have 3rd dimension (~8μm) also.

4. Conclusion

1. Successfully able to draw 8μm size feature on silver nanoparticle film.

2. Laser drawn structures were fluorescent at the edges.

5. References

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