Silver nanoparticle doped As_2S_3 chalcogenide films: A Photo-induced dissolution study

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Photo-induced dissolution of silver across an As_2S_3 thin film layer is studied.

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I. INTRODUCTION

Chalcogenide glass material exhibit a variety of optical properties that make them desirable for near- and mid-infrared communications and sensing applications. We have developed silver nanoparticle doping techniques to obtain optically sensitive chalcogenide materials, whose response to light radiation is controllable. Such new materials hold promise for new devices in the field of mid-IR technologies.

The diffusion of silver into chalcogenide glasses (ChG) has been reported already more than 40 years ago by Kostyshin, but it is still intensly studied worldwide due to the variety of its potential applicability in areas like Mid-IR holographic volume gratings.

By doping silver nanoparticles into chalcogenide, we creates a novel material which response to light radiation sensitively. Exposed to visible light, either broadband source or laser, silver particles shall react with chalcogenide matrix, and get absorbed. This structure changes results in all kinds of physical parameters modification, such as absorption coefficients of light, refractive index, which enables appropriate application.

Particle doping technology, employed in preparation process, endows a whole set of freedom to control the properties of the resulting material. The size, shape, concentration of the particles, as well as preparation environment like temperature and pressure, provide a powerful parameter space to fabricate the desired material.

II. EXPERIMENT

A. Synthesis of Silver Nanoparticles

Materials. Ag_2SO_4 (Baker Analyzed reagent), $AgNO_3$, (MCB), sodium citrate (Mallinckrodt, Analytical Reagent), poly(viny1 alcohol) denoted PVA (Polysciences, hydrolysis 99.0-99.8 mol%), were used as received. Water was triplly distilled.
Preparation of Sols. Three different kinds of Ag sols were prepared according to the following procedures:

(a) Ag_2SO_4 (80 mg) was dissolved in 200 mL of hot water and then mixed with 5 g of PVA dissolved in 200 mL of hot water. The mixture was then bubbled with H_2 at near boiling temperature for 3 h. The final volume was adjusted to 500 mL.

(b) A solution of $5 \times 10^{-3} M$ $AgNO_3$, (100 mL) was added portionwise to 300 mL of vigorously stirred ice-cold $2 \times 10^{-3} M$, $NaBH_4$. A solution of 1% PVA (50 mL) was added during the reduction. The mixture was then boiled for 1 h to decompose any excess of $NaBH_4$,. The final volume was adjusted to 500 mL.

(c) $AgNO_3$, (90 mg) was dissolved in 500 mL of H_2O and brought to boiling. A solution of 1% sodium citrate (10 mL) was added. The solution was kept on boiling for 1 h. The Ag sols prepared by procedures a and b were brownish and had absorption maximum at 400 nm while that prepared by procedure c was greenish yellow and had absorption maximum at 420 nm.

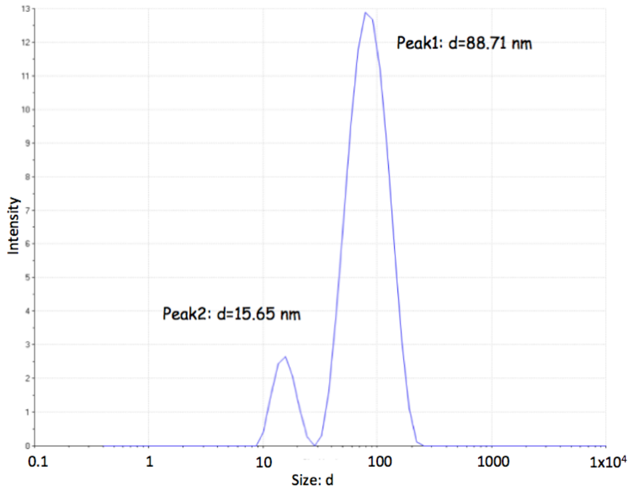

FIG. 1: DLS study of the silver colloid solution

B. Film Exposure and Test

Chalcogenide materials are first dissolved in an appropriate amine solvent, such in arsenic sulfide in propylamine.

Silver nanoparticle of different size, shape are synthesized by chemical reduction reactions, where species of reagents, temperature of reaction will affect the properties of resultant particles.

Silver nanoparticles, in an appropriate concentration, are mixed into chalcogenide solution. The solution is

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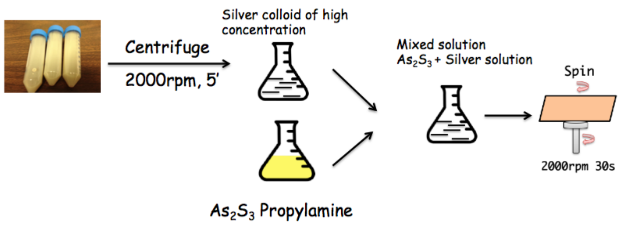

FIG. 2: Preparation of the film

Estimation: # of Ag particles

Density: 10490 kg/m^3

Average radius of particles: 70nm

Volume of each particle: $4/3\,\pi\,R^3 \sim 2 \times 10^{-25}$ m^3

Weight of each particle: 2×10^{-17} g

# of particles in 0.04g (10ml): 2×10^{15}

# of particles in each film: ~ 10^{12}

FIG. 3: Estimation of # of silver particles

ready to use after an incubation time.

Mixed silver-chalcogenide solution is spin-coated onto substrates, like glass slides, silicon, or sodium chlorides to fabricate films for future use. A baking process is employed thereafter to get rid of the amine solution.

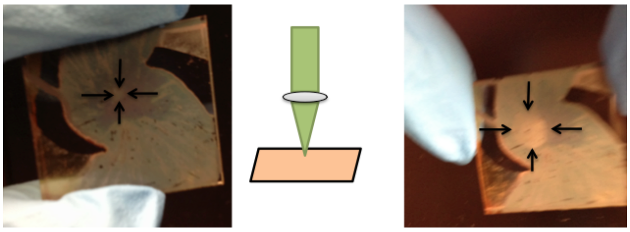

FIG. 4: Film Illumination with Green laser ($\lambda = 532nm$) 50mW 0.5 hours in Air.

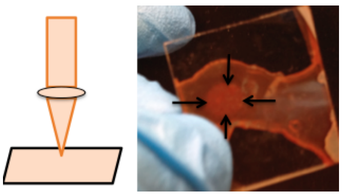

FIG. 5: Film Illumination with Broadband 100mW 0.5 hours in Glovebox.

C. Transmission Study

III. RESULTS AND DISCUSSION

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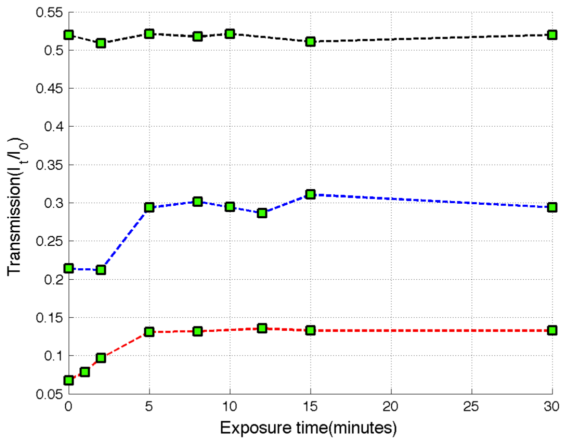

FIG. 6: Transmission study of Ag-doped As_2S_3 film, exposed to $\lambda = 532nm$ green laser light. ($I_0 \approx 10$mW; Film thickness: $1.54 - 2.42\mu m$).

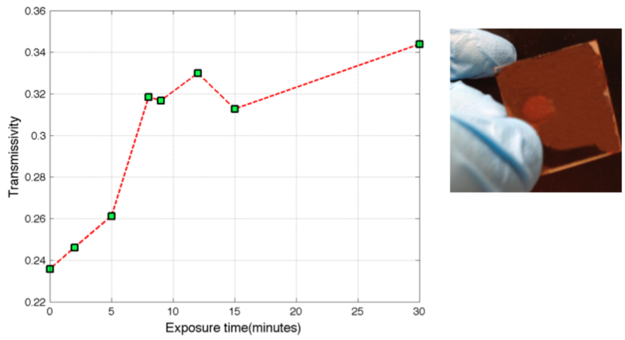

FIG. 7: Transmission study of Ag(20nm) doped As_2S_3 film, exposed to $\lambda = 532nm$ green laser light. ($I_0 \approx 10$mW).

IV. CONCLUSIONS

[1] D. L. Recht, *A phenomenological model of photoinduced surface relief formation in arsenic sulfide* (2006), Princeton University Thesis.