Femtosecond Optical Nonlinearity Signal and Dark Field Scattering Microscopy of Gold Coated Zinc Oxide Nanowires

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Abstract

The current work presents practical study on improved second-harmonicgeneration; SHG signal in individual ZnO NWs coated with gold nanoparticles., experiments on the growth of gold nanoparticles (Au NPs) onto zinc oxide nanowires(ZnO NWs) by several densities of gold nanoparticles coated are prepared via an impregnation simple method. The surface morphologies and the propagation manner of hybrid nanostructures the "TEM' was utilized to study the optical properties of samples nanostructures. The dark – field scattering microscopy was used to characterize single ZnO NW and confirm the coated of hybrid Au/ ZnO nanowires and characterize the density effect of the gold nano particles. By make a comparison between a single zinc oxide with and without gold nano particles coated, nonlinear experiment was studied through it, we got to the estimated improvement of second - harmonic generation signal about ~ 1.5 times, ~ 7 times, and ~ 7.5 times for low, moderate and full coated of gold nanoparticles.

Key Words: Oxide Nanowires, Optical Nonlinearity, Second Harmonic Generation.

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Introduction

Due to the unique optical and electrical properties as well as the potential applications in integrated nanophotonic devices, hybrid nanostructures have attracted great attention of the scientific researchers. considered nonlinear optical properties as important part in nanostructures systems and second harmonic generation is one of these properties, where the photons create with half essential wavelength and double frequency. The relative low conversion efficiency of Nano scale coherent light sources and integrated optical circuits leads to the limitation of the second harmonic generation in Nano-structures, so the current work constrated on the second harmonic generation signals improvement in Nano-structures types. Specially the nanostructures systems which included semiconductor and metal nanostructures have important function because of nonlinear optical properties improvement due to the unique localized surface plasmons resonance (LSPRs) phenomena.

The goal work is to study and investigate on improved SHG signal in single ZnO NWs coated with Au NPs. using femtosecond laser pulses. In the current study we also focus on the development of simple methods for the preparation of semiconductor-metal hybrid nanostructures with low preparation cost.

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The hybrid Au-ZnO NWs by several densities of the coated Au NPs were prepared by a simple solution impregnation method. The dark – field scattering microscopy was used to characterize single ZnO NW and confirm the coated of hybrid Au- ZnO nanowires and exhibit the influence of the Au NPs density An improvement of second harmonic generation "SHG" of the nano structures systems which prepared by simple and cheap way is of important purpose of their practical applications.

The Experimental Work

1) Synthesis of the bare ZnO NWs

Zinc oxide (ZnO) is an significant kind of II-VI semiconductor nanowire by a wide band width of 3.37 eV [1-5] which has unique chemical and physical preperties of optoelectronic, optical devices system and optical microscopy applications[6,7]. A hexagonal wurtzite ZnO structure belongs to the non-centro symmetric crystal class of 6mm[2,8,9] were synthesized via chemical vapor deposition technique(CVD). A mixture of high purity ZnO and graphite powders (1:1 ratio weight) was used as a precursor and was put into aqurtz boat that was placed in the center of a tube furance. Gold catalyses nano particles with diameter 30 nm coated Si(001) substrates were paces downstream of the source materials. The quartz tube furanance was flushed with(5 sccm) oxygen and (100 sccm) argon carrier gases. the tube furances was heated to 950 C° for one hour and finally the tube furance was cooled naturally to room temperature. The products synthesized of ZnO NWs were dispersed with ethanol transferred onto the quartz substrate for optical measurments and characterizations of material.

2) Synthesis of Au Coated ZnO NWs

Gold nanoparticles Au with 10 nm diameters (NANO.COMoSIX COMPANY) were used for coating naoparticles on the zinic oxide NWs by a impregnation method by dipping in gold nanoparticles solution for more once time to improve the SHG signal originated from ZnO NWs[3], where the Au NPs solution was diluted with etanol to three different densities (low, moderate and high densities), and the substrates Si by ZnO N.Ws was prepare to suitable pieces. Once that, the substrates Si included nanowires was dipped more once time in to the solutions Au of three several densities, in that order. Lastly, the Au N.Ps coated ZnO NWs on silicon substrates was air dried. For further optical measurements, the zinc oxide coated gold nanoparticles samples was dispersed of the quartz substrates. The bare ZnO N.Ws was marked as sample A and the hybrid nanotructures coated via the little, moderate and great densities of solutions Au was marked as sample B-D separately.

Characterization of Bare and Coated Samples

The morphology of bare ZnO N.Ws and the ZnO-Au hybrid nanowires was observed utilizing a transmission electron microscopy (TEM, Tacna G.220). A microscope technique by a mode-locked Ti sapphire femtosecond laser technique (Tsunemi, Spectra-Physics, 800 nm, 50 fs and 76 MHz) served as the pumping source was utilized to study the S.H.G signals of samples at temperature room. Dark –field scattering microscopy was used to clear and confirm the improvement of electromagnetic response of nanostructures.

Results and Discussion

Zinc Oxide nanowires were prepared with various densities of plasmonic gold nanoparticles coated as a platform to examine the Plasmon-induced affects of non-linear optical second – harmonic generation property. A set of images TEM in **Fig. 1 appear of** morphology of bare ZnO N.Ws and Au NPs coated ZnO nanowires. From the TEM images, it can be seen that Au NPs are arbitrarily distributed on to surface of the N.Ws, and the Au solution with a higher density leads to more Au N.Ps attached of N.Ws. The density of Au N.Ps attached gradually rises as the increased density of solutions Au.

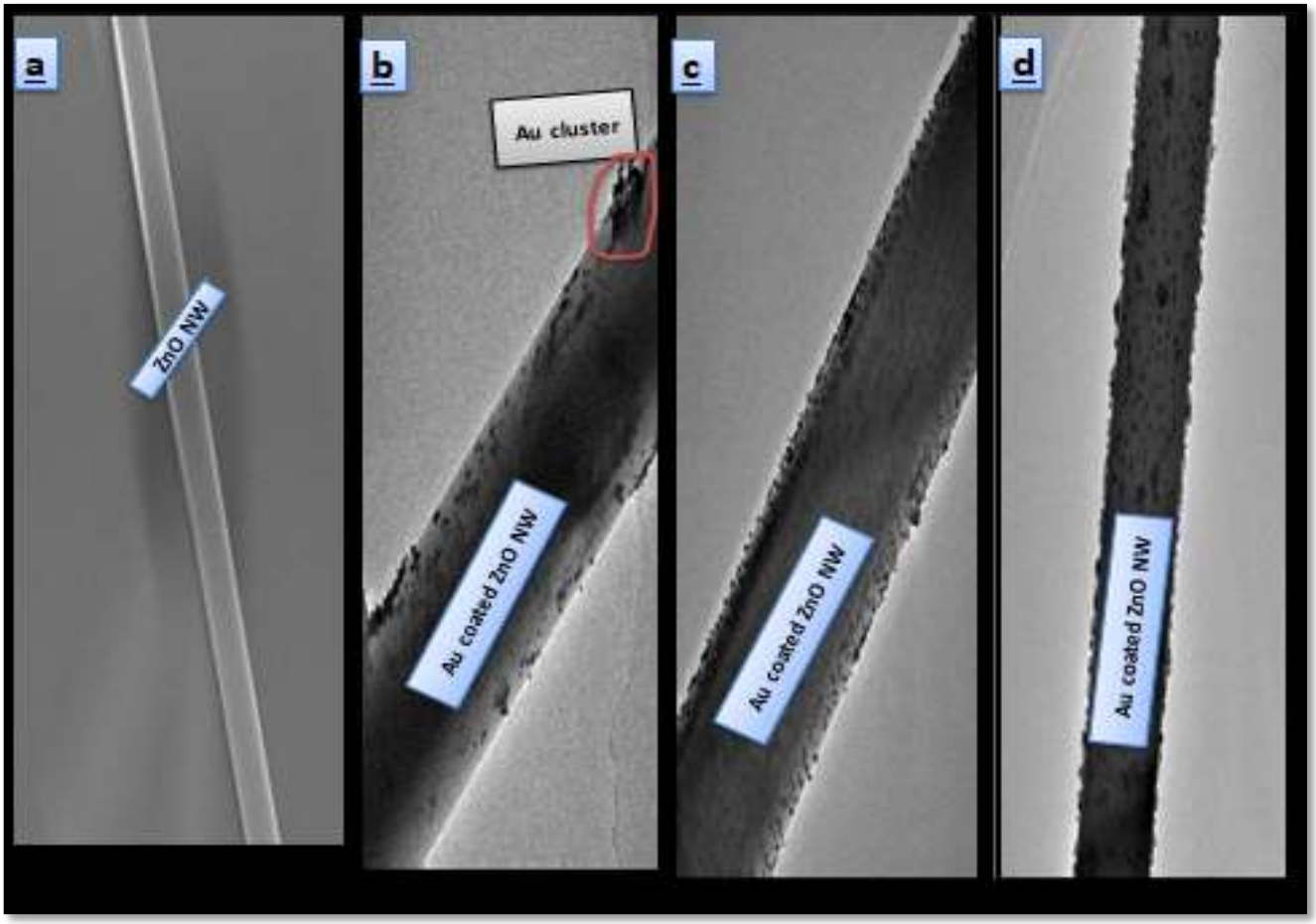

Figure 1. TEM images of naked ZnO N.Ws and ZnO NWs of three various coatedAu NPs.(a)TEM image of bare ZnO N.Ws,(b) TEM image of ZnO N.Ws with low density of coated Au NPs. (c,d) TEM images of ZnO N.Ws with moderate and high densities of coated Au NPs, respectively.

A microscopy system was used to accomplished and study the non-linear characteristic of samples, where, titanume-saphire femtosecond laser was used to com with parameters 800nm wavelength, 50 femtosecond pulsed width and 76 mega hertiz repetition frequency rate. Laser energy was focused by a 40x objective, these objective was used to collect the reflected intensity of second-harmonic generation. The laser energy was filtered by 700nm short - pass filter. The measurement of the polarization-dependent second harmonic generation response of the single ZnO NWs was done via rotating the polarization direction of the pumping laser by the half-wave plate (A2). Figure2 showed the experimental graphic, an intense peak at 400 nanometer indicates to the intensity spectrum of second harmonic generation. It's clear from this spectrum the wavelength at half the original wavelength that represented 800nm which generated from the samples is the intensity of second harmonic generation. Moreover this figure shows the dark field image of single ZnO nanowire as well as the linear relationships between the second harmonic generation intensities of samples as a function of the square laser power P2.

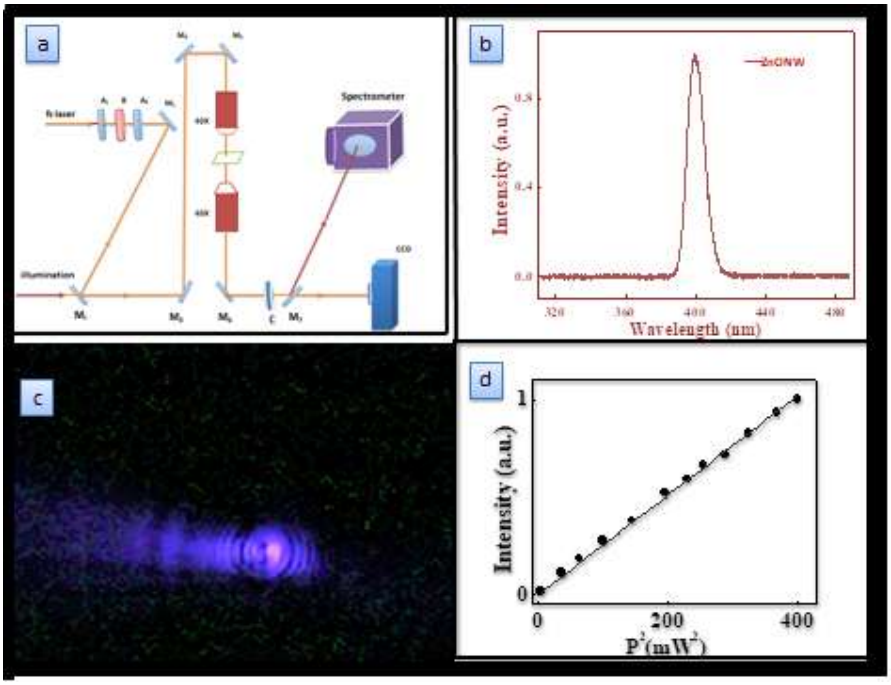

Fig.2. Experimental set up shows in (a), (b) shows the intensity spectrum of second harmonic generation, the dark field image of single ZnO nanowire shown in (c), as well as (d) shows the linear relationships between the second harmonic generation intensities of samples as a function of the square laser power P2

Figure 3, appears the relationship among the average SHG intensity and samples by several conc. of Au N.Ps attached. Note that varies N.Ws were measured corresponding to the same sample, and the mean value of these NWs' average SHG intensity were assessed to be the value final [9]. That appear in Figure2 that the average SHG intensity increased as Au N.Ps density attached on the NWs increase. The enhancement of the SHG intensity is estimated by calculating the ratio between the SHG signal by and without the N.Ps attached. 1.5 times, 7 times and 7.5 times improvement were observed for the low, moderate, and high density of Au NPs attached on the ZnO N.Ws, in that order. But it is worth to note that, under high NPs density situation, the extraplasmonic waves could be generated due to the plasmonic wave coupling of the NPs.

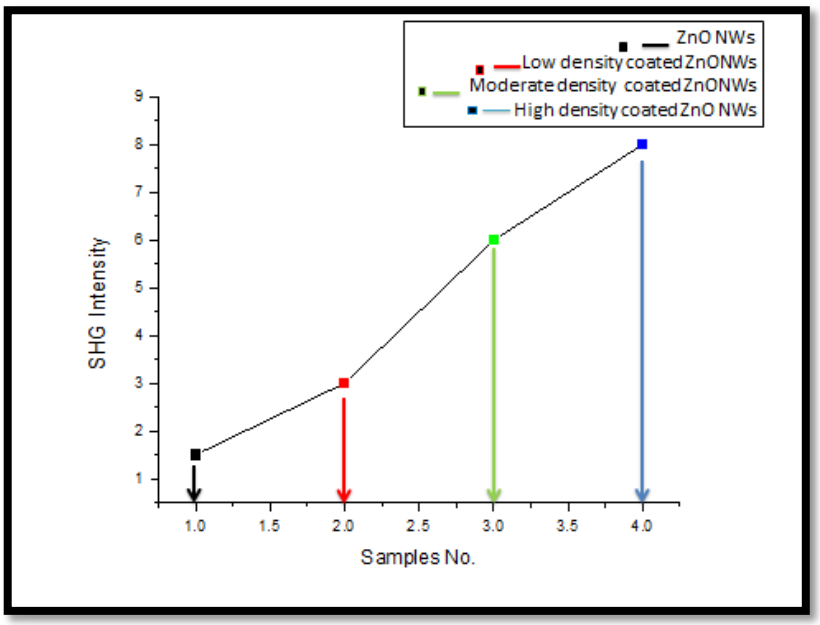

Figure 3. The relationship among the average intensity of SHG and the number of samples with various densities of Au N.Ps attached on N.Ws.

The observed improvement can be attributed to the localized surface plasmon of Au NPs. The plasmonic resonance of the metallic Au NPs locally improves the electric field of the incident fundamental light near the ZnO NWs [3, 10]. The SHG signal improvement, the space among semiconductor and metal is not basic to avoid the charge transfer. Anther benefit of like hybrid Nano structures is that the enhancement times can be simply tuned via controlling the density of metal N.Ps coated. 2D second- harmonic generation maps experiment was used to make a simple comparison between bare zinc oxide nanowires and zinc oxide nanowire with various densities of gold nanoparticles under a specific laser polarization direction.

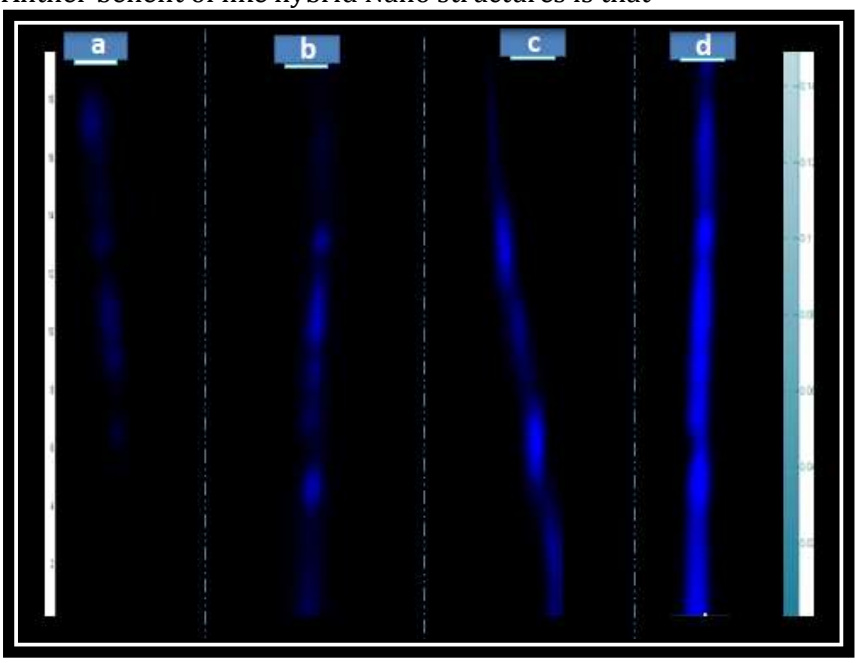

Figure 4. 2D second- harmonic generation maps of, (a) single bare ZnO NW, (b-d) ZnO NWs with various densities of Au NPs.

The second- harmonic generation signal of bare and coated samples is obtained when the laser beam is parallel to the c- axis of nanowires[5,11]. From the figure the SHG signal of zinc oxide coated gold nanoparticles with various densities were improved about 2,5,8 times respectively for low, moderate and full coated of gold nanoparticles.

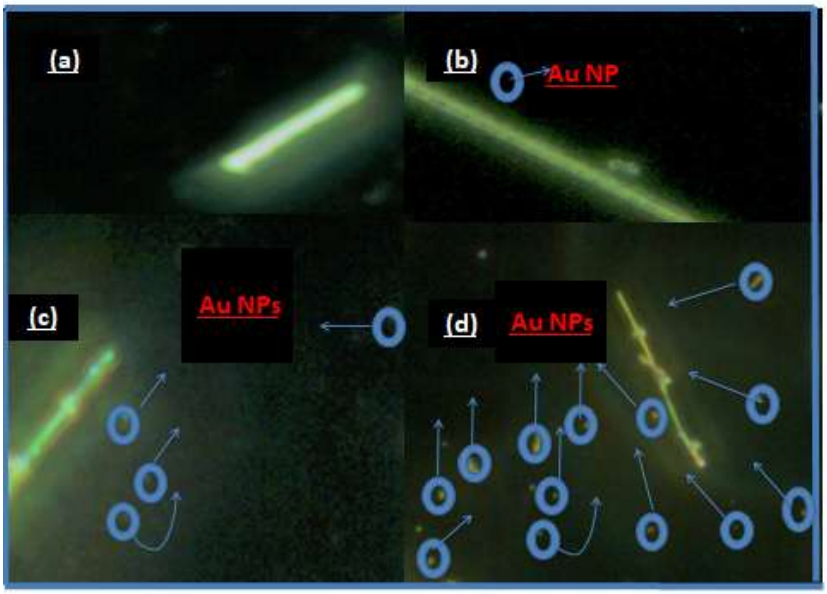

Figure 5. Shows the dark field scattering images of,(a)single naked ZnO NW and (b-d) ZnO NWs coated with three various densities of gold nanoparticles.

Dark field scattering microscope was used to confirm the coated of single zinc oxide nanowires with various densities of gold nanoparticles and the effect of the densities of gold nanoparticles were shown in Figure5, where (a) shows the dark field scattering image of naked single zinc oxide nanowires and (b-d) shows the gradually increased of the gold nanoparticles densities coated zinc oxide nanowires, the fully covered was obtained with high density of gold nanoparticles shows in (d).

Conclusions

Femtosecond laser has played a significant role in promoting the study on the semiconductor nanomaterial and hybrid nanostructures. This work studies the Optical properties of a single ZnO NWs and ZnO coated with different layeres of gold nanoparticles. In this work, we provide a simple platform of enhancing Non linear optical responses, that have potential applications in Nanoprobing and bio-nanotechnology. Second – harmonic generation map intensities was investigated in order to compare with the SHG intensity of different NWs. The dark – field scattering microscopy was used to characterize single ZnO and exhibit the influence of the Au NPs concentration. Nonlinear experiment demonstrate that by comparing the SHG signals from ZnO NWs by and without Au N.Ps attached, a tunable enhancement factor was obtained, the assessed improvements of 1.3 times, 7 times, and 7.5 times were achieved and the second-harmonic intensity was improved upper to one order of magnitude.

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