A Review on Synthesis on ZnO nanostructures for antibacterial applications.

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Abstract:

Nowadays increasing bacterial infection in medical field becomes major problem in health sector. ZnO nanostructures act as promising material due to its high antibacterial activity and non-toxic effect on human health. In this article, we summarise potential approach of synthesis and applications of ZnO nanostructures by different approaches.

Keywords: ZnO, antibacterial activity, nanotechnology.

Introduction:

ZnO is a wide-band gap semiconductor of the group. ZnO with wurtzite structure has transparency in visible range, resistivity of semiconductor and absence of toxicity. Zinc oxide has found use as antimicrobial agent and has several applications in health sector, food packaging industry [4]. To date, large number of approaches for synthesis of different nanostructure with various applications.

Literature Review:

1) Researcher focuses on synthesis of ZnO with different properties of Mg using spray pyrolysis method. BY spraying 0.15M solution of Zn $(CH_3COO)_2$ and $MgCl_2$:$6H_2O$ dissolved in distilled water and 2-propanol (1:3), films are synthesized. XRD pattern predicts more crystalline nature due to increase of amount of Mg doping, peaks become weaker and with 15% Mg doping peaks disappears. UV shows that with increase in Mg concentration leads to increase in transmittance. As increase of Mg concentration particle size of sample decreases leading to increase surface-to-volume ratio, giving rise to more reactive surface to interact with bacteria which enhances antibacterial activity against E.Coli.

2) According to researcher, nanoparticles associated drug delivery; cell imaging and cancer therapy are consider as promising biomedical application. Nowadays Microbial contamination is serious issue, so antimicrobial agents and surface coatings attract attention of lots of researchers. For these purpose antibacterial properties of ZnO nanoparticles prepared by low temperature solution combustion method is studied. ZnO nanostructures prepared using zinc nitrate and Oxalyse Di Hydrazide as fuel, at lower temperature for antibacterial activity, different concentration of ZnO nanoparticles like 100, 75, 50 and 25µg/L along with bacterial culture used.XRD reveals high purity ZnO nanoparticles having 30-40 nm size.SEM images shows large network system with irregular pore sizes and shapes. The result reveals that, ZnO responsible for destructive effect on DNA, results in loss of replication and degradation of DNA.

3) Researcher mix 15gram of Trachyspermum ammi seeds powder with 50ml of double distilled water, boil for 10 minutes. Filtered extract about 2ml slowly added to 25ml solution of 0.05M $ZnNO_3$. The solution continuously stirs for 2 hours at 50°Celsius with help of magnetic stirrer and obtained precipitate washed with Ethanol, centrifuge and dried at room temperature at 35°Celsius to get ZnO nanoparticles. By using same procedure having 4ml and 6ml concentration of extract, ZnO nanoparticles prepared labelled as sample a, b, c respectively. XRD pattern shoes diffracted angle between 30 to 80 degree with diffracted intensities for samples a, b and c. EDAX confirmed presence of zinc as majority compared to oxygen. UV-VIS analysis shows optical absorption coefficient in wavelength range of 300-800nm. The average diameter of nanoparticles is approximately 41 nm. When quantity of seed extract increases, antibacterial activity of ZnO nanoparticles for both gram positive and negative bacteria increases.

4) In hospitals, majority of infections occurs due to contaminated touch surfaces. So, Disinfection of such surface required to avoid antimicrobial bacteria. Oxidative stress in ZnO is primary mode of antibacterial activity. Using aerosol-assisted chemical vapour deposition (AACVD), pure and Cu-doped thin films of ZnO deposited on glass substrate from methanol

solutions of $Zn(OAc)_2.2H_2O$ and different molar concentrations of $Cu(OAc)_2.H_2O$ at 350degree Celsius. Powder X-ray diffraction shows broad peaks suggesting poor crystallinity of film. UV-Vis measurement shows high transmittance in visible and near-IR region and doping of Cu concentration increases, decrease in transmittance observed. Cu-doped sample shows better antimicrobial activity compared to pure ZnO under light and dark condition.

5) ZnO is a material which has harmless for human body due to its antibacterial and antifungal activity. Researcher developed ZnO thin film on glass substrate by modified SILAR method. Developed film annealed at three different temperatures of 250° C,350° C and 450°C for one hour.UV-Spectroscopy reveals that increase in annealing temperature responsible for increase the crystalline nature of film while photoluminescence spectra shows slightly Blue shift with increase in annealing temperature from 250 degree Celsius to 450 degree Celsius.XRD gives size of crystalline ZnO thin film 19.39nm,19.41nm and 19.08nm for 250°C,350°C and 450°C respectively using Debye-Scherer formula .Antimicrobial activity of ZnO film annealed at 350°C is highest against E.coli and for S.aureus highest at 250°C

6) Researcher studied interaction of nanostructure thin film of ZnO with colony of Bacillus Cereus, strain 11778. Interaction between E.Coli and ZnO nanorods studied by transmission electron microscope. Bacterial suspension after 24 hour cultivation, dried at room temperature in sterile Petri dish for month covered with thin Au film and SEM was recorded. ZnO film influence cell growth and division rate of gram positive bacteria of genus Bacillus. According to this researcher, film influence depends on chemical composition of film and synthesis method.

7) Different molar concentration like 0.1, 0.3 and 0.5M NaOH and Oxalic acid aqueous solutions prepared. Steel and zinc foil used as cathode and working electrode respectively. Anodizing process conducted at constant voltage of 10V for 60 minute at room temperature. SEM reveals morphologies of anodized Zn Plates significantly influenced by electrolyte concentration.XRD pattern provides presence of Zn peaks due to Zn plates used as substrate, hexagonal phase with wurtzite structure obtained by XRD patterns. UV-Visible spectra able to calculate band gap of ZnO film around 3.2eV. Anodized zinc oxide is effective both towards Gram positive bacteria and gram negative bacteria.

8) ZnO has biocompatibility and antibacterial activity in pH neutral range. Sol-gel spin coating method adopted for synthesis of film on glass substrate which coated in aqueous solution containing 0.05M zinc nitrate hexahydrate and 0.05M hexamethylenetetramine at 90°C for 3 hours.Cobalt,manganese and copper added to above solution separately having 0.05M concentration. With the help of liquid culture test, antibacterial activity against Gram positive Escherichia Coli (E.Coli) and gram positive bacterium staphyloccus aureus recorded for pure as well as TM doped ZnO thin film. XRD patterns shows small shift towards lower angle for Co and Cu doped ZnO samples while higher angle shift for Mn doped sample. UV spectra recorded in wavelength range of 300-800nm for both i.e. pure and TM doped ZnO thin films, release of ROS which kills bacteria enhanced by doping since metal ions acts as trapping centre of photo generated electrons result in reducing recombination. Cu doped ZnO thin film has higher bacterial inhibition.

9) In this article, researcher investigates pure and Cadmium doped ZnO prepared by Co-precipitation method which is simple, fast and eco-friendly in nature. For synthesis of nanoparticles, 0.2M of zinc acetate dissolved in 20ml of absolute ethanol. The NaOH solution added to zinc acetate solution in drop wise manner with constant stirring maintaining pH12, stir for 2 hours at room temperature. Precipitates obtained after filtering washed with ethanol and acetone several times and nanoparticles annealed at 200°C for 1 hour. Cadmium doped zinc oxide nanoparticles synthesize by same route by adding 0.002M Cadmium sulphate in 20 ml ethanol. XRD analysis shows a narrow line width indicates high crystalline nature of synthesize material. With help of Debye-Scherer's formula particle size obtained 21nm for pure ZnO and 18 nm for Cd doped ZnO respectively. FTIR analysis confirms Cd presence in ZnO nanolattice due to shift of vibrational frequency to lower frequency side.SEM image reveals polycrystalline, porous morphology with interconnected grains present on pure ZnO nanoparticles. With UV-Vis spectra, band gaps found 3.1eV and 3.2eV for pure and doped ZnO. Antibacterial activity of pure and doped ZnO is due to chemical interaction between hydrogen peroxide and membrane proteins or between chemical produced in presence of pure and Cu doped ZnO nanoparticles and outer bilayer of Bacteria.

10) ZnO Thin film deposited on polyethylene Terephthalate (PET) and silicon substrate by reactive DC magnetron sputtering.XRD used to investigate crystallographic nature of ZnO thin films. Thickness of film controlled by changing deposition time to study influence of coating on antimicrobial activity. Thickest coating reduces bacterial load which is important characteristics for food packaging applications. Ag doping causes morphological change in ZnO thin films.Simillarly, increase in silver content, decrease of E.Coli growth rate is observed.

11) ZnO thin films coated on glass substrate by alternately dipping in Sodium zincate bath at room temperature and in hot water at 90-95°C.Dopping of cadmium done by adding 3% cadmium chloride in Sodium zincate bath. Prepared film annealed at 450°C for half an hour.XRD shows wurtzite hexagonal structure having particle size calculated by Debye- Scherer's formula are found 26.9nm and 17.5nm for pure ZnO and 3% Cd: ZnO respectively. Cd doped ZnO shows more activity against bacteria than pure ZnO.

12) Zinc Acetate Dehydrates (ZAD), Ethanol and monoethanolamine used as precursor, solvent and stabilizing agents respectively. 0.1 ZAD dissolved in Ethanol. Mixture of this solution with MEA stirs for 45 minutes at room temperature having pH value neutral. This solution acts as cationic precursor solution and hot deionised water acts as anionic precursor solutions. Glass substrate alternately dipped in this solution for different time. Prepared films annealed at 250°C, 350°C and 450°C for one hour. Potato dextrose agar medium dispensed in petridish and spores of fungi shake into distilled water added to petridish in equal proportion with agar medium. Calculate thickness of film by using gravimetric weight difference method found 673,549 and 630nm for 250°C, 350°C and 450°C respectively. XRD confirms intensity of peaks in diffraction pattern is simultaneously increased with increasing temperature. FESEM confirms that films are homogeneous.Antifugal activity of 350° annealed ZnO thin films is high as compared to other films.

13) Zinc oxide synthesis due to ease of deposition of technique, efficiency and cost-effectiveness having antibacterial property useful in surface coating in food packages. For synthesis using spray pyrolysis, 0.1M $ZnCl_2$ aqueous solution used as precursor.SEM reveals randomly oriented grains in surface of films.The results from antibacterial experiments indicate that ZnO films yielded low antibacterial activity against bacteria E.Coli and S.aureus in agar diffusion assays.

Summary:

Sr no	Synthesis method	Nanostructure	Source	Application	Doppant
1	Spray pyrolysis	Thin film	$Zn(CH_3COO)_2$	Antibacterial activity	Magnesium(Mg)
2	Low temperature solution combustion method	Nanoparticle	Zinc nitrate	Biomedical	------
3	Co-precipitation method	Nanoparticle	$ZnNO_3$	Antibacterial activity	------
4	Aerosol-assisted chemical vapour deposition	Thin Film	$Zn(Oac)_2.2H_2O$	Antimicrobial activity	Copper(Cu)
5	Sucessive ionic layer adsorption reaction(SILAR)	Thin Film	Zinc Acetate Dehydrates	Antibacterial & antifugal activity	-----
6	RF magnetron sputtering	Thin Film	Zinc Acetate	Antibacterial activity	Silver(Au)
7	Anodizing	Thin film	Zinc foil	Antibacterial activity	----
8	Sol-gel spin coating	Thin Film	Zinc nitrate hexahydrate	Antibacterial activity	Cobalt, manganese and copper
9	Co-precipitation method	Nanoparticle	Zinc Acetate	Antibacterial activity	Cadmium
10	Reactive DC magnetron sputtering	Thin Film	Zinc target	Antibacterial activity	Silver(Ag)
11	Sucessive ionic layer adsorption reaction(SILAR)	Thin Film	Sodium Zincate	Antibacterial activity	Cadmium
12	Sucessive ionic layer adsorption reaction(SILAR)	Thin Film	Zinc Acetate Dehydrates	Antifugal	-----
13	Spray pyrolysis	Thin Film	$ZnCl_2$	Antibacterial activity	-----

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