Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

Synthesis of Ni-Ag-ZnO Solid Solutions Nanoparticles for Photoreduction and Antimicrobial Applications

Sania Naseer, [a] Muhammad Aamir, [a]* Muhammad Aslam Mirza, [a] Uzma Jabeen, [b] Raja Tahir, [c] Muhammad Najam Khan Malghani, [d] and Qamar Wali [e]

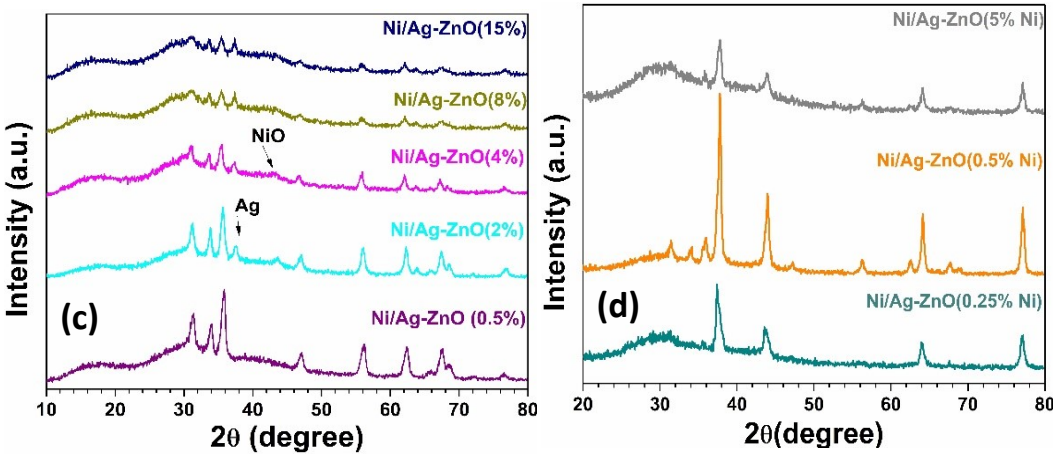


Figure S1 Comparative XRD spectra of (a) pure ZnO, Ni-ZnO (1:1 molar ratio) and Ag-ZnO (1:1 molar ratio) NPs samples. (b) Focused spectra indicate the shift in diffraction peak by the Ni and Ag incorporation in ZnO.

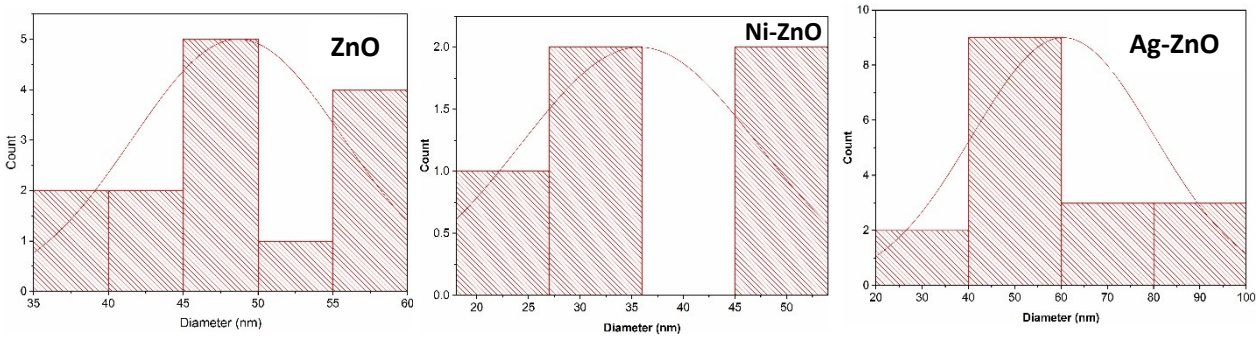


Figure S2. Size distribution histograms of (a) ZnO (b) Ni-ZnO (c) Ag-ZnO

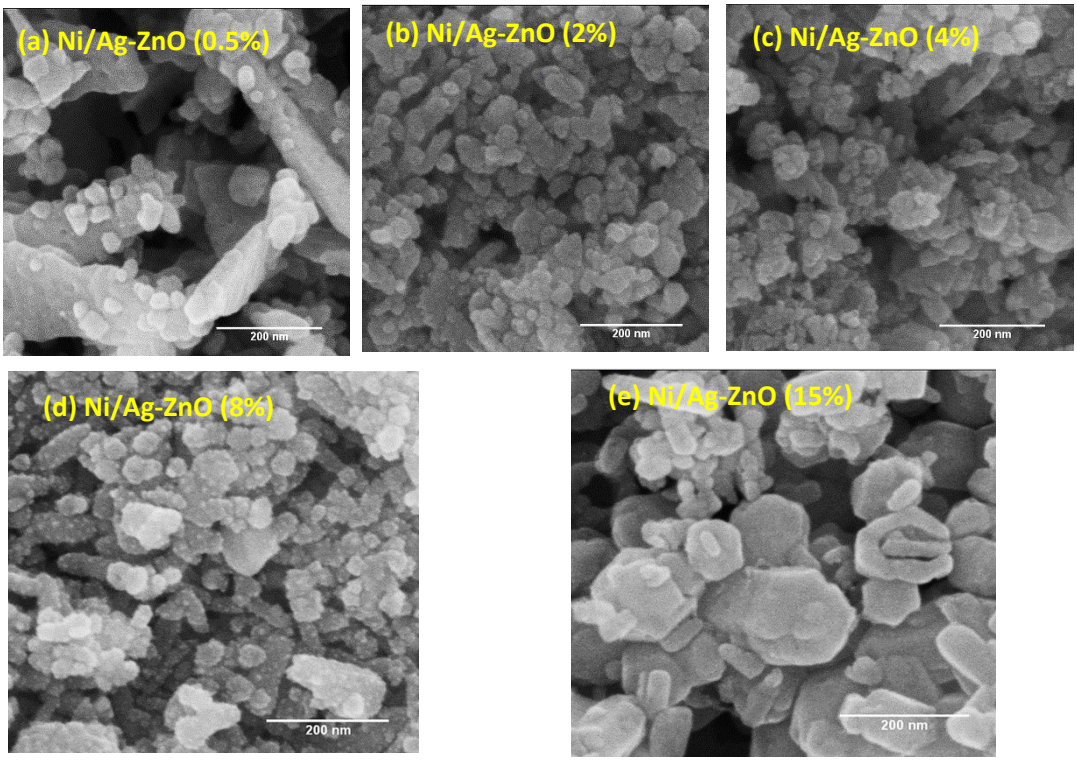


Figure S3. SEM micrograps of (a) Ni/Ag-ZnO (0.5%) (b) Ni/Ag-ZnO (2%) (c) Ni/Ag-ZnO (4%) (d) Ni/Ag-ZnO (8%) (e) Ni/Ag-ZnO (15%)

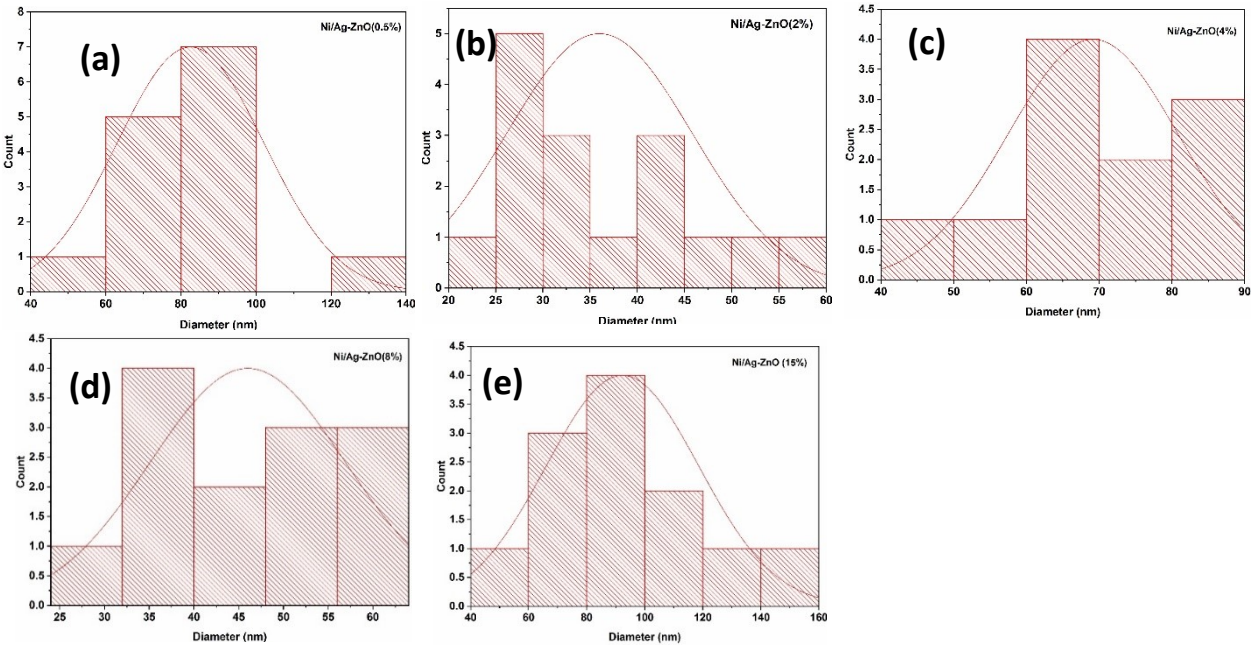


Figure S4. Particle size histograms of (a) Ni/Ag-ZnO(0.5%) (b) Ni/Ag-ZnO(2%) (c) Ni/Ag-ZnO(4%) (d) Ni/Ag-ZnO (8%) (e) Ni/Ag-ZnO (15%).

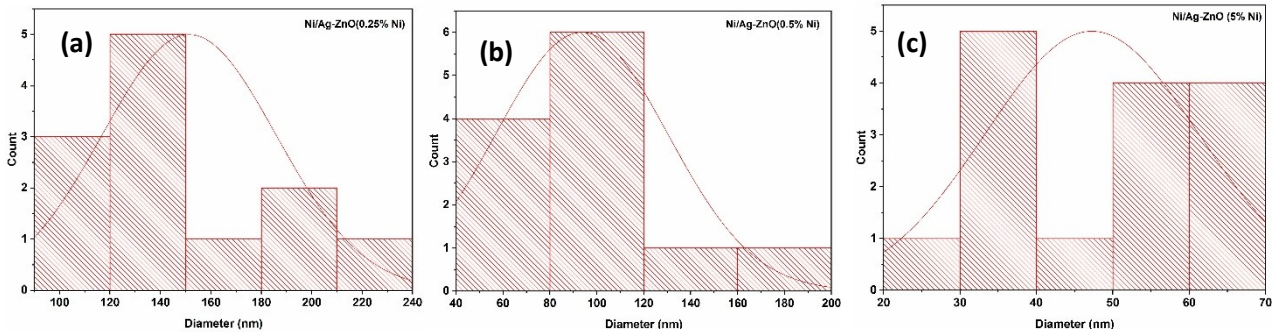


Figure S5. Particle size distribution graphs of (a) Ni/Ag-ZnO(0.25% Ni) (b) Ni/Ag-ZnO (0.5% Ni) (c) Ni/Ag-ZnO (5% Ni).

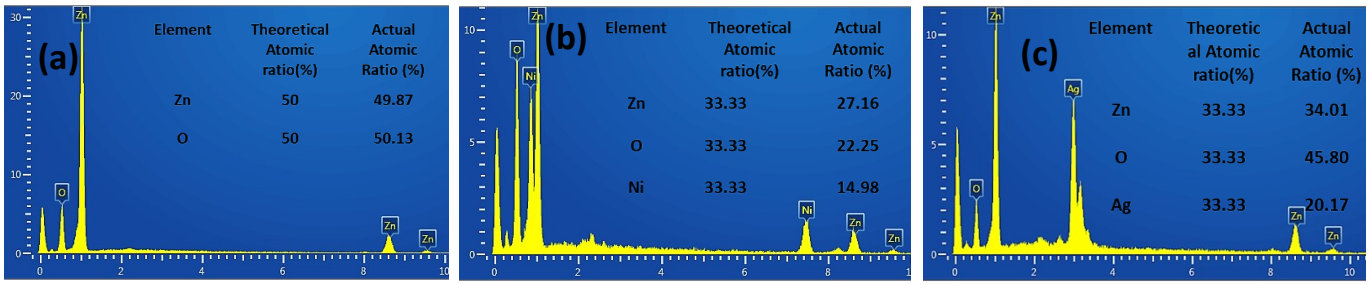
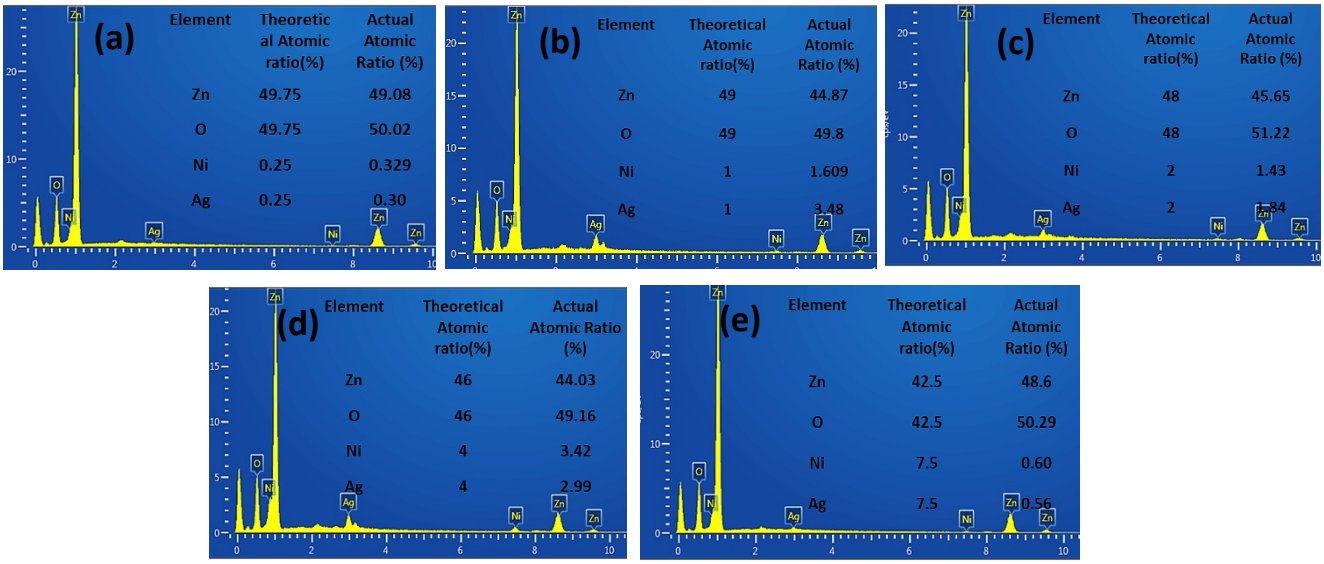
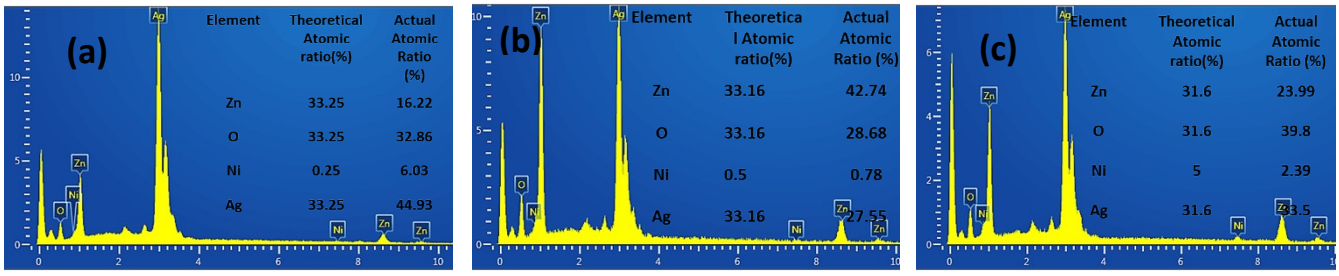


Figure S6. EDS spectra and elemental compositions of (a) ZnO (1:1) (b) Ni-ZnO (1:1) (c) Ag-



ZnO (1:1).

Figure S7. EDS spectra and elemental composition of (a) Ni/Ag-ZnO(0.5%) (b) Ni/Ag-



ZnO(2%) (c) Ni/Ag-ZnO(4%) (d) Ni/Ag-ZnO(8%) (e) Ni/Ag-ZnO(15%)

Figure S8. EDS spectra and elemental composition of (a) Ni/Ag-ZnO(0.25% Ni) (b) Ni/Ag-ZnO(0.5% Ni) (c) Ni/Ag-ZnO(5% Ni)

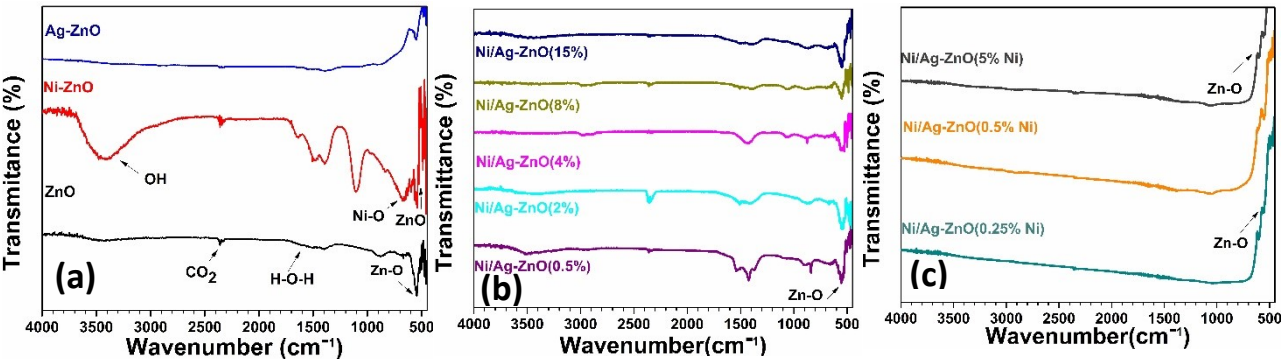


Figure S9. FTIR spectra of (a) pure ZnO, Ni-ZnO (1:1), and Ag-ZnO (1:1), (b) Ni/Ag-ZnO (0.5, 2, 4, 8, 15%), (c) Ni/Ag-ZnO (0.25, 0.5, 5% Ni).

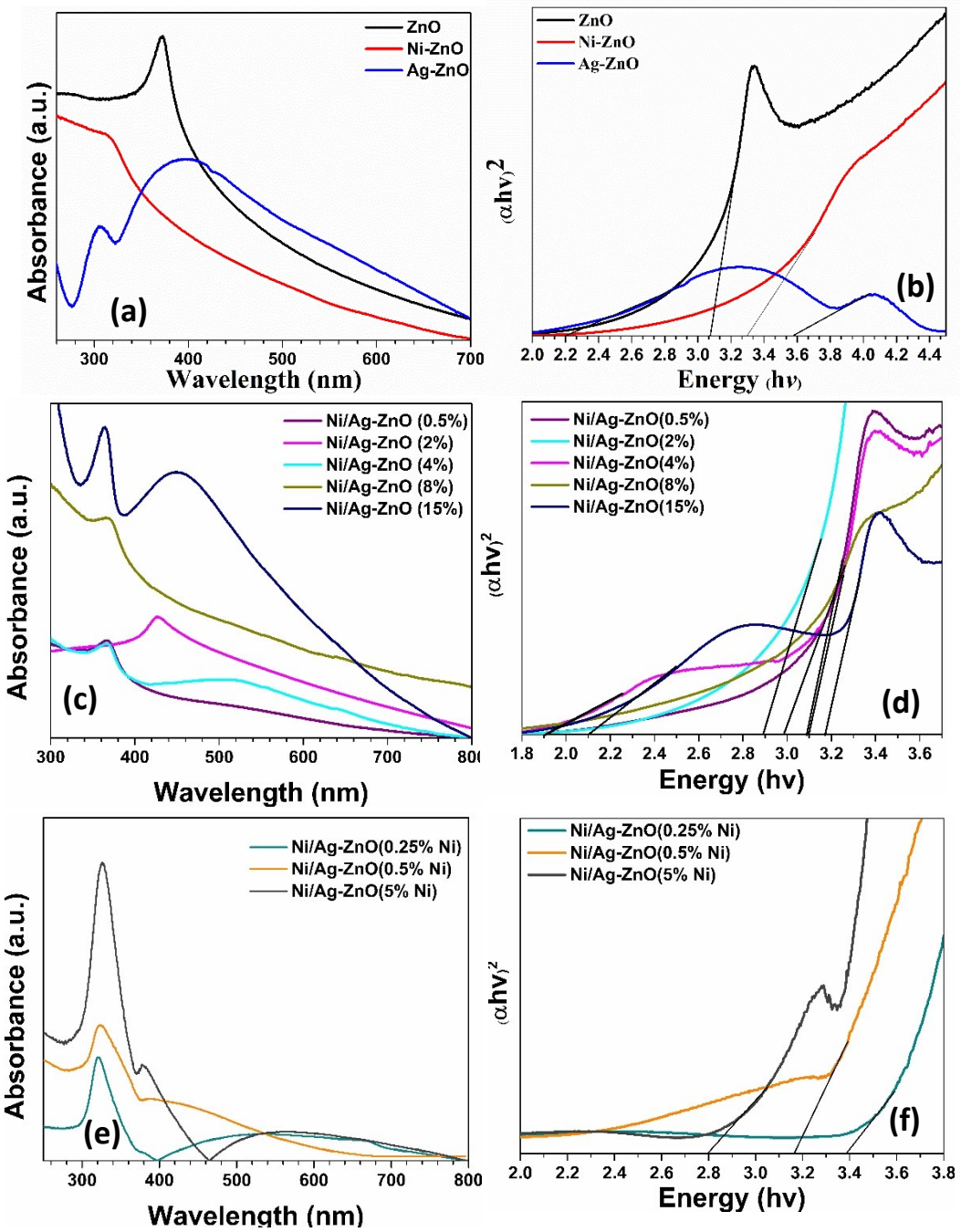


Figure S10. UV-vis absorption spectra of pure ZnO, Ni-ZnO and Ag-ZnO and (b) is the tauc's plot of pure ZnO, Ni-ZnO and Ag-ZnO (c-d) Ni/Ag-ZnO (0.5, 2, 4, 8, 15%), and (e-f) Ni/Ag-ZnO (0.25, 0.5, 5% Ni).

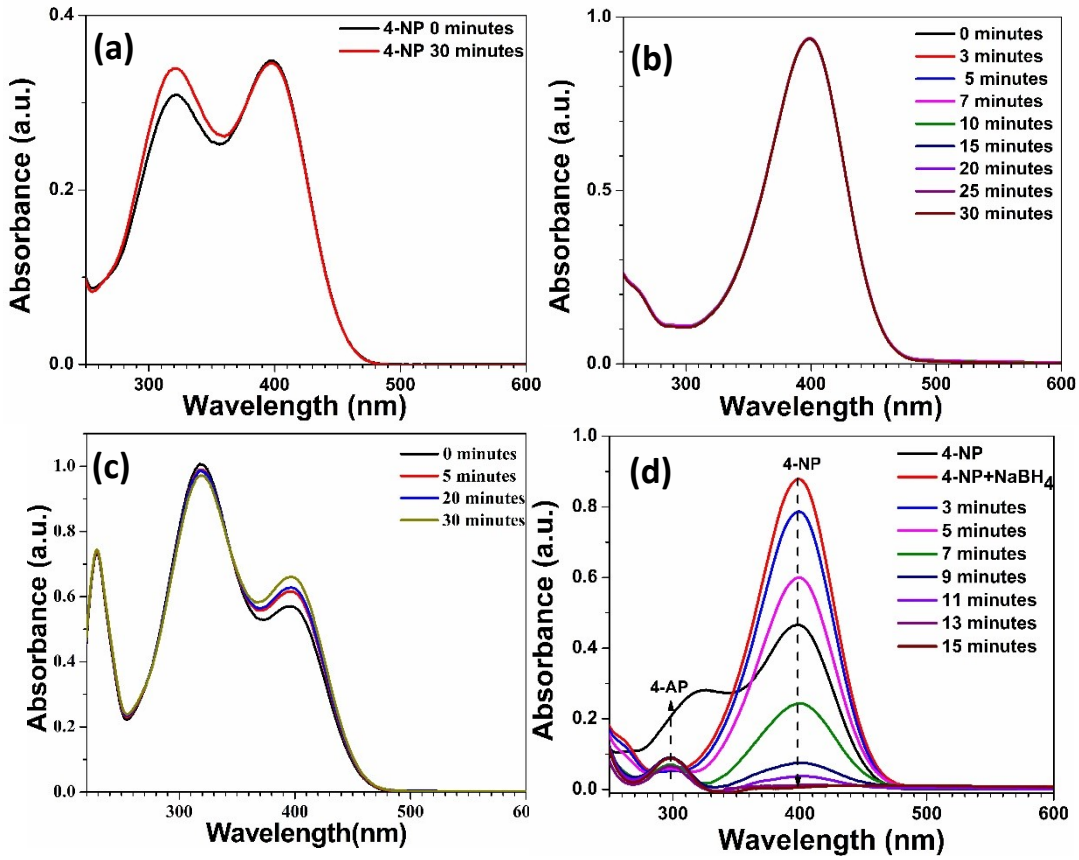


Figure S11. UV-Vis absorption spectra of (a) 4-NP (b) 4-NP + $NaBH_4$ (c) 4-NP + catalyst and (d) 4-NP + $NaBH_4$ + catalyst under light irraiations.

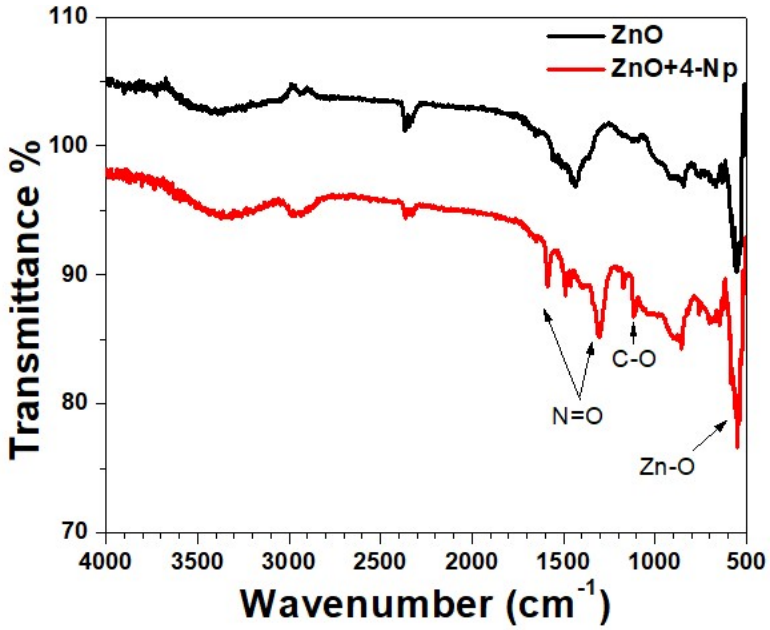


Figure S12. FTIR spectrunm of untreated ZnO NPs and 4-nitrophenolate solution treated ZnO NPs.

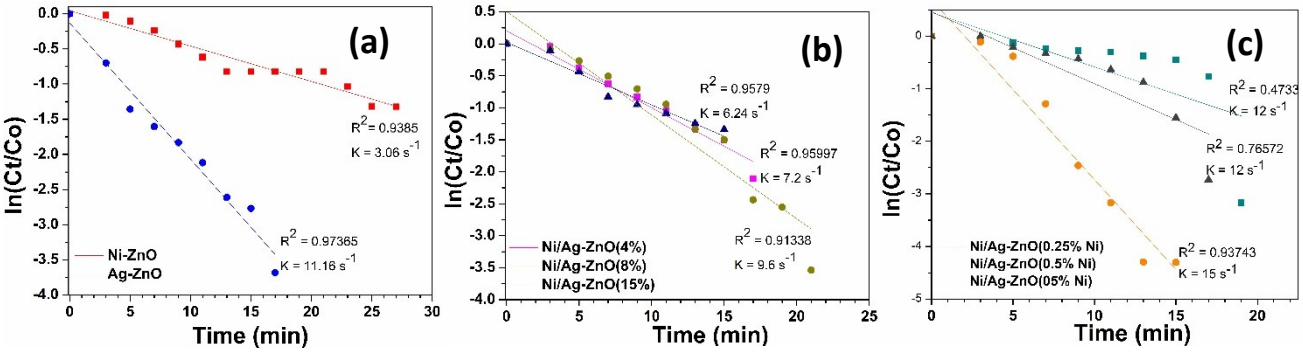


Figure S13. Kinetics studies of 4-NP reduction (a) ln(ct/Co) vs t graph of Ni and Ag-ZnO (b) ln(ct/Co) vs t graph of Ni/Ag-ZnO (4, 8, 15%) (c) ln(ct/Co) vs t graph of Ni-Ag-ZnO (0.25, 0.5, 5% Ni).

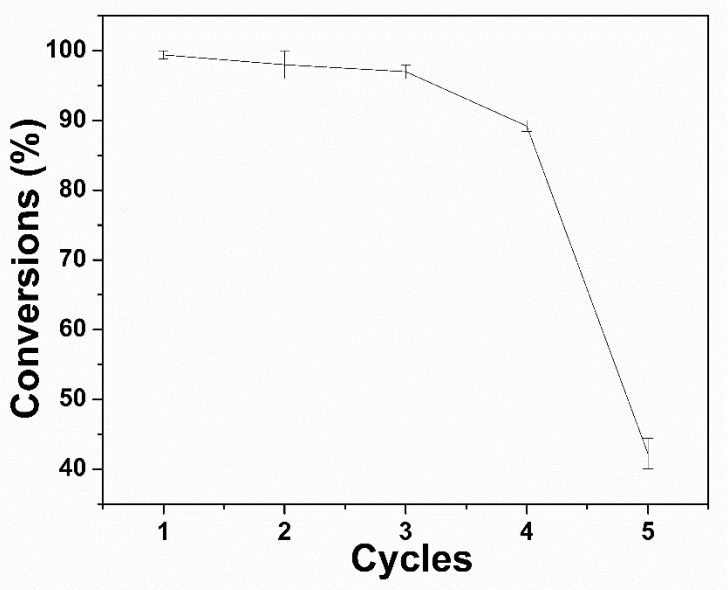


Figure S14. Conversion effeciency of as prepared nanopartilces.

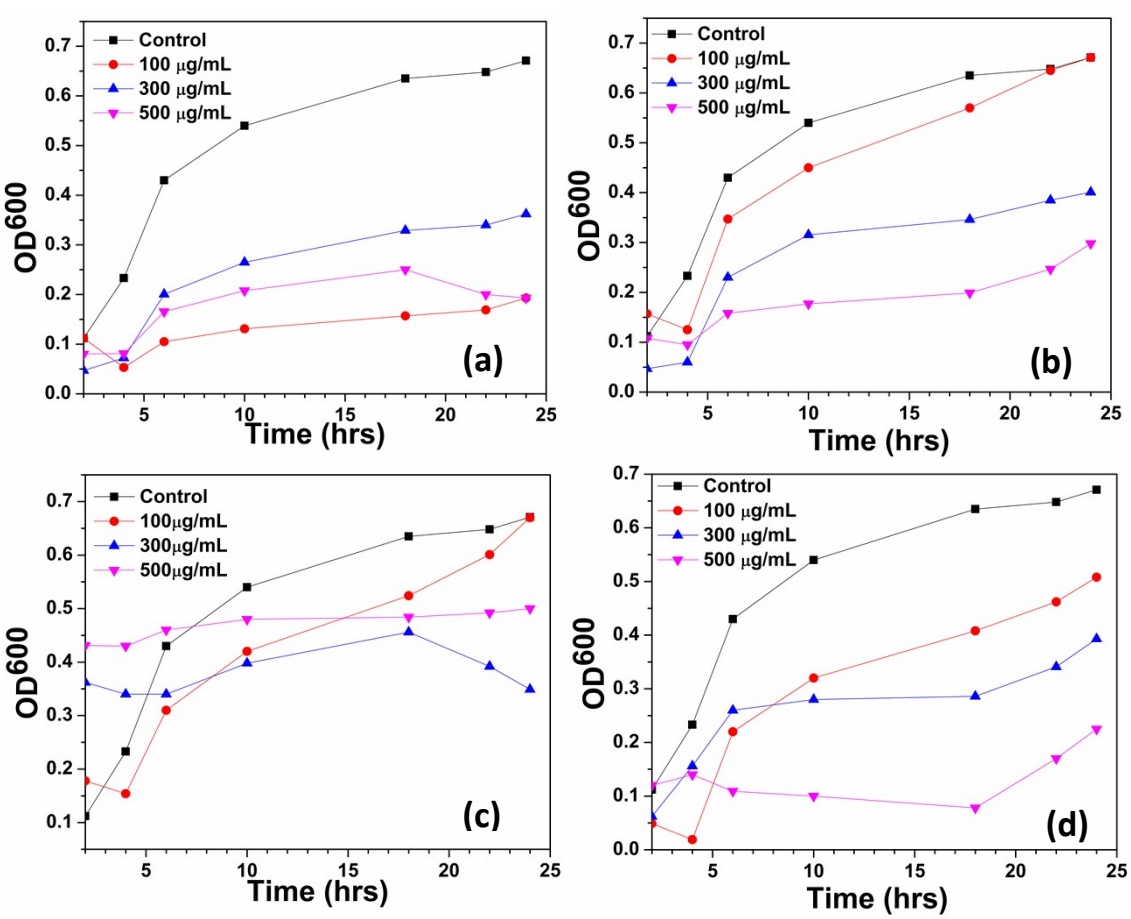


Figure S15 Growth inhibition pattern of E.coli by (a) Ni-ZnO (b) Ag-ZnO Growth inhibition pattern of E.coli by (a) Ni/Ag-ZnO (8%) (b) Ni/Ag-ZnO (5% Ni)

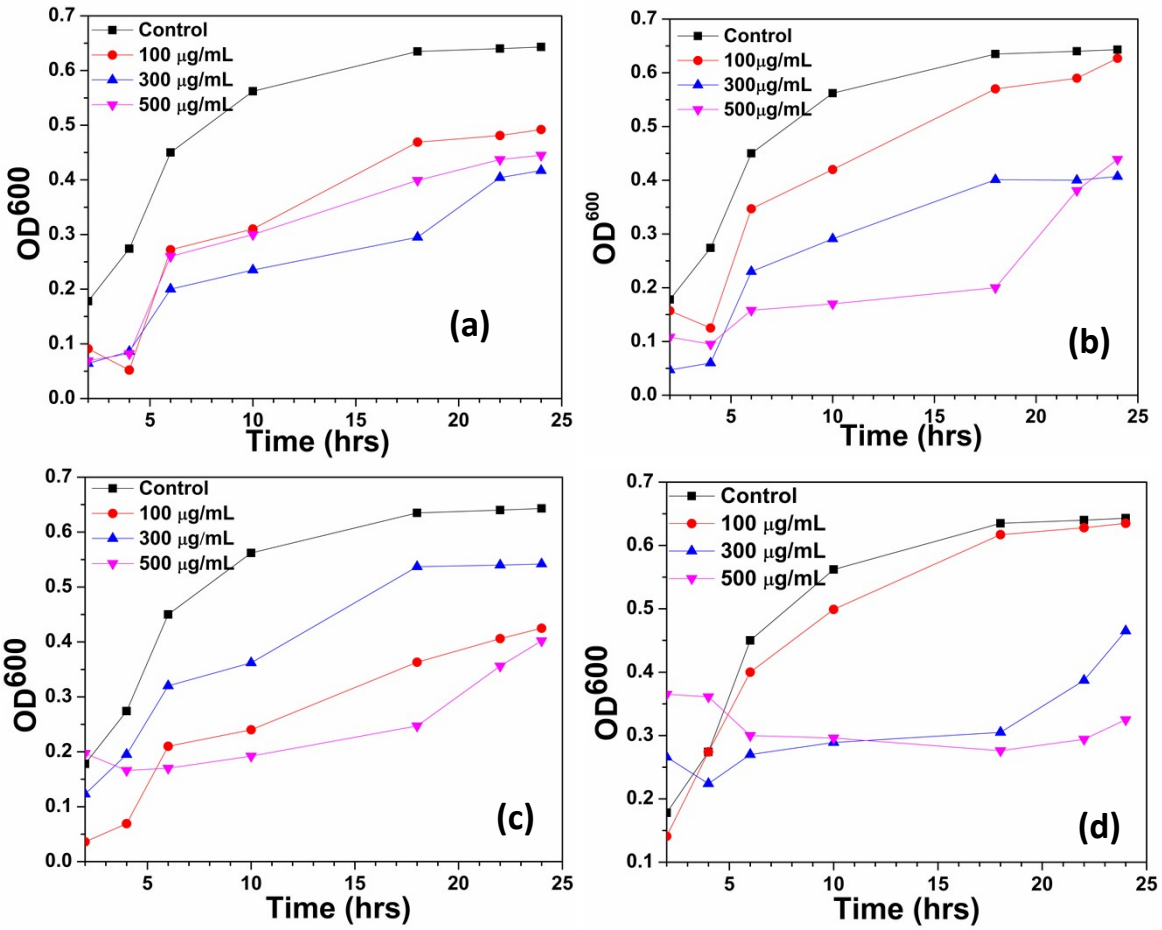


Figure S16 Growth inhibition pattern of S. aureus by (a) Ni-ZnO (b) Ag-ZnO (c) Ni/Ag-ZnO (8%) (d) Ni/Ag-ZnO (5% Ni)

Catalyst	Catalyst loading	Reaction time	References
Bare ZnO	30 mg	No conversion	present work
Ag NPs	30 uL, 20 mg, 10 uL	12 min, 45 min, 8 min	[1],[2],[3]
Ni NPs	-	16 min.	[4]
Ag-ZnO	30 mg	17 min.	Present work
Ni-ZnO	30 mg	27 min.	present work

Table S1. Performance comparison of bare ZnO, Ag and Ni NPs, and Ag, Ni doped ZnO NPs based catalyst

Table S2. The information on lattice parameters of of pure ZnO and solid solutions of Ni/Ag-ZnO.

Catalysts	**Lattice Parameters (Å)**		**c/a ratio**	Volume of **Lattice (Å)³**
	a	**c**		
Pure ZnO	3.27237	5.24424	1.602582	48.6338
Ni-ZnO	5.25877	4.13472	0.786252	99.0252
Ag-ZnO	5.10661	4.45977	0.873333	100.7186
Ni/Ag-ZnO (0.5%)	4.35472	4.36707	1.002836	71.7201
Ni/Ag-ZnO (2%)	5.02675	4.37858	0.871056	95.8163
Ni/Ag-ZnO (4%)	5.06451	4.40038	0.868866	97.7451
Ni/Ag-ZnO (8%)	4.9832	4.25153	0.853173	91.431
Ni/Ag-ZnO (15%)	5.06384	4.35156	0.85934	96.6352
AgZnO(1:1)/Ni(0.25%)	4.730665	4.4134	0.932934	86.22098
Ag-ZnO(1:1)/Ni(0.25%)	4.9326	4.39713	0.891443	92.6512
Ag-ZnO(1:1)/Ni(0.25%)	5.18904	4.57409	0.881491	106.6621

References:

1. Safari, J.; Enayati Najafabadi, A.; Zarnegar, Z.; Farkhonde Masoule, S. J. G. C. L.; Reviews, Catalytic performance in 4-nitrophenol reduction by Ag nanoparticles stabilized on biodegradable amphiphilic copolymers. **2016,** *9* (1), 20-26.
2. Saha, S.; Pal, A.; Kundu, S.; Basu, S.; Pal, T. J. L., Photochemical green synthesis of calcium-alginate-stabilized Ag and Au nanoparticles and their catalytic application to 4-nitrophenol reduction. **2010,** *26* (4), 2885-2893.
3. Kaur, J.; Singh, J.; Rawat, M. J. S. A. S., An efficient and blistering reduction of 4-nitrophenol by green synthesized silver nanoparticles. **2019,** *1* (9), 1-6.
4. Jiang, Z.; Xie, J.; Jiang, D.; Wei, X.; Chen, M. J. C., Modifiers-assisted formation of nickel nanoparticles and their catalytic application to p-nitrophenol reduction. **2013,** *15* (3), 560-569.