

Sustainable Green Synthesis of CeO₂-ZnO Nanocomposites using *Rhazya stricta*: Enhanced Synergistic Solutions for Biomedical Challenges and Environmental Remediation

Amjid Khan^{1,2,3*}, Tauqeer Ahmed Qadri⁴, Rashid Abbas Khan^{1,2,3}, Dilawar Hassan^{1,2,3}, Bushra Ashiq⁵, Ayesha Sani^{1,2,3}, Zabta Khan Shinwari⁶, Malik Maaza^{1,2,3*}

¹UNESCO-UNISA Africa Chair in Nanosciences and Nanotechnologies, College of Graduate Studies, University of South Africa, 1 Preller Street, Muckleneuk Ridge, P.O. Box 392, Pretoria, Gauteng Province, 0003, South Africa

²Nanosciences African Network (NANOAFNET), Materials Research Department, iThemba LABS-National Research Foundation, Western Cape Province, South Africa

³African Centre of Competencies in Enhanced Nanosciences & Nanotechnologies for SDGs (ACCENTS), 1 Preller Street, Muckleneuk Ridge, P.O. Box 392, Pretoria, Gauteng Province, 0003, South Africa

⁴Department of Biosciences, COMSATS University Islamabad, Islamabad-45550, Pakistan

⁵Department of Biomedical Engineering, Research Center for Nano-biomaterials & AMP; Regenerative Medicine, College of Artificial Intelligence, Taiyuan University of Technology, Taiyuan 030024, PR China

⁶Department of Plant Sciences, Faculty of Biological Sciences, Quaid-i-Azam University, Islamabad, 45320, Pakistan

*** Correspondence:**

Amjid Khan. Email: khana2@unisa.ac.za

Malik Maaza. Email: maazam@unisa.ac.za

Table S1. FTIR Absorption Bands and Functional Group Assignments of RS Extract, CeNPs, ZnNPs, and Ce-Zn Nc.

Sample	Wavenumber (cm^{-1})	Assigned Functional Group (s)	Possible Chemical Bonds / Vibrations
RS	2925	C–H stretching	Alkanes/Terpenoids
	1645	C=O / N–H Stretching	Amide I (Proteins)
	1052	C–O stretching	Ethers/Alcohols
CeNPs	3392	O–H stretching	Capping interaction
	2913	C–H stretching	Alkanes
	1612	C=O stretching	Carbonyl groups
	523	Ce–O Stretching	Cerium Oxide formation
ZnNPs	3371	O–H stretching	Polyphenol involvement
	1602	C=O stretching	Amides/Carbonyls
	544	Zn–O stretching	Zinc Oxide formation
Ce-Zn Nc	3292	O–H Stretching	Capping stabilization
	1705	C=O Stretching	Carboxylic acids
	1516	Aromatic C=C Stretching	Flavonoids/Aromatic rings
	515	M–O Stretching	Bimetallic Oxide junction

Table S2. Raman Shift Bands and Functional Group Assignments of CeNPs, ZnNPs, and Ce-Zn Nc.

Sample	Raman Shift (cm ⁻¹)	Assigned Vibrations	Possible Chemical Bonds / Functional Groups
CeNPs	70	Lattice vibrations	Metal oxide lattice modes
	2919	C-H stretching	Alkanes/Methyl groups
	3525	O-H / N-H stretching	Hydroxyl/Amine groups
ZnNPs	76	Lattice vibrations	Metal oxide lattice modes
	3017	C-H stretching	Alkanes/Capping residues
	3526	O-H stretching	Hydroxyl groups
Ce-Zn Nc	68	Lattice vibrations	Bimetallic lattice modes
	2927	C-H stretching	Alkanes
	3411	O-H / N-H stretching	Hydroxyl/Amine groups