The Synthesis of Core-Shell Nanowires with Intense Dielectric and

Magnetic Resonance Properties at Microwave Frequency

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1. Experimental Section.

1.1 Materials

Silver nanowires (Ag NW) were purchased from XFNANO Scientific Co., Ltd. (Nanjing, China). Cobalt chloride hexahydrate (CoCl₂·6H₂O, 99%), Zinc nitrate hexahydrate (Zn(NO₃)₂·6H₂O, 99%), 2-methylimidazole (2-MIM, 98%), methanol (99.5%), and ethanol (95%) were purchased from Titan Scientific Co., Ltd, Shanghai, China. Other reagents were used without further purification.

1.2 Synthesis of AZ-Zn

In the synthesis process, methanol was used as the solvent. Firstly, Ag nanowires (80 mg), $Zn(NO_3)_2 \cdot 6H_2O$ (0.82 g) and methanol (500 ml) were mixed in a 1000 mL beaker and stirred for 1 h at room temperature. Then, 100 mL of 2-MIM (0.56 M) was added to the above solution drop by drop, the mixture solution was placed at room temperature with slowly stirring for 15 h. Afterwards, the as-obtained product was collected by filtration, washed with ethanol for several times, and dried at 50 °C under vacuum.

1.3 Synthesis of AZ-Co

In the synthesis process, methanol was used as the solvent. Firstly, Ag nanowires (80 mg), $CoCl_2 \cdot 6H_2O$ (0.806 g) and methanol (500 ml) were mixed in a 1000 mL beaker

and stirred for 1 h at room temperature. Then, 100 mL of 2-MIM (0.56 M) was added to the above solution drop by drop, the mixture solution was placed at room temperature with slowly stirring for 15 h. Afterwards, the as-obtained product was collected by filtration, washed with ethanol for several times, and dried at 50 °C under vacuum.

1.4 Synthesis of AZ-CoZn

In the synthesis process, methanol was used as the solvent. Firstly, Ag nanowires (80 mg), $Zn(NO_3)_2 \cdot 6H_2O$ (0.61 g), $CoCl_2 \cdot 6H_2O$ (0.203 g) and methanol (500 ml) were mixed in a 1000 mL beaker and stirred for 1 h at room temperature. Then, 100 mL of 2-MIM (0.56 M) was added to the above solution drop by drop, the mixture solution was placed at room temperature with slowly stirring for 15 h. Afterwards, the asobtained product was collected by filtration, washed with ethanol for several times, and dried at 50 °C under vacuum.

1.5 Pyrolysis of AZ-Zn, AZ-Co and AZ-CoZn

The as-synthesized three products were annealed under argon atmosphere. The samples were heated to 600 °C at a heating rate of 2 °C per minute, where it remained for 5 h in tube furnace, their calcined products were named PAZ-Zn, PAZ-Co and PAZ-CoZn, respectively.

1.6 Characterization and Measurement

The detailed morphologies of the products were observed with a field emission scanning electron microscope (SEM, S4800, Hitachi), transmission electron microscope (TEM, Tecnai G2 F30, FEI) and a high-resolution transmission electron microscope (HR-TEM, Tecnai G2 F20, FEI). The crystal structure of the as-synthesized samples was identified by X-ray diffractometer (XRD, X' Pert Pro, Philips), using Cu K α (λ = 1.54 Å) radiation source (40.0 kV, 30.0 mA). Fourier transfor infrared (FT-IR) spectra were recorded on a Nicolet iS10 FT-IR instrument (Thermo Fisher Scientific, USA). Raman spectroscopy (RAMAN, Aramis) was carried out using a Renishaw in Via Raman Microscope, equipped with a 532 nm laser. The thermo-gravimetric analysis was carried out on an SDT Q600 TGA (TA Instruments) in the temperature range of

room temperature to 700 °C at a heating rate of 10 °C/min. The relative complex permittivity (ε_r) and permeability (μ_r) were measured by a vector network analyzer (VNA, N5242A PNA-X, Agilent) in a frequency range of 2-18 GHz. The tested samples were prepared 10 wt.% mass percentage of samples in wax, and then pressed into cylindrical specimens with an outer diameter of 7.00 mm and inner diameter of 3.04 mm.

2. Supporting Figures.



Figure S1. TEM images of AZ-Zn.



Figure S2. Element mapping analysis of AZ-Zn.



Figure S3. TEM images of AZ-Co.



Figure S4. Element mapping analysis of AZ-Co.



Figure S5. TEM images of AZ-CoZn with Co/Zn ratio of 3:1.



Figure S6. Element mapping analysis of AZ-CoZn with Co/Zn ratio of 3:1.



Figure S7. SEM images of PAZ-Zn.



Figure S8. XRD patterns of AZ-Zn and PAZ-Zn.



Figure S9. Element mapping analysis of PAZ-Zn.



Figure S10. FT-IR spectra of AZ-Zn and PAZ-Zn.



Figure S11. Raman spectra of AZ-Zn and PAZ-Zn.



Figure S12. SEM images of PAZ-Co.



Figure S13. XRD patterns of AZ-Co and PAZ-Co.



Figure S14. Element mapping analysis of PAZ-Co.



Figure S15. FT-IR spectra of AZ-Co and PAZ-Co.



Figure S16. Raman spectra of AZ-Co and PAZ-Co.



Figure S17. XRD patterns of AZ-CoZn and PAZ-CoZn.



Figure S18. FT-IR spectra of AZ-CoZn and PAZ-CoZn.



Figure S19. Raman spectra of AZ-CoZn and PAZ-CoZn.



Figure S20. Hysteresis loops of AZ-Zn, PAZ-Zn PAZ-Co and PAZ-CoZn at room temperature.



Figure S21. The measured complex permittivity of AZ-Zn with filler-loading ratio of (a) 5 wt.% and (b) 15 wt.% in wax.



Figure S22. The measured complex permittivity of (a) AZ-Co and (b) AZ-CoZn a fillerloading ratio of 10 wt.% in wax.



Figure S23. The measured complex permeability of AZ-Zn with filler-loading ratio of (a) 5 wt.% and (b) 15 wt.% in wax.



Figure S24. The measured complex permeability of (a) AZ-Co and (b) AZ-CoZn a filler-loading ratio of 10 wt.% in wax.



Figure S25. RL values of AZ-Zn.



Figure S26. RL values of PAZ-Co.