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Research Article

Multifunction of Ni/Ag Nanocompound Fluid

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An arc-submerged nanoparticle synthesis system (ASNSS) is proposed and developed for fabricating Ni/Ag nanocompound fluid. In the development process, the positive and negative electrodes in the system are Ni and Ag, respectively. Applied electrical energy then produces heating source by generating an adequate arc with a high temperature that can melt and vaporize the two electrodes. The nanocompound fluid that is generated by the synthesis system is analyzed by morphological analysis, Zeta potential analysis, heat conductivity analysis, magnetic characteristic analysis, and UV-Vis absorption spectra analysis. Experimental results show that increasing the concentration of added particles and the higher temperature can be helpful to the enhancement of thermal conductivity. The Ni/Ag nanofluid not only preserves the magnetic character of the nickel and the ability of silver to absorb visible light but also enhances the thermal conductivity. The absorption occurs at 406 nm wavelength (redshift from 396 nm to 406 nm), which means that, under the excitement of visible light range (400~700 nm), it can let more easy electrons jump to the conductivity zone from the valence electron zone.

1. Introduction

Ni nanofluid is ferromagnetism and can be used to target drug to treat localized disease. The applications of nanomagnetic particles have recently been expanded to such fields as biomedicine, ferrofluids, data storage, and others. Clinically, drugs against cancer can be desorbed from [1]. Nickel, a magnetic material, is also widely used, in electrical generators, adaptors, tape recorders, and other devices [2, 3].

Considering metallic silver (Ag) as a multifunctional material, the antimicrobial effects of Ag ion or salts are well known; the National Aeronautics and Space Administration used silver containers to preserve the purity of drinking water on spacecraft in the 1970s. Silver foil was used to protect wounds from infection during Word War I [4, 5].

In the fabrication process, the positive electrode uses an Ag rod and the negative electrode uses a Ni rod, and the two electrodes are processed in the dielectric liquid to form Ni/Ag nanofluid [5, 6]. Nanocomposite fluid is analyzed by morphological analysis, heat transfer analysis, and magnetic analysis. Nanocomposite fluid had a small size of a nanomaterial, and the number of atoms on its surface increases with its volume and the surface potential also increases and an increase in the concentration of the added particles and temperature rise can be helpful to the enhancement of thermal conductivity [7, 8]. Furthermore, when the wavelength of illumination light is in the range of 410 nm~800 nm, the produced Ni/Ag nanocomposite fluid has stronger light absorbance.

2. Materials and Methods

Low-pressure control methods for ASNSS were proposed and developed for the Ni/Ag nanofluid, which is a suspension of nanoparticles in deionized water [6]. Figure 1 shows the schematic of fabrication system. The pressure control system uses the pressure differential created between the chamber bodies of the working chamber and collection chamber to induce the particles that become nucleus after vaporization into the collection chamber from the working chamber. The nanofluid collection system and cooling circulation system precondense the dielectric liquid to maintain a low temperature during the collection of nanofluid and further suppress the overgrowing and clustering of the particles.

The particles suspended in the loading solution will lower its reactivity in a low temperature environment and they will

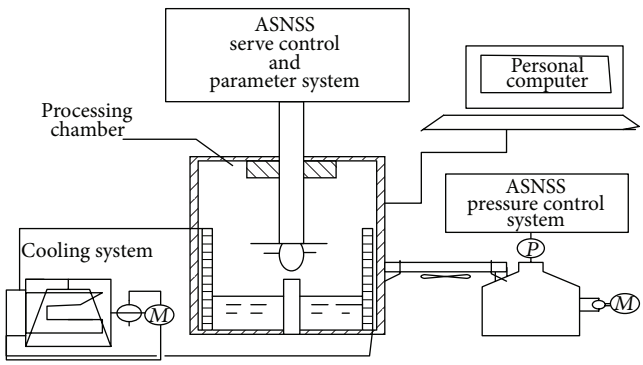

Figure 1: Schematic of fabrication system.

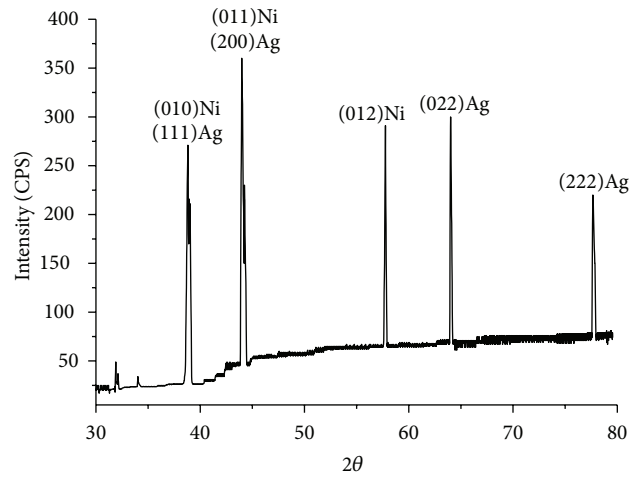

Figure 2: XRD pattern of nanocompound fluid.

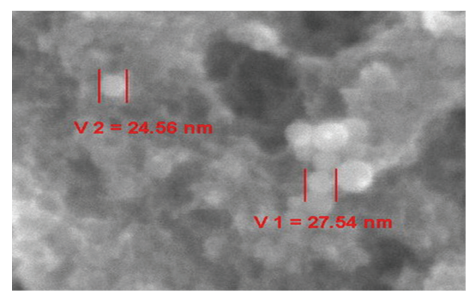

Figure 3: FE-SEM image showing the Ni approach to sphere.

steadily become nuclii because of their difficulty in continuous growth, acquiring smaller nanoparticles. Finally, the collected Ni/Ag nanocomposite fluid is extracted for relative examination of its material properties.

The high energy produced by an electrical arc will vaporize the metal into vapor. The theory of droplet nucleus generated by vapor can be used to approximate the crystalline nucleus generated by balanced gas phase. Supersaturated vapor would generate cluster of molecular agglutination. Nucleation requires a considerable amount of undercooling to grow into a crystal. There are two kinds of free energy changes that must be considered: (1) the surface energy required to form the new solid surfaces and (2) the volume free energy released by the liquid-to-solid transformation. The free energy change, ΔG, of the generated globe with radius of r during the process of clustering can be expressed as the following equation:

$$\Delta G = 4\pi r^2 \sigma + \frac{4}{3}\pi r^3 \Delta G_v \quad (1)$$

in which σ is the interfacial tension and ΔG_v is the free energy change during the generation of unit dimensional liquid by the vapor. The process parameters of this device can be controlled by different working currents. A nanofluid collection system and cooling circulation system are used to precondense the deionized water so as to maintain a low temperature during the collection of nanofluid and further suppress the overgrowing and clustering of the particles. X-ray diffraction (MAC-MXP18) is used to obtain the pattern of nanoparticles. Through XRD analysis, the related XRD pattern of the nanocompound fluid under analysis is shown in Figure 2.

FE-SEM (EM0039) and a Decagon KD2 measure meter also are used to obtain the nanoparticles' images and the thermal conductivity. To analyze their magnetic properties, a Superconducting Quantum Interference Device Magnetometer (MPMS7) is used with magnetic field intensity set from -10^5 to $+10^5$ Gauss at 25°C. Meanwhile, Zeta meter is used to analyze the produced nanoparticle suspension and through UV-vis light absorption spectrum meter the absorbency can be tested.

3. Results and Discussion

Comparing the peaks generated in Figure 2, the compound fluid is associated with Ni and Ag. EDS and FEG-SEM are used to check the further identification and confirmation can check the fluid particle's components and appearance. Figure 3 shows that the Ni particles are in ionic state and will form metallic oxides after reacting with oxygen ions in water, which would form a more spherical shape. In Figure 4, the FEG-SEM shows the figure of nonoxidized Ag.

The Zeta potentials of mixed Ni/Ag nanocomposite fluids with different pH values are measured. The results in Figure 5 reveal that when the pH value of the produced nanofluid is about 9.6 and the Zeta potential carried on the particles is zero, this is called the isoelectric point (IEP). As the surface potential becomes farther from the IEP, the suspension becomes more stable.

When the pH value is greater than 9.6, the surfaces of the particles carry negative charge. Figure 6 plots the ratio of coefficient of thermal conductivity. A higher Ni/Ag nanofluid concentration is associated with higher thermal conductivity, clearly verifying that adding nanoparticles improves the coefficient of thermal conductivity of the working fluid. The effect of temperature can be evaluated as follows. When the temperature of the working fluid is 10°C, the curves of concentration (wt%) versus thermal conductivity coefficients

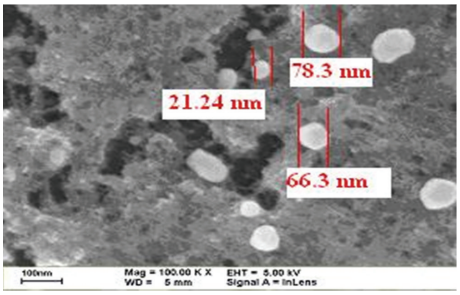

Figure 4: FE-SEM image showing the almost spherical Ag approach.

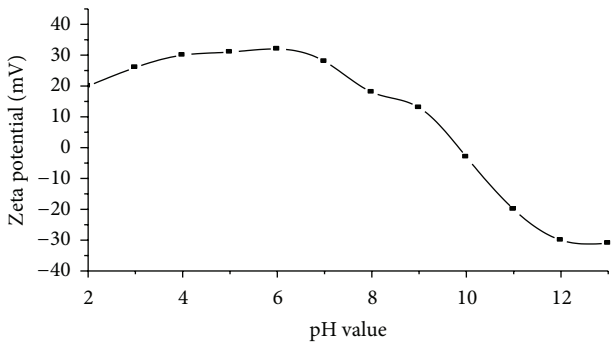

Figure 5: Zeta potential and the pH value.

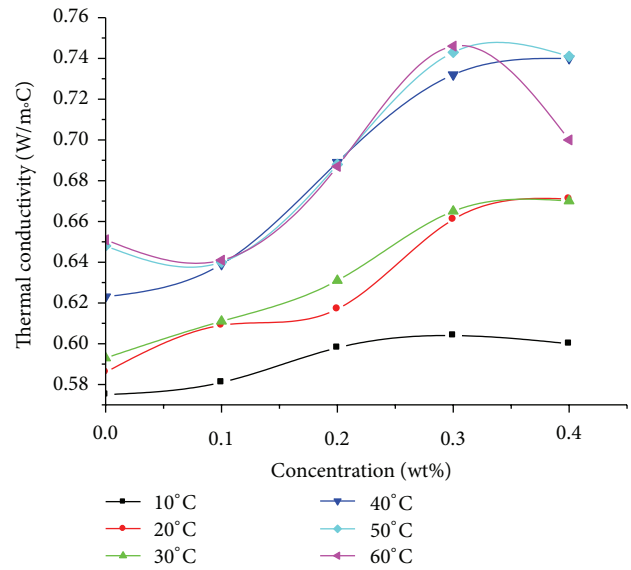

Figure 6: Weight concentration (wt%) versus thermal conductivity.

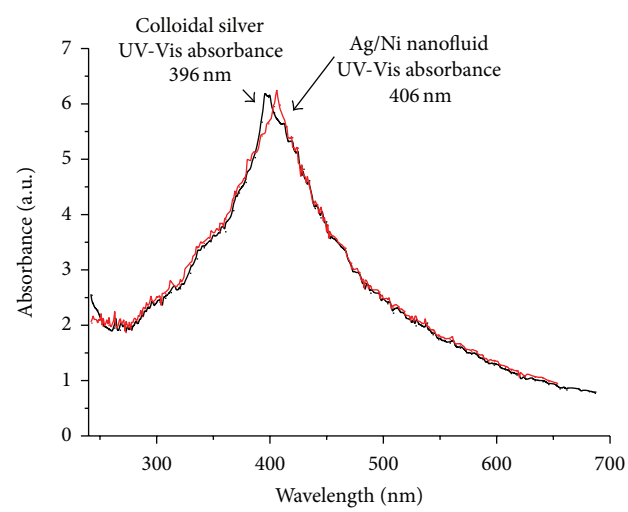

Figure 7: UV-Vis absorption spectra of colloidal silver and Ni/Ag nanofluid.

approach linearity. At 30°C, the curve is similar to that at 40–60°C but with a steeper slope. When the temperature reaches 60°C, the curve's slope becomes negative for 0.4% weight concentration. The weight concentration between 0.3 and 0.4% is in negative slope. It seems to the nanoparticle's cluster due to temperature rising, especially in temperature at 60°C. The temperature dependence of the thermal conductivity enhancement is considered to be attributed to the variation of Brownian motion velocity for the particles. As the cluster is decreased, the effect of random motion becomes dominant. The experiment reveals that when the temperature exceeds 30°C and concentration (wt%) is over 0.3%, particles in the nanocompound fluid would aggregate to form sediment at a certain ratio, which will reduce the thermal conductivity of nanofluid. Overall, this experiment has shown that both temperature and concentration will have substantial influence on the thermal conductivity coefficient of a nanofluid. By comparing the rates of temperature rise and concentration (wt%) rise, the influence of thermal conductivity coefficient ratio to the rate of temperature rise is clear.

Figure 7 presents the UV-Vis absorption spectra of a suspension of silver nanoparticles and reveals that their absorbance is maximal at around 396 nm; this result has been confirmed elsewhere. The UV-Vis absorption spectrum of Ni/Ag nanofluid is redshifted and its absorbance is maximal at about 406 nm so it has greater ability to absorb visible light.

Figure 8 displays that the Ni/Ag nanofluid's saturated magnetized amount at 0.895 emu/g is smaller than Ni nanofluid's saturated magnetized amount at 0.905 emu/g and saturated strength is 1250 Oe. The hysteresis slopes are very close to each other. The residual magnetism and coercive force are close to zero, confirming that the magnetic particles are superparamagnetic particles. For 0.4% Ni/Ag weight concentration in this work, it is too small for saturated magnetized amount to change. That is, the reason for adding Ag in Ni did not improve the properties of Ni.

4. Conclusions

Based on above results and analyses, we propose the following three conclusions concerning the Ni/Ag nanocompound fluid.

(1) The thermal conductivity experiment confirmed that a higher Ni/Ag nanofluid concentration is associated

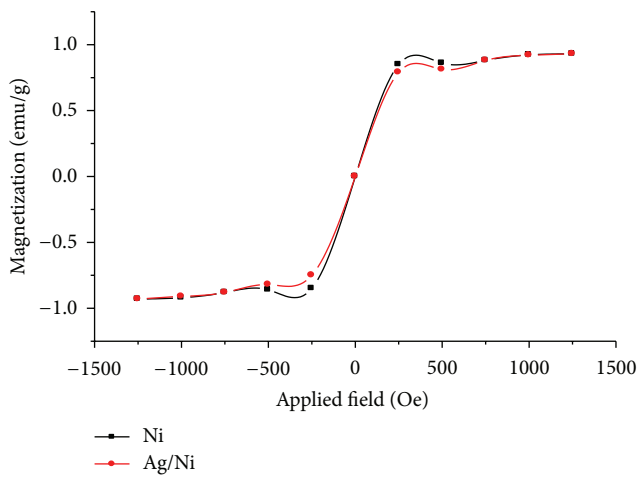

Figure 8: Hysteresis curve of Ni and Ni/Ag nanofluid.

with higher thermal conductivity and therefore better heat transfer.

(2) Ni/Ag nanocompound fluid absorbs at 406 nm wavelength (redshifted from 396 nm to 406 nm), so it can be excited under visible light (400~700 nm).

(3) Ni/Ag nanofluid has a residual magnetism and coercive force close to 0, confirming that its particles are superparamagnetic particles. The Ni/Ag nanofluid not only preserves the magnetic character of the nickel and the ability of silver to absorb visible light but also enhances the thermal conductivity.

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