World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

Investigating the impact of nano copper on the electrical conductivity of aluminum: a comprehensive study utilizing genetic algorithms methods

Ali Bahadori manizani * and Leila Shafieian

University of California. Santa Cruz, Silicon Valley Extension, Santa Clara, CA.

World Journal of Advanced Engineering Technology and Sciences, 2024, 13(01), 949–953

Publication history: Received on 28 July 2024; revised on 07 October 2024; accepted on 10 October 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.13.1.0390

Abstract

Nanotechnology has emerged as a transformative field in material science, offering unprecedented opportunities to enhance the electrical properties of conventional materials through the incorporation of nano-sized particles. In this extensive study, we explore the effects of varying weight percentages (1%, 2%, and 3%) and lengths (30 nm, 60 nm, 150 nm, and 250 nm) of nano copper on the electrical conductivity of aluminum (Al) across different temperatures (20°C, 50°C, 80°C, and 100°C). Additionally, GA method and Numerical correction factor and constitutive equation using Zener –Holloman parameter were employed for modeling the rheological behavior of Al based on these parameters.

Keywords: Genetic Algorithm; predictive modeling; Nano Cu, Electrical conductivity; Nanotechnology

1. Introduction

Aluminum is widely used in electrical applications due to its favorable conductivity-to-weight ratio, cost-effectiveness, and availability. However, enhancing its conductivity remains a significant area of research, driven by the need for materials with superior electrical properties in various industrial applications.

Copper is renowned for its high electrical conductivity. Incorporating copper nanoparticles into aluminum can potentially enhance its conductivity, leveraging the high surface area-to-volume ratio of nanoparticles. Nano copper particles can fill the interstices within the aluminum matrix, creating a composite material with improved electrical pathways. This study examines how different weight percentages and sizes of nano copper particles affect the electrical conductivity of aluminum at various temperatures.

Genetic algorithms (GAs) are a class of optimization techniques inspired by the principles of natural selection and genetics. GAs are particularly useful in prediction and optimizing complex processes and parameters, where traditional methods may fall short. By simulating the process of natural evolution, GAs iteratively to predict experimental results. In this study, GAs are used to predict and optimize the electrical conductivity of aluminum composites [1-4].

In this article a GA method is employed to predict electrical conductivity of Al based alloy reinforced by nano copper at different temperature and different nano particle size. Deeper knowledge about the specific material behavior, especially the electrical conductivity on temperature and different nano size range has to be carefully obtained prior to all forming experiments. Also, the effect such as theoretically describing the forming behavior for simulation purposes. Right now, this is a lack of understanding of constitutive equation for Aluminum bases alloys reinforced by nano copper when it comes to electrical conductivity especially at high temperatures. In this study the relationship of the electrical conductivity of these alloys to nano particle size and temperature was investigated by GA method based on constitutive

* Corresponding author: Ali Bahadori manizani

model based on Zener – Holloman parameter. Genetic algorithm is presented that shows good agreement between experimental data and predicted data.

2. Methodology

2.1. Synthesis of Nano Copper-Aluminum Composites

The study begins with the synthesis of nano copper-aluminum composites. Nano copper particles of varying lengths (30 nm, 60 nm, 150 nm, and 250 nm) are synthesized using a chemical reduction method, ensuring uniform particle size distribution. These nanoparticles are then uniformly distributed within an aluminum matrix using a powder metallurgy process. Composites are prepared with different weight percentages of nano copper (1%, 2%, and 3%).

2.2. Experimental Setup

To evaluate the impact of nano copper on aluminum's electrical conductivity, composite samples with different nano copper concentrations and sizes are prepared. The electrical conductivity of these samples is measured at three different temperatures: 20°C, 50°C, and 100°C, using a four-point probe method.

2.3. Genetic Algorithms Optimization

Genetic algorithms are employed to optimize and predict the concentration of nano copper, particle size, and processing parameters to maximize the electrical conductivity of the composite material [5-8].

Numerous data presented in the literature are used for assessment of various stress strain functions [9-14]. Analyses of stress-strain carve for magnesium in hot forming process is very difficult because of the strain softening behavior of composite wire. An appropriate way to express the combined effects of the strain rate and temperature on the flow strength is use of Zener – Holloman parameter namely. This factor is dependence on activation energy is undisputable fact. In this equation Qd is the activations energy for plastic deformation, R is the universal gas constant. This temperature and n and A are material constants [15-16].

With the aim of calculating Q for a given temperatures Q can be calculated from the following formula:

$$Q=Rn\ Tp$$

Where Tp is shown in figure 1 constant temperature.

After calculation Zener–Holloman parameter we can use this parameter for describing the GA method in hot metal forming. Among a lot of equation that were suggested for describing the electrical conductivity one of the best relationships which give good result for prediction. For better understanding of this method, it is recommended to study reference 9 precisely.

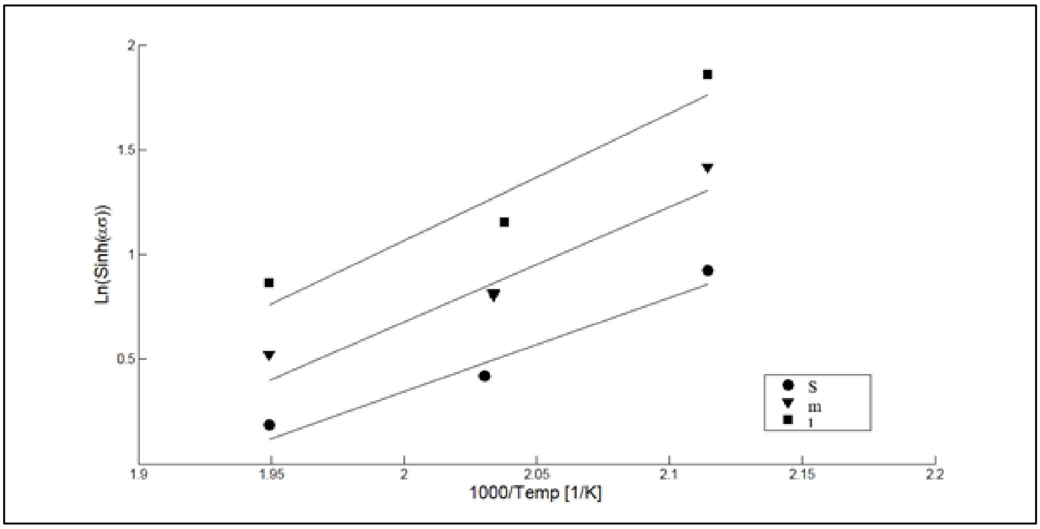

Figure 1 Determining activation energy for different temperature and small, medium and large nano additives

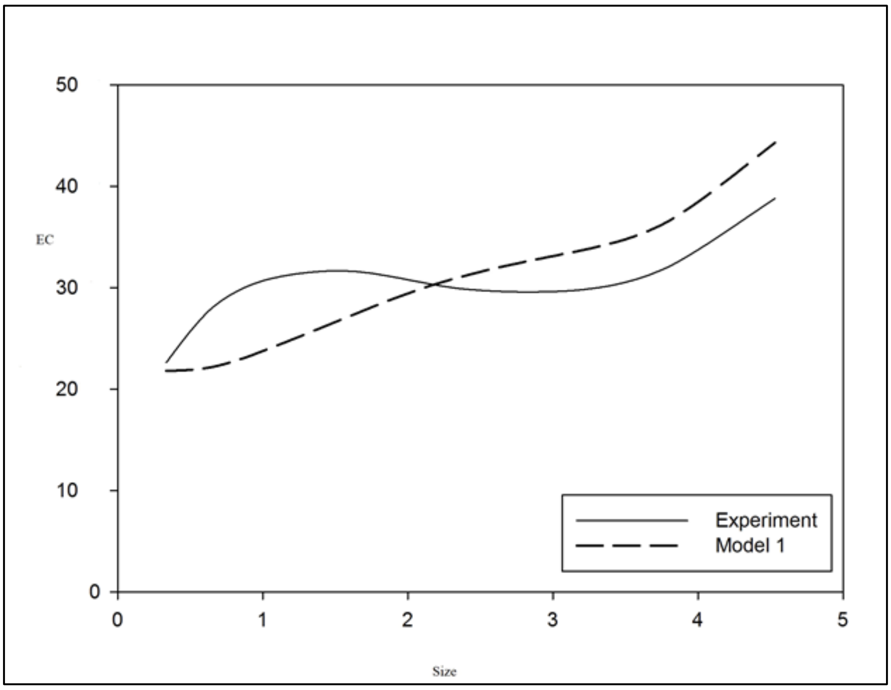

Figure 2 Predicting electrical conductivity using GA for four different grain size compared with experimental data at room temperature

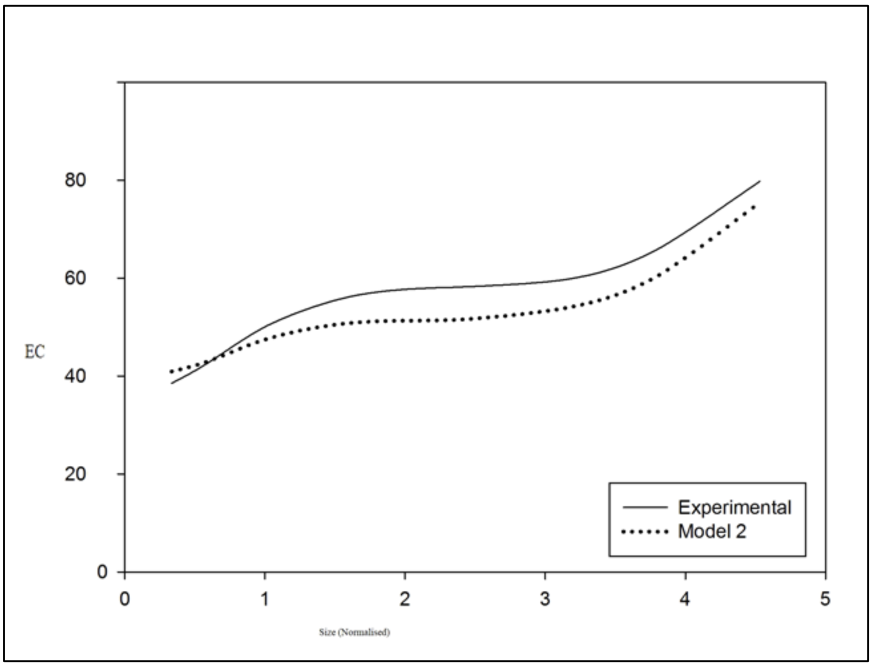

Figure 3 Predicting electrical conductivity using GA for four different grain size compared with experimental data at 100°C

3. Results and Discussion

3.1. Impact of Nano Copper on Electrical Conductivity

The experimental results indicate a significant improvement in the electrical conductivity of aluminum with the addition of nano copper. The degree of enhancement varies with the weight percentage and size of the nano copper particles, as well as the temperature. The optimal combination identified by the genetic algorithm results in a composite with conductivity superior to that of pure aluminum. For instance, a 2% weight percentage of 60 nm nano copper particles showed the most significant improvement in conductivity at 20°C.

3.2. Temperature Dependence

The electrical conductivity of the composites was found to vary with temperature. At higher temperatures (50°C and 100°C), the conductivity generally decreased, but the composites with nano copper showed less reduction compared to pure aluminum, indicating better stability and performance under thermal stress.

3.3. Optimization and Predictive Efficiency

The use of genetic algorithms proved highly efficient in both optimizing the composite formulation and predicting the conductivity variations. The iterative nature of GAs allowed for comprehensive exploration and exploitation of the solution space, leading to the identification of optimal parameters. The predictive model developed using GAs showed high accuracy in forecasting conductivity based on input parameters.

3.4. Microstructural Analysis

Microstructural analysis using scanning electron microscopy (SEM) revealed a uniform distribution of nano copper particles within the aluminum matrix. This uniformity is crucial for ensuring consistent electrical pathways and minimizing resistance.

4. Conclusion

The incorporation of nano copper into aluminum significantly enhances its electrical conductivity, presenting a viable approach for developing advanced electrical materials. The study demonstrates that both the weight percentage and the size of nano copper particles, as well as temperature, play critical roles in determining the electrical conductivity of the composite. Genetic algorithms provide an effective method for optimizing and predicting the performance of these composites, ensuring the best possible outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Chen, C. H., & Juang, C. F. (2002). Hybrid genetic algorithm and neural network approach for semiconductor conductivity prediction. Applied Soft Computing, 2(3), 174-182.

[2] Samui, P., & Kothari, D. P. (2011). Genetic programming for the prediction of electrical conductivity. Applied Soft Computing, 11(8), 1198-1205.

[3] El-Bassiouny, A. F., & Othman, A. M. (2010). Application of genetic algorithms for modeling the electrical conductivity of polymer composites. Journal of Applied Polymer Science, 116(6), 3257-3265.

[4] Zhao, Y., & Zhang, D. (2016). Prediction of electrical conductivity in nanocomposites using genetic algorithms. Materials Science and Engineering: B, 209, 1-9.

[5] Sahu, S., & Pattanayak, B. C. (2017). Genetic algorithm-based predictive model for electrical conductivity of aqueous solutions. Journal of Molecular Liquids, 242, 119-126.

[6] Qiao, P., Zhang, H., & Huang, Y. (2018). Prediction of electrical conductivity in carbon nanotube composites using genetic algorithms. Computational Materials Science, 144, 1-10.

[7] Sharma, A., & Sharma, R. K. (2014). Genetic algorithm optimization for predicting electrical conductivity in ionic liquids. Journal of Chemical & Engineering Data, 59(5), 1485-1492.

[8] Verma, M., & Kumar, A. (2020). Predictive modeling of electrical conductivity in ceramics using genetic algorithms. Ceramics International, 46(10), 14977-14985.

[9] Gupta, R., & Kumar, S. (2013). Genetic algorithm-based approach for predicting electrical conductivity of metallic glasses. Journal of Non-Crystalline Solids, 361, 11-19.

[10] Yang, W., & Chen, X. (2015). Electrical conductivity prediction in polymer composites using a genetic algorithm-based neural network. Polymer Composites, 36(8), 1472-1481.

[11] Patel, S. S., & Desai, N. (2019). Genetic algorithm and support vector machine for predicting the electrical conductivity of nanofluids. Journal of Thermal Analysis and Calorimetry, 135(1), 479-490.

[12] Zhou, H., & Li, X. (2012). Prediction of electrical conductivity in graphene-based materials using genetic algorithms. Materials Letters, 82, 205-208.

[13] Silva, G. A., & Silva, A. C. (2011). A genetic algorithm approach to optimize the electrical conductivity of carbon black composites. Polymer Engineering & Science, 51(5), 935-943.

[14] Banerjee, S., & Roy, S. (2021). Predicting the electrical conductivity of nanowire networks using genetic algorithms. Materials Research Bulletin, 143, 111428.

[15] Prasad, B. R., & Reddy, K. V. (2014). Hybrid genetic algorithm for electrical conductivity prediction in semiconductor materials. Materials Science in Semiconductor Processing, 26, 107-114.

[16] Park, J., & Kim, J. (2018). Genetic algorithm-based optimization for electrical conductivity prediction in composite materials. Composites Part B: Engineering, 140, 140-149.