Simulation of Resistivity in Silver and Copper Nanowire Composite Filament using Composite Filament Simulation 3D to predict the Resistivity of the Nanowire

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ABSTRACT

Aim: The aim of this research work is to determine and compare the electrical resistivity of silver and copper nanowire by using the Novel Composite Filament Simulation Tool. Materials and Methods: This study was carried out at the Simulation laboratory, Saveetha School of Engineering, Chennai. The sample size calculation was done using clinical.com by keeping alpha error-threshold by 0.05, enrollment ratio as 0:1, 95% confidence interval, power at 80%. Group 1 was silver nanowire (N=20) and group 2 was copper nanowire (N=20). The total sample size was 40. Results: Comparison of electrical resistivity is done by independent sample test using SPSS software. There is a statistical indifference between silver and copper nanowire. Copper nanowire (55%) showed higher resistivity in comparison to silver nanowire (45%). There appears to be a statistically insignificant difference (p=0.269, p>0.05) by using an independent sample T test. Conclusion: Silver nanowire appears to give better electrical conductivity than in copper nanowire.

Keywords
Nanowire, Silver nanowire, Copper nanowire, Electrical resistivity, Electrical properties, Novel Composite Filament Simulation Tool, Nanotechnology

INTRODUCTION

In nanotechnology, nanowires are thin wires composed of 10^-9 nm. Nanowires are promising materials for many novel applications (Gomes 2020). It is used for nano/biochemical sensors, data storage/transfer, batteries, generators, transistors, LEDs, optoelectronic devices. It has unique properties including physical (Vázquez 2015), electrical (Nam et al. 2013), mechanical and optical (Madkour 2019). Nanowires have potential impact on electronics, computers, memory, data storage, communications, manufacturing, health and medicine (Raj and Balwinder 2020).

About 10 google scholar and 7 science direct articles were found related to this work in the past few years. A research work propose that the silver nanowire gives a resistivity of 1 × 10^6 Ω cm for the volume range from 0.75 to 4 vol% and copper nanowire gives a resistivity of 1 × 10^8 Ω cm for the volume range from 1 to 4 vol% (Gelves et al. 2006). Electrical resistivity was found to increase as the wire width decreased and was found to be a result of surface and size effects (Huang et al. 2008). Electrical resistivity experiments done on nanowires having different volume fractions from 0.25 and 0.75 vol% shows the low percolation threshold (Nam et al. 2013). The resistivity increases once the wire width decreases below about 45–50 nm (Durkan and Welland 2000). Our team has extensive knowledge and research experience that has translate into high quality publications (Chellapa et al. 2020; Lavanya, Kannan, and Arivalagan 2021; Raj R, D, and S 2020; Shilpa-Jain et al. 2021; S, R, and P 2021; Ramadoss, Padmanaban, and Subramanian 2022; Wu et al. 2020; Kalidoss, Umapathy, and Rani Thirunavukkarasu 2021; Kaja et al. 2020; Antink et al. 2020; Paul et al. 2020; Malaikolundhan et al. 2020)

There are numerous reports on the determination of resistivity of nanowires such as silver, copper, gold etc. There are less reports on the determination of resistivity of the same while used as a matrix element in a nanocomposite. This work is to determine the electrical resistivity of silver nanowire and copper nanowire by its volume, alignment range and the resistivity is compared.

MATERIALS AND METHODS

This study of electrical properties was carried out using the Novel Composite Filament Simulation Tool.
at the Simulation laboratory, Saveetha School of Engineering, Chennai. The sample size calculation was done using past study results (Gelves et al. 2006) using clinical.com by keeping alpha error-threshold by 0.05, enrollment ratio as 0:1, 95% confidence interval, power at 80%. Group 1 was silver nanowire (N=20) and group 2 was copper nanowire (N=20). The total sample size was 40.

The dataset for calculating the electrical properties is obtained from (nanohub.org) by using the Novel Composite Filament Simulation Tool. The simulation of electrical resistivity was processed for silver and copper nanowire. And the comparison of resistivity was done between silver and copper nanowire. The resistivity was obtained by its alignment range. The size of Ag and Cu nanowire having diameter of 25 nm and a length of 10 to 20 μm, respectively was taken. In this tool the input parameters are given and the variable output is obtained. Where the tool has the nanowire diameter (nm) range from 25 to 250 nm, length ranges from 1 to 10 micrometre and the volume ranges from 1 to 10%. The Alignment limit is 90. It is done by the Monte Carlo method of simulation. This tool is used to process by entering the size and volume of the nanowire with respect to alignment range. First It will take a few mins of time and an output resistivity of nanowire in graphical representation is obtained.

Statistical Analysis

The accuracy learning is done by IBM SPSS software for the sample size of the nanowires Group 1 and Group 2 using an independent sample T test. Here, the independent variable is size and length and the dependent variable is alignment range.

RESULTS

In this study the sample size is simulated in accordance to their specific parameter, By using the Novel Composite Filament Simulation Tool. The simulation gives the electrical resistivity of the nanowires and the resistivity between silver and copper nanowire is compared. Table 1 represents the electrical resistivity of silver nanowire based on its alignment range and Table 2 represents the electrical resistivity of copper nanowire based on its alignment range. The copper nanowire had the highest accuracy, 65% in comparison to silver nanowire, 45%. These results showed that silver nanowire can be used for better conductivity in comparison with copper nanowire. The descriptive statistics in table 3 demonstrates the silver nanowire had less error rate than the copper nanowire. Table 4 demonstrates the independent sample T test in predicting using silver nanowire and copper nanowire. There appears to be a statistically insignificant difference (p=0.269; p>0.05) using an independent sample T test. This result shows that copper nanowires are significantly better than silver nanowires.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Alignment range (degrees θ)</th>
<th>Electrical resistivity Ωm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>4x10⁻⁶</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>6x10⁻⁶</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>8x10⁻⁶</td>
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<tr>
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<td>1x10⁻⁵</td>
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<td>4x10⁻⁵</td>
</tr>
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<td>8x10⁻⁵</td>
</tr>
<tr>
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<td>40</td>
<td>1x10⁻⁴</td>
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<td>9</td>
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</tr>
<tr>
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</tr>
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<td>11</td>
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<td>17</td>
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<td>20</td>
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<th>Electrical Resistivity Ωm</th>
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<tr>
<td>1</td>
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<td>2x10⁻⁶</td>
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<tr>
<td>2</td>
<td>10</td>
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<td>45</td>
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Table 3
Comparison of mean and accuracy using Silver Nanowire and Copper Nanowire.

<table>
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<tr>
<th>Parameter</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
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<tr>
<td>Resistivity</td>
<td>Silver Nanowire</td>
<td>20</td>
<td>0.00153</td>
<td>0.000760</td>
<td>0.000170</td>
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<td>Resistivity</td>
<td>Copper Nanowire</td>
<td>20</td>
<td>0.00187</td>
<td>0.00104</td>
<td>0.000234</td>
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Table 4
Independent sample T-test in predicting the accuracy of Resistivity using Silver nanowire and Copper nanowire. There appears to be a statistically insignificant difference (P=0.269>0.05).

<table>
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<tr>
<th>Resistivity</th>
<th>Leven's test for equality of variance</th>
<th>T-test for equality of variance</th>
<th>95% of confidence interval of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f</td>
<td>sig</td>
<td>t</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>0.273</td>
<td>0.269</td>
<td>-1.175</td>
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<tr>
<td>Equal variances not assumed</td>
<td>-1.175</td>
<td>34.689</td>
<td>0.248</td>
</tr>
</tbody>
</table>

Fig. 1 Comparison of electrical resistivity of silver nanowire and copper nanowire. Both the nanowires appear to have different results ranging from 45% to 55%. The X axis represents the comparison of Silver nanowire and Copper nanowire and the Y axis represents Electrical resistivity. Mean +/- 1SD.

DISCUSSION
To simulate the electrical resistivity of the nanowire by their alignment range and comparing the outcome of each other. The analysis of silver and copper nanowire the P value is obtained as 0.269 which is greater than 0.05 and it is insignificant.

A calculation indicates that the resistivity of nanowire increases significantly once the wire width decreases below 25 nm, at odds with our experimental observation (Durkan and Welland 2000). In nanotechnology, silver nanowire has gotten a lot of attention as a result of its great potential for applications and excellent electrical properties (Cheng et
The resistivity decreases when the volume is greater than 0.25% and 0.50% for the composites using the small-scale and the large-scale nanowires, respectively in CuNW (Lin et al. 2007). Low percolation threshold was measured in variation of size of the nanowire in 10^8 Ωm resistivity (Al-Saleh, Gelves, and Sundararaj 2011). The electrical resistivity of nanowire is independent of its size and area (Gu, Choi, and Kim 2006). The silver nanowire has a good transparent conducting network of resistance of...
6.5Ω/sq (Groep et al. 2012). CuNW composites are having highly electrical insulating properties (Yuan et al. 2018). Basically Nanowires have good electricity conducting properties where the silver nanowire has better conductance than copper nanowire (Langley et al. 2013). Therefore in comparison of electrical resistivity copper nanowire has higher resistivity than silver nanowire. From this silver nanowire appears to have high conductivity. Silver nanowire has high electrical conductance and flexibility in many applications (Ji et al. 2019).

Limitations of this work include decrease in the conductivity of the silver nanowires while used in nanocomposite. This could be due to the short circuit in the wires due to agglomeration. In the future, dispersion of nanowires could be enhanced to increase the conductivity of silver and can be implemented in the nanodevices as such memory devices for huge memory storage.

CONCLUSION

In this study of the nanotechnology field, simulation on resistivity the copper nanowire obtained had better resistivity than silver nanowire. It performs significantly better than silver nanowire. The simulation tool appeared to give better resistivity to copper nanowire (55%) than silver nanowire (45%). This shows that silver nanowire has better conductivity. The electrical resistivity also increases with decrease in size of nanowire.

DECLARATION

Conflicts of Interests
No conflict of interest in this manuscript.

Authors Contribution
Author MHS was involved in data collection, data analysis, and manuscript writing. Author SCK was involved in conceptualization, data validation, and critical review of manuscript.

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4. Saveetha School of Engineering.

REFERENCES


