Carbon nanotubes (CNTs) are promising materials due to their outstanding mechanical and electrical properties. However, the electrical percolation threshold obtained in epoxy/carbon nanotube (CNT) nanocomposites is one of the lowest among conductive nanocomposites. There exist research efforts to improve the electrical percolation threshold of epoxy/CNT with the addition of silver nanoparticles. The aim of this novel work is to use biosynthesized silver nanoparticles (GAg.NPs) as a replacement for high-cost Ag.NPs for the enhancement of the electrical properties of epoxy/CNT. The nanocomposites were produced by using 0.1, 0.2, 0.3, 0.4 and 0.5% CNTs and 0.5% GAg.NPs in the epoxy matrix. The morphology, electrical conductivity and thermomechanical properties of the developed composites were determined. The results show an increment in the electrical conductivity and storage modulus of the epoxy/CNT with the addition of GAg.NPs. The work established that the addition of GAg.NPs to epoxy-CNT can be used to improve electrical conductivity and storage modulus of epoxy-CNT composites for electronic applications.
2021). The silver acts as a transport medium to CNTs and enhances better dispersion. Ma et al. (2014) reported improved electrical conductivity when Ag nanoparticle are decorated with carbon nanotube for epoxy composites. The decoration of CNTs using Ag enhanced uniform dispersion of CNTs in polymer matrix, although the cost of silver does not justify continuous usage of Ag in CNTs. Hence, there is urgent need to synthesize Ag nanoparticles from local sources to ameliorate the prohibitive cost and achieve sustainability This work will report the decoration of CNTs using biosynthesize Ag nanoparticles.

2. Materials and Method
The CNTs with 10-20µm length and the average size of 10-40nm was purchased in China (Hongwu International group of company), see Figure 1. The high peak of carbon obtained in EDS in Figure 1 shows the high purity of CNTs used in the research.

![Figure 1. TEM/EDS image of CNTs](image)

The GAg.NPs were synthesized using Cashew leaves. The fresh Cashew leaves used in this work were gotten around the environment of the University of Nigeria Nsukka Nigeria. The fresh leaves were washed with distilled water and dried. 100ml of ethanol was then added to the washed Cashew leaves and left for 1hr, after then a solution of AgNO₃ (100ml) was added. The addition of AgNO₃ to the Cashew leaf extract samples produced an instant colour change from an original yellow solution to a dark brown solution, see Figure 2. The reaction was left for 30min before heating in an electric oven at 100°C under stirring at a speed of 2000rpm. After heating the solution, there was centrifugation for 1hr to obtain the solid Ag-NPs (Mudasir et al., 2016). Figure 2 display the TEM image of the GAg.NPs. Spherical and round image of GAg.NPs are visible in Figure 2. The average size obtained for the GAg.NPs was 45-65nm. The high peak of Ag in the EDS spectrum shows that high purity GAg.NPs was obtained.
It is worthy of note that LY556 (HERENBA BRAND) epoxy with density 1.15-120 g/cm\(^3\) and HY951 Hardener with density 0.98 g/cm\(^3\) were used in this research. Before decoration of CNTs with GAg.NPs, the CNTs were modified by treating with 100ml of 30%H\(_2\)O\(_2\) and 65%HNO\(_3\). The functionized CNTs were mixed GAg.NPs using sonicator Sonics ultrasonicated model: Vibra-Cell model VC 505 (solid probe) for 60 min at 400 W with optimal addition of 0.5% GAg.NPs was obtained in the formulation. The modified solution stir casting method was used in the development of the novel composites. The white Epoxy resin and Hardener (HY951) were mixed using a ratio of 10:1 and then stirred with a magnetic stirrer for 15 min. The composites were produced using 0.1, 0.2, 0.3, 0.4 and 0.5 with constant 0.5% GAg.NPs. Kaise insulation equipment model SK5010) was used to determine the electrical conductivity of the samples. The test was conducted per ASTM by placing the samples between two electrodes. Equation 1 was used to compute the electrical conductivity

\[
\sigma = \frac{1}{\rho} = \frac{d}{(R_p)A}
\]

The microstructure of the samples was determined using a scanning electron microscope (SEM) model: VEGA 3 TESCAN. Thermomechamical tests were carried out as per ASTM D4065 standard using DMA machine model: Perkin Elmer 8000

### 3. Results and Discussion

Figure 3 displayed the results of the electrical conductivity of the conductive polymer. It was observed that the addition of GAg.NPs to CNTs raises the electrical conductivity of the epoxy nanoparticles. The composites with GAg.NPs @CNTs have higher conductivity than the epoxy/CNTs composites. The improvement of the epoxy/GAg.NPs @CNTs can be attributed to the imminence of electric percolation, in which polymer (dielectric) is separated by mini capacitors and leads to increment in electrical conductivity. A 9.1x10^{-3} S/cm and 5.6x10^{-13} S/cm were obtained for epoxy-0.5%CNTs-0.5%GAg-NPs and epoxy matrix. The increment in electrical conductivity is expected since GAg.NPs @CNTs developed conductive network configurations and 3-D dense structures in the epoxy matrix. The conductive paths in the epoxy matrix creates quick mobility of charge carriers in the system. The direct contact of the GAg.NPs @CNTs in the epoxy resulted in ohmic conduction and non-ohmic conduction which results in indirect contact of GAg.NPs @CNTs in the matrix. This work is in par with the work of Smolen et al (2021).
Figure 3. Variation of electrical conductivity with CNTs addition

Figure 4 displayed the DMA results of the nanocomposites. It was seen that the epoxy-0.5%CNTs-0.5%GAg.NPs have a higher storage modulus of all samples under investigation. Addition of 0.5%GAg.NPs to CNTs helps to shift the storage modulus curve to higher temperatures and elevates the glass transition temperature. As per Putz et al (2008), the DMA properties of thermoset materials are influenced by the CNTs by the creation of an interface that is rigid between the CNT and epoxy resin and restricts epoxy chains and also incomplete crosslinking reaction which lead to the formation of epoxy-CNTs interphase. However, greater interphase leads to a greater impact on the mobility of the polymer chains, which resulted in higher thermal stability as observed in Figure 4. It was observed that the composite with GAg.NPs @CNTs has the higher DMA of all the samples under investigation. This was attributed to the formation of strong GAg.NPs @CNTs. The GAg.NPs @CNTs lower the rate of burning and raise the DMA of the composite for an electronic application. A similar observation was obtained in the work of Backes et al. (2017).

Figure 4. Variation of Storage modulus with Temperature
Figures 5 through Figure 6 present the SEM images of the epoxy and the composites. It is evident that the lamellar structure of the polymer was revealed in Figure 5. There were uniformity in the distribution of CNTs@GAg.NPs, which appears as white phases visible in Figure 6. Defect such as segregation of particles was not observed in the composites. This white phase can explain can account for the observed higher electrical conductivity and storage modulus in the composite. The presence of GAg.NPs @CNTs helps to alter the network multilayer structure of CNTs and enhances good interfacial bonding between the polymer and the reinforcement.

4. Conclusions

New information was obtained in using biosynthesized silver nanoparticles in the decoration of CNTs for the production of conductive polymer for electronic industries. In the course of the work, the following conclusions can be made:

1. The epoxy-0.5%CNTs-0.5%GAg.NPs composite was successfully produced using the modified solution stir cast method.
2. The uniform epoxy-0.5%CNTs-0.5%GAg.NPs and good dispersion of the CNTs can help to raise the electron path and hence increase the electrical conductivity, and storage modulus of the developed composite.

3. Biosynthesized silver nanoparticles can be used for ensuring good dispersion of CNTs for the production of conductive polymer.

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