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ORIGINAL RESEARCH

CONDUCTIVITY ANALYSIS OF CU/N-GRAPHENE AND NI/N-GRAPHENE AS ELECTRODES ON PRIMARY BATTERY ANODES

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Abstract. This study used a modified Hummer method to synthesize Graphene and nitrogen dopant to produce N-Graphene. Cu/N-Graphene and Ni/N-Graphene electrodes were each made using the impregnation method. Conductivity analysis of graphene, N-graphene, Cu/N-Graphene, and Ni/N-Graphene was carried out using a multimeter. The conductivity data of Cu/N-Graphene (83.16 µS/cm) and Ni/N-Graphene (85.67 µS/cm) produced were higher than commercial battery anodes (26 µS/cm). These data prove that N-graphene can improve the performance of Cu/N-Graphene and Ni/N-Graphene on primary battery anodes and can be used as an alternative anode on primary battery anodes.

Keywords: conductivity, dopant, graphene, impregnation, N-graphene.

INTODUCTION

Graphene, a single layer of carbon arranged in a 2D lattice, has garnered attention as a material for studying electrochemical devices[1], [2]. Its key characteristics, including being 2D carbon, sp2 hybridized, highly hard, flexible, and elastic, with a surface area of 2600 m2g-1, electrical conductivity of 1250 S cm-1, and thermal conductivity in the range of 4840-5300 Wm-1K-1 [3], highlight its potential. The addition of graphene has been found to enhance the transport of electrons and ions from electrode materials, leading to improved electrical properties of primary batteries and better chemical stability[4]. However, graphene's lack of an energy gap (band gap) and lower conductivity than graphene combined with metal underscore the need for modification. This emphasizes the importance of your work in altering graphene's electronic properties, such as through doping, to overcome these limitations.

Graphene can be doped by inserting electron donors such as nitrogen into its structure, resulting in N-graphene. Nitrogen doping can also be achieved chemically using ammonia or other nitrogen sources. N-graphene forms C-N interactions in the graphene structure, which are expected to enhance the conductivity of graphene [5]. The conductivity of N-graphene was measured at 1157.33 µS $cm{-1}$ when used as an anode material in primary battery cells [6]. This indicates that N-graphene still exhibits low conductivity values without the presence of metal.

Metal Nanoparticles (Nps) such as Au, Ag, Pd, Pt, Fe, Co, Cr, Ni, and Cu can increase the effectiveness of carbon nanostructure materials [7]. Ni is the second most abundant Nps metal after Fe. In addition, Ni has good electrochemical stability, catalytic activity, and cost efficiency [8]. Nickel has a standard cell potential of around -0.23V, meaning that the reduction power of nickel is lower than that of lithium (-3.05V). Therefore, graphitic carbon (N-graphene) is expected to be able to modify the potential of Nickel cells. Copper or Cu is relatively cheap compared to noble metal Nps such as Au, Ag, Pd, and Pt, which have sizeable electrical conductivity but low oxidation properties [9]. Cu has a standard cell potential of around +0.34 V. Due to the low oxidation ability of Cu, Cu can be combined with other materials to increase conductivity and density.

Primary batteries pose challenges in their development due to the discharge of electrons from the anode to the external circuit, the storage of electrons on the cathode, and the flow of electrons from the cathode to the anode. Support materials like N-Graphene can augment metal activity and modulate the dimensions of metal particles and electron transport. Cu/N-Graphene and Ni/N-Graphene can modulate electron transport at the anode of primary batteries.

METHODOLOGY

This research was conducted in the physics laboratory at Universitas Sumatera Utara. The materials used were $CuCl_2.2H_2O$, $NiCl_2.6H_2O$, ethanol, graphene, and N-graphene.

1. Preparation of Cu/N-Graphene and Ni/N-Graphene as Anodes in Primary Battery Cells

0.2 g of $CuCl_2.2H_2O$ and 0.2 g of N-Graphene were added to 50 mL of ethanol each and stirred for 1 hour. The mixture of CuCl2.2H2O and ethanol and the mixture of N-Graphene and ethanol were mixed and stirred again for 2 hours. Then, the mixture was filtered and dried in an oven at 80ºC. The conductivity of Cu/N-Graphene powder was measured using a multimeter. The same experiment was carried out for the manufacture of Ni/N-Graphene.

2. Conductivity Measurement of Cu/N-Graphene and Ni/N-Graphene as Anodes in Primary Battery Cells

A total of 0.1400 g of Cu/N-Graphene powder was inserted into the Fuse (Glass fuse), compacted until full and covered with a fuse cover. The alligator clip cable was connected to the negative and positive poles of the Multimeter and Regulated DC Power Supply circuits. Then the Regulated DC Power Supply was turned on. The conductivity of Cu/N-Graphene was measured at a voltage of 5,10,15,20,25,30 Volts. The current (μA) that came out of the Multimeter was recorded. The same experiment was carried out to measure the conductivity of Ni/N-Graphene.

RESULTS AND DISCUSSION

Conductivity analysis of graphene, N-graphene, primary battery anode, Cu/N-Graphene and Ni/N-Graphene.

The activity of primary battery anode materials was tested by conductivity analysis. Conductivity (σ) is defined as the ability of a material to conduct electric current. The input voltage Vin is set at 1.5 volts, the length of the semiconductor material is 1.2×10-2 m with a cross-sectional area of 2.46×10-7 m2. Observations are made for a voltage interval of at least 5◦C. For each predetermined voltage interval, the current I (read on the multimeter) flowing through the semiconductor material will be read, so that the material's conductivity can be calculated. The results of conductivity measurements on Graphite, Graphene, and N-Graphene at room temperature, with each sample weighing 1.59 g, can be seen in Table 1 below.

Table 1 Comparison of conductivity of graphene, N-Graphene anode of primary battery, Cu/N-Graphene, and Ni/N-Graphene

Voltage (V)	Conductivity (σ) (µS/cm)				
	Graphene	N-Graphene	Primary Battery Anode	Cu/N-Graphene	Ni/N-Graphene
5	45	13	20	38,59	42,60
10	45,4	12	20,2	59,49	60,10
15	33,53	14	21,93	61,60	61,99
20	35,95	14.5	23,95	64,84	74,35
25	35,6	14.68	25,4	78,56	79,40
30	30,2	15.14	26	83,16	85,67

Table 1 shows that the conductivity of commercial primary battery anodes at a voltage of 5-30 V has increased significantly. Primary battery anodes still have a fairly low conductivity value compared to graphene but higher than N-Graphene. The highest conductivity of graphene is 35.95 µS/cm, the conductivity value is higher than the primary battery anode. This graphene conductivity comes from π electrons delocalized along the C=C bond, which acts as an electric charge carrier, and graphene has a flat structure with a specific surface area of 2630 m2/g so that electrons can mobilize to all surfaces. From Table 1, the conductivity value of N-graphene is lower when compared to graphene conductivity. This is thought to be due to the absence of Nitrogen doping into graphene. The addition of nitrogen into the graphene structure will cause electron donation so that N-graphene will form C-N interactions in the graphene structure that can change the band gap of graphene and increase the conductivity of N-Graphene [10]. Therefore, N-Graphene is very promising for batteries, supercapacitors, solar cells, sensors, and hydrogen storage [11].

The conductivity produced by the alternative anode Ni/N-Graphene is higher compared to Cu/N-Graphene. This is due to the distribution of Nickel particles in N-Graphene being more homogeneous and the size of Ni particles (0.40 µm) in N-Graphene being smaller than Cu (0.81 µm). This proves that N-Graphene can increase metal conductivity.

To determine the stability of the current strength of Cu/N-Graphene and Ni/N-Graphene, current strength measurements were carried out at a voltage of 30 Volts with a time variation of 5 - 60 minutes (Table 2) and Figure 1.

Table 2. The current strength of Cu/N-Graphene with time variation of 5 – 60 minutes at a voltage of 30 Volts

Time (Minute)	Cu/N-Graphene	
	Inflow (µA)	Outflow (µA)
5	1,29	1,44
10	1,27	1,43
15	1,27	1,43
20	1,28	1,43
25	1,28	1,44
30	1,28	1,44
35	1,27	1,43
40	1,28	1,43
45	1,28	1,44
50	1,28	1,44
55	1,28	1,44
60	1,28	1,44

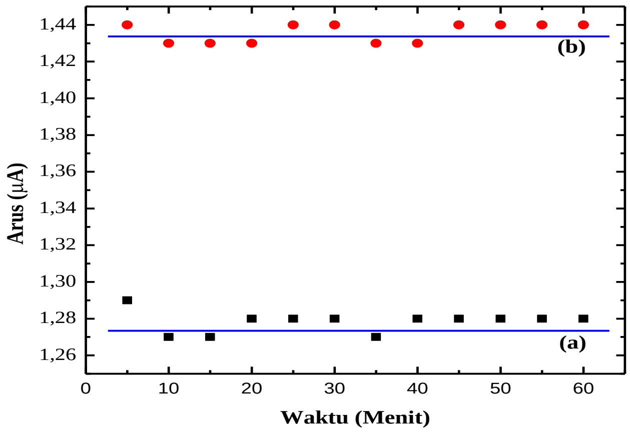

Figure 1. Relationship between Current (µA) and Time (Minutes) of Cu/N-Graphene

The Cu/N-Graphene electrode showed stable performance as an anode based on current measurement. The inflow and outflow values were very stable in the time variation of 5-60 minutes at a voltage of 30 V. This indicates that the Cu/N-Graphene electrode has good durability. This means that the Cu/N-Graphene electrode is still stable even at high voltages. The chemical interaction between Cu/N-Graphene can contribute to the stability of the electric current. The results of current measurements against the time variation of Ni/N-Graphene are shown in Table 3 and Figure 2.

Table 3. The current strength of Cu/N-Graphene with time variation of 5 – 60 minutes at a voltage of 30 Volts

Time (Minute)	Cu/N-Graphene	
	Inflow (µA)	Outflow (µA)
5	1,29	1,44
10	1,29	1,44
15	1,28	1,44
20	1,29	1,44
25	1,29	1,44
30	1,29	1,44
35	1,29	1,43

40	1,29	1,43
45	1,28	1,44
50	1,29	1,44
55	1,29	1,44
60	1,29	1,44

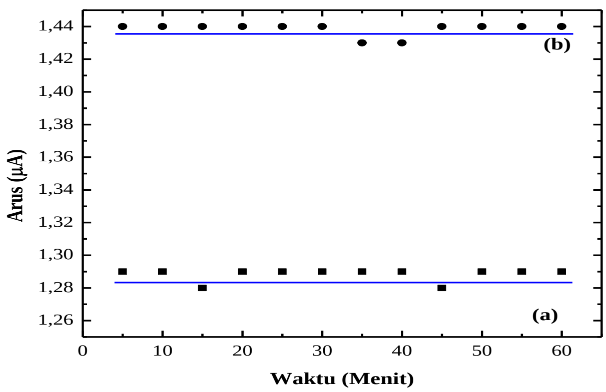

Figure 2. Relationship between Current (µA) and Time (Minutes) of Cu/N-Graphene and Ni/N-Graphene

The current loss ratio of Ni/N-Graphene (11.64%) is smaller than Cu/N-Graphene (12.32%). This means that Nickel metal in N-Graphene has better durability than Cu. N-Graphene as a supporting material can modify the metal character (π-d interaction). In addition, the electron mobility of Ni/N-Graphene is better than Cu/N-Graphene.

CONCLUSION

Ni/N-graphene has higher conductivity (85.67 µS/cm) than Cu/N-Graphene (83.16 µS/cm). Therefore, Both can be used as alternative anodes in primary batteries.

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