Electrical properties of Al-, Cu-, Zn- rice husk charcoal junctions

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Electrical properties of Al-, Cu-, Zn- rice husk charcoal junctions

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Abstract. Rice husk in the Philippines is considered as an agricultural waste. In order to utilize the material, one common technique is to carbonize these rice husks to produce charcoal briquettes. These materials are porous in nature exhibiting electrical properties from carbon structures. In this study, rice husk charcoals (RHC) were deposited on different metal substrates (Al, Cu, Zn) via a simple solution casting method. The deposited RHC on metal substrates was observed using Scanning Electron Microscopy (SEM). The films were characterized using two-point probe technique and the I-V curves were plotted. Al-RHC films appear to deviate from an ohmic behaviour while Zn-RHC and Cu-RHC showed diode-like behaviours.

1. Introduction
Nowadays, carbon materials are of great interest because of its physical and chemical properties which are useful in applications such as battery electrodes [1], capacitors [2], gas storage [3], biomedical engineering [4], thermoelectric materials [2] and catalytic supports [5]. Carbon exists in many forms such as diamond, graphite and charcoal [3]. Among all these forms, charcoal is the most readily available.

Charcoal is a material derived from the carbonization of wood and other plant biomasses [6]. Charcoal is commonly used as adsorbent for the removal of organic dyes since it is resistant to alteration and degradation [7, 8]. Raw materials from plants such as wood, bamboo and rice hull or rice husks are considered to be exceptional precursor to produce carbon structures from their natural porous matrices. These porous carbon materials provide electrical transport from the fundamental properties of carbon structures [9]. The conductive property of charcoal is attributed to its π-electron system that originates from the conjugated bonds [10, 11]. The formation of intermolecular bonding and bridge structure between its pyranose rings during carbonization of charcoal also contributes to its conductivity [12].

Rice husks are considered agricultural waste in rice-producing countries after being separated from the rice grains during the milling process. These husks, as wastes, are either burnt or dumped [13]. Rice husks are composed of cellulose, hemicelluloses, lignin, silica and other organic compounds [14]. Because of its high silica content, rice husks were commonly used as fuel in power plants and as raw material for the synthesis of new compounds [15]. Properties of these poor crystalline carbon materials are not yet studied in detail but the presence of sp2 orbitals enhances the possibility of using these materials for applications involving electrical conduction [11]. Some studies performed techniques...
such as acid etching, hydrogenation and irradiation to fabricate a schottky diode from charcoals as hydrogen sensor [16].

In this study, rice husk charcoals were used as the active material in the preparation of rice husks charcoal junctions using different metals as substrate. Lastly, the structural, morphological and electrical properties of the fabricated junctions were characterized.

2. Experimental details

Preparation of metal substrates: Copper, Zinc and Aluminum sheets were purchased from B.E. Scientific Glass Instruments. These metal sheets were cut into 2.5 cm x 2.0 cm dimensions. Metal sheets were then polished using silicon carbide and were ultrasonically cleaned using ethanol. After the process, the metal sheets were placed in a beaker.

Preparation of RHC films: Rice husk charcoals were grounded using mortar and pestle. Powders were mixed with acetone having a concentration of 12.5 mg/ml. The RHC solution was then poured in a beaker containing the metal sheets. The solution was air dried until the acetone evaporated.

Characterizations: The morphology and the junction of the RHC films were observed using scanning electron microscope (SEM, JEOL Ltd., JSM-5310). For the electrical characterization, two-point probe method was used. The sizes of the particles were measured using Image Analysis and Processing in Java (ImageJ) software. Fourier Transform Infrared Spectroscopy (FTIR) was done to elucidate the molecular structures in the RHC.

![Figure 1. Schematic diagram for the two-point probe set-up.](image)

3. Results and discussions

Figure 2 shows the FTIR spectra of the rice husk charcoals that were used in the fabrication of junctions. The characteristic peaks of the charcoal occur at the range of 1022-1044 cm\(^{-1}\), 787-791 cm\(^{-1}\) and 1569-1593 cm\(^{-1}\). The broad shoulder at the range of 1044 cm\(^{-1}\) corresponds to the presence of silica in the rice husk charcoal [11]. Sharp peaks that can be found at 787-791 cm\(^{-1}\) corresponds to the presence of C-H aromatic hydrogen while peaks at 1569-1593 cm\(^{-1}\) described the C=C stretching [17]. RHC is intrinsically insulating. However, the electrical transport in RHC is attributed to the carbon structures in the material. Although RHC is highly amorphous, the sp\(^2\) orbital sites in graphite-like structures provide charge transport in the material.
Rice Husk Charcoal (RHC) was successfully casted on metal substrates to fabricate metal-insulator junction. Figure 3 shows the SEM image of the fabricated Zn-RHC film.

Figure 2. FTIR spectra of the rice husk charcoals.

Figure 3. Cross-sectional area of the fabricated film.
Figure 4a shows highly heterogeneous structures of RHC. Grinding produced smaller particles with sizes following normal distribution as seen in the histogram plot in figure 4b. The particle size of the rice husk charcoals deposited was measured to be on the range of 1.874 to 7.774 μm having an average of 4.693 μm.

![Figure 4a SEM Image of the particles deposited.](image)

![Figure 4b Histogram plot of the particle sizes.](image)

Figure 4. (a) SEM Image of the particles deposited. (b) Histogram plot of the particle sizes.

For the electrical characterization, forward bias configuration was done by connecting the positive terminal on the metal and the negative terminal on the RHC. Reverse bias configuration was done by interchanging the terminals. Figures 5 showed the current-voltage plots of Al-, Cu-, and Zn- RHC junctions obtained using two point probe technique. Figure 5a shows deviation from an ohmic behaviour for Al-RHC junction. The Cu- and Zn- RHC junctions showed diode-like behaviours as seen in figures 5b and 5c, respectively. The diode-like behaviour of the junctions can be attributed to the presence of potential barriers between organic material and the metal substrate. Based from the thermionic emission-diffusion theory of diode [18], the computed barrier height for Al-, Cu-, and Zn – RHC junctions was summarized in table 1. The estimated ideality factor computed for each junction was less than 1. Ideality factors estimated for Al-, Cu-, and Zn- RHC films are also indicated in table 1. The estimated ideality factors computed for each junction were less than 1. This suggests that there are other factors and mechanisms that could describe the behaviour of RHC-metal junction.
Figure 5. Current-Voltage plots for a) Al-RHC junction, b) Cu-RHC junction and c) Zn-RHC junction.

Table 1. Computed barrier height and ideality factor for RHC junctions.

| Junction Type | Barrier Height (eV) | Ideality Factor |
|---------------|---------------------|-----------------|
| Al-RHC        | 0.623 eV            | 0.823           |
| Cu-RHC        | 0.577 eV            | 0.889           |
| Zn-RHC        | 0.645 eV            | 0.796           |

The amorphous nature of RHC involves hopping mechanism for charge transport. Based on the study of Novikov [19], the total energetic disorder in organic materials is due to randomly oriented dipoles present in the material. Also, the sizes, in micrometer range, of the charcoal particles suggest aggregation forming dense packing arrangement [3]. This provides larger interparticle interactions for conduction.

4. Conclusion
Al-, Cu- and Zn- RHC junctions were successfully fabricated via simple solution casting method using acetone as the dispersing solvent. Connections between the two materials were characterized using two-point probe technique. Current-voltage plots of metal-charcoal junctions showed interesting diode-like behaviours. Mechanism regarding can be further studied for future electronic applications.
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