Electrical and Thermal Properties of Carbonized Wood Based Composites

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Considerably interest has developed in the use of wood-based carbon material as new source of carbon for engineering applications [1]. Carbonized wood has been widely utilized for many applications, from adsorbents [2], to carbide ceramics for thermoelectric materials [3] and high temperature filters [4], etc. These variety applications of carbonized wood-based composites are influenced by the pores and microstructure in carbonized wood. The control of pores and microstructure in carbonized wood through heat treatments conditions such as temperature, heating rate and reaction time, may lead to new applications of the material. The microstructure and pores in carbonized wood in this study were exploited to the development of carbonized wood-based composites for thermal management in space solar power satellite (SPS). This application needs thermal conductive materials exhibiting high thermal conductivity with anisotropic behavior. The thermal conductive materials were tried to be developed by alternates layering of carbonized wood and graphite in three-layer laminated composite or by generating silicon carbide-carbon (SiC/C) composites from reaction of carbonized wood with turbostratic structure with SiO_2.

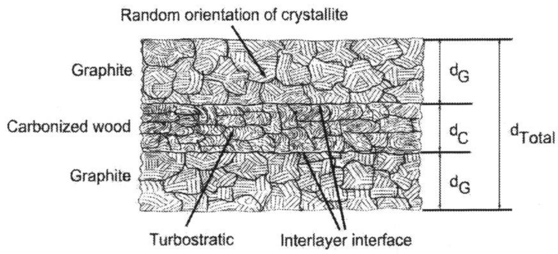

Figure 1. Schematic structure of three-layer laminated C/G composites for thermal conductive material with a function to discharge the heat from two sides

Table 1. Thermal conductivity of C/G composites, single layer of graphite and carbonized wood

Sample name	Structure (Layers)	Measured (W/m K) k_H	Measured (W/m K) k_V	Measured (W/m K) *H/V ratio*
G100	1	33.30	8.81	3.78
C/G=5/95	3	18.93	3.45	5.49
C/G=10/90	3	19.85	1.95	10.17
C/G=20/80	3	13.25	1.58	8.40
C/G=33/67	3	8.86	1.20	7.41
C/G=60/40	3	5.66	0.81	7.02
C/G=70/30	3	5.23	0.80	6.55
C/G=80/20	3	3.53	0.61	5.80
C100	1	1.14	0.50	2.31

k_H, thermal conductivity in the horizontal direction; k_V, that of in the vertical direction; *H/V ratio*, ratio of thermal conductivity between in the horizontal and in the vertical directions; SL-G, single layer composite, of graphite; SL-C, that of carbonized

In first part of study, microstructure arrangement and pore structure development in carbonized biomass during heat treatment at 700 °C with slow or fast heat treatment were investigated. Oil palm shell heat treated at 300 °C followed by slow heat treatments at 700 °C with a heating rate of 10 °C/min created opened micropores with a broad size distribution together with ordering microstructure of carbon. Fast heat treatments at same temperature with heating rates from 75 to 2000 °C/min produced microstructure with a narrow pore size distribution of 0.1-0.28 nm at the maximum distribution due to cracks generated during heat treatment [5] which appeared as structural disordering. Slow and fast heat treatments produced dissimilar micropore distributions. Oil palm shell heat treated at 300 °C and then at 600 °C influenced on less structural arrangement of microstructure and micropore development during slow or fast heat treatments. The heat treatment at 700 °C was necessary to develop micropore and microstructure in carbonized biomass which is crucial in the development of thermal conductive materials.

In 2nd part, composites with anisotropic thermal behavior for thermal conductive material in SPS were developed by alternating layers of laminated graphite and carbonized wood (C/G composite), as shown in

Fig. 1, which were prepared by heat treatment at 700 °C. The effect of the weight fraction of carbonized wood, particle size and interlayer interface on the thermal conductivity and the ratio of thermal conductivity in the horizontal and vertical directions (H/V ratio) to the plain surface of samples were discussed. Alternate layers of graphite and carbonized wood improved the anisotropic thermal conductivity of C/G composites. Thermal conductivity was good within graphite layers due to the high order microstructure and poor perpendicular to the graphite layers due to the presence of a layer of carbonized wood consisted of turbostratic microstructure and micropores [6]. The weight fraction of carbonized wood affected the thermal conductivity and the H/V ratio. The highest H/V ratio was obtained at 10 wt% of carbonized wood particles with a size of 25-32 μm. Particle size and interlayer interface were found to affect the anisotropic thermal conductivity. Alternately layered composites of two-phase components, such as graphite and carbonized wood, may be useful in thermal management applications in SPS. Improved thermal conductivity is necessary in order to obtain an effective thermal conductive material.

In 3rd part, a high electrical and thermal conductivities SiC/C composite as alternative surface layer in a three-layer laminated thermal conductive material was developed from carbonized wood. SiC composite was potential due to exhibiting good thermal conductivity, high strength, heat-resistance and low density and being produced not at very high temperature [4]. The electrical and thermal conductivities were investigated in relationship with the microstructure and growth of β-SiC crystal and carbon crystallite in SiC/C composite which was maintained by a solid-solid reaction between SiO_2 and carbonized wood or a gas-solid reaction between SiO and carbonized wood. The highest electrical and thermal conductivities of 1.17 x 104 $\Omega^{-1}m^{-1}$ and 25 w/m.K were obtained in SiC/C composite prepared by a solid-solid reaction followed by sintering at 1800 °C, due to the largest amount of β-SiC, the highest degree of ordering of the carbon microstructure and the smallest amount of SiO_2. The thermal conductivity could be improved to 101 W/m.K by increasing the density of the composite from 1.2 to 1.82 g/cm^3. In the case of SiC/C composite prepared by a gas-solid reaction, SiO gas infiltrated carbonized wood to form β-SiC which may suppress the growth of carbon crystallite resulted in the low thermal conductivity of 1.6 w/m.K, due to the less growth and the less ordering the microstructure of β-SiC crystal and carbon crystallite in the composite. Such high thermal conductivity SiC/C composites are preferable for alternative face in three-layer laminated thermal conductive material for an effective thermal management in SPS. The low thermal conductivity of the composites, can be used for an alternative core layer. A three-layer laminated composite of SiC/C with markedly different thermal conductivity of 101 W/m.k on the surface layers and 1.6 W/m.K on the core at a thickness ratio of 50/50 was predicted to exhibit anisotropy behavior with the calculated H/V ratio of 15.9 and the thermal conductivity in the horizontal and vertical directions of 51.2 and 3.2 W/m.K, respectively.

References

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