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Specific heat capacity of new porous carbon materials: Woodceramics

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Abstract

New porous carbon materials, 'Woodceramics', have been developed by carbonizing wood or woody materials impregnated with thermosetting resin, such as phenol resin, in a vacuum furnace at high temperatures. Woodceramics have superior characteristics from the viewpoint of engineering and ecological materials: they are hard and strong, have porous structure and low density, are made from natural resources, do not cause environmental pollution, and are cheap to manufacture. We have carried out differential scanning calorimetry in order to determine the heat capacity at high temperatures. © 1997 Elsevier Science B.V.

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1. Introduction

In general, people associate porcelain and chinaware with ceramics. In a broader sense, however, a ceramic is defined as an inorganic material which contains ionic or covalent bonds. In this sense, carbon materials are also categorized into ceramics.

Replacing the infrastructure of the traditional industry of mass production, consumption, and waste systems, a sustainable technology system is expected to develop by considering the limitations on environment, resources, and market [1]. As a part of this trend, woodceramics harmonizing with ecological systems have been now focused from the viewpoint of global environmental issues [2–7].

Woodceramics are new porous carbon materials obtained by carbonizing wood or woody material impregnated with thermosetting resin, such as phenol resin, in a vacuum furnace. During the carbonizing process, the thermosetting resin changes into glassy carbon, which has superior corrosion resistance and mechanical strength, reinforces the material and suppresses the fissures and warps (caused by the porous structure characteristic of wood) that develop during thermoforming [3].

In order to measure the specific heat capacity of woodceramics, we have carried out differential scanning calorimetry (DSC) [8].

2. Experimental method

The following types of specimens were used: medium-density fiberboards (air-dried, density 0.66 g cm^{-3}, moisture content – 8.5%) made from *Pinus radiata* were impregnated with phenol resin at

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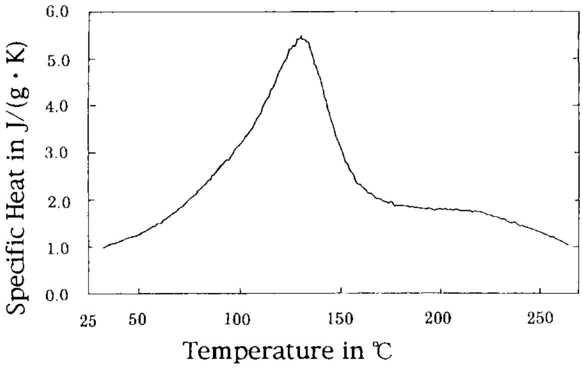

Fig. 1. Temperature dependence of specific heat capacity c_p of woodceramics burned at 800°C. Apparent peak around 150°C is associated with dehydration and chemical processes.

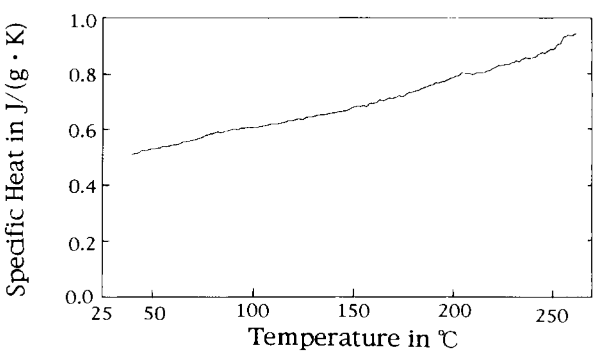

Fig. 2. Temperature dependence of specific heat capacity c_p of woodceramics burned at 2800°C.

mass ratio 1 : 1 using ultrasonic impregnation system [4]. These were dried and harden-treated in a high temperature oven at 135°C for 10 h, and then burned to make woodceramics specimens.

Each specimen was burned at 800°C and 2800°C, respectively. Burning system consists of an air-tight furnace and an exhaust system for the decomposed products. Heating is done using an indirect system which protects the exothermic body from a reaction by decomposed gases and provides a uniformly heated environment. Resultant decomposing gases were led to a water tank and completely removed through a cold trap at −80°C and charcoal filter.

The heat capacity of a powdered specimen with a grain size of 50–200 μm was measured using a DSC 8230 analyzer (Rigaku-Denki Kogyo). The measurements covered the temperature range from room temperature to 270°C, at a heating rate of 5 K min^{-1}. Just prior to the measurement, calibrations of the temperature and the enthalpy change quantification of DSC were conducted, using In, Pb, Al, and Au as the standard specimens. The powdered specimen of 16.600 mg, burned at 800°C and the one of 16.070 mg, burned at 2800°C were filled in an aluminum pan and placed in atmospheric conditions. Alumina was used as the standard specimen to convert the heat absorbed to a value of specific heat capacity. Sampling time of each measurement was 0.3 s.

3. Results and discussion

Fig. 1. shows the temperature dependence of specific heat capacity of woodceramics burned at 800°C. The value of the specific heat capacity is 1.0 J/(g·K) around room temperature. It increases with temperature up to about 100°C, then shows a maximum peak at 5.5 J/(g·K). Thereafter, it decreases with temperature, and reaches values of 2.0–1.0 J/(g·K) at temperatures above 150°C. This peak shows a behavior similar to mass reduction and that of endothermic dehydration process which was reported in our previous paper [9]. Thus, we can conclude that this anomaly of specific heat capacity occurs as a result of dehydration reaction from the porous woodceramics sample.

On the contrary, none of the peaks shown in Fig. 2 were obtained for the specimen burned at 2800°C. This behavior is also very similar to the TG–DTA curves of woodceramics of the same origin [9]. The heat capacity values are almost linear with respect to temperature in the range from room temperature to 280°C. This suggests that woodceramics become thermally stable when burned at temperatures as high as 2800°C.

When wood is carbonized, its size and weight are reduced due to evaporation of moisture and by pyrolysis of constituents such as cellulose, hemicellulose, and lignin and by degenerative combination. Woodceramics undergo a small structural change during the carbonization process and, after exposure to heat, they show larger similarity to vitreous carbon. It exhibits special characteristics like high heat resistance, corrosion resistance, heat and electrical conductivity, strength, hardness, and impermeability to gas [3,4]. These characteristics seem to support the present experimental data, showing improved thermal stability when burned at high temperature.

The value of specific heat capacity of the specimen burned at 2800°C is 0.5 J/(g·K) around room temperature, and is increasing linearly with temperature to the value 0.94 J/(g·K) up to 280°C. These values and the ones of specimen burned at 800°C are relatively large compared to the ones of metals and alloys. They are rather close to the values of rubber, paper, porcelain, quartz and concrete.

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