FEECT OF SURFACE ROUGHNESS ON MECHANICAL STRENGTH OF GLASSY CARBONS AT HIGH TEMPERATURES

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Abstract:

The four-point bending strength of the glassy carbons is measured at the temperature region from room temperature to 2600 ºC. The glassy carbon samples with different surface roughness are used in the series of the test. Normally, it has been known that the mechanical strength of glassy carbon at ambient temperature is dependence on their surface roughness. The sample with a rough surface shows lower strength than the sample with a fine polished surface. In the present work, the effect of surface roughness on the mechanical properties of glassy carbons at high temperatures is studied. It is characteristic that the flexural strength of glassy carbons is strongly dependent on the surface roughness at the test temperature below 2000 ºC. In the case of high density isotropic graphite materials, the mechanical strength and Young's modulus increase with increasing in test temperature up to 1800 ºC. At the high temperature above 2200 ºC, however, it is found that the flexural stress of glassy carbons reduce with increasing in test temperature. And the effect of roughness on the strength is neglected.

Keywords: glass-like carbon, mechanical property, high temperature

Introduction

Many graphite and carbon materials are utilizing at a high temperature of the range from 1000 to 2000ºC, for refining such as steal, aluminum, silicon, etc. For such applications, it is important to understand physical properties of carbon materials under a high temperature, as well as the chemical properties. So, we have measured mechanical properties of isotropic graphite and carbon fiber reinforced carbon (C/C) composites at the temperatures of the range from 1000 to 2600ºC [1].

In recent years, glassy carbons have been widely used as essential materials for components of silicon wafer processing equipment used in the manufacture of semiconductor devices and other applications including fuel cell components, electrochemical electrodes etc. For glassy carbon, however, a dependence of mechanical properties on test temperature was unknown.

In the present work, 4-point bending tests various glass-like carbons with different surface roughness are carried out under a high temperature of the range from 1000 to 2600ºC. The mechanical properties of these materials at high temperatures are compared. The effect of surface roughness on mechanical properties at high temperatures is discussed.

Experimental

Glassy-like carbon (GC10, manufactured by Tokai Carbon, Japan) is used. The specimen size is 2.5 x 5 x 65 mm. Three types of specimens with different surface roughness are used. One of the specimens the surface is polished by the abrasive paper of #800 (Sample Code: GC10-N). This is a normal commercializing specimen. The second type of specimen surface is polished by diamond slurry, like a mirror surface (Sample Code: GC10-M). The other is roughly set by the abrasive paper of #80 (Sample Code: GC10-R).

Flexural test used the 4-point bending configuration with a span of 51 mm and a distance between the upper loading points of 17 mm. Isotropic graphite rods with diameter of 6 mm were used as the span and the loading points. The tests were carried out at crosshead speeds of 0.1, 0.2 and 0.5 mm/min at temperatures up to 2600ºC in an argon atmosphere. The Photos of view of test machine equipment, furnace inside, bending zig (top and side) are shown in **Figure 1**.

Results & discussion

The flexural strength and modulus of glassy carbon samples, GC10-N, -R and -M, are shown in **Figures 2** and **3**, respectively. The strength of these specimens at ambient temperature is dependent on the surface condition, as well as inorganic glasses. The strength of GC10-N is *ca*. 100 MPa at room temperature (25ºC). The specimen GC10-R with rough surface shows a half of strength as the GC10-N. The high temperature strength of GC10-N and -R is independent of the test temperature up to 1800ºC. At the test temperature of the range from 1800 to 2400ºC, it is observed that strength increases with increasing test temperature and the maximum strength is

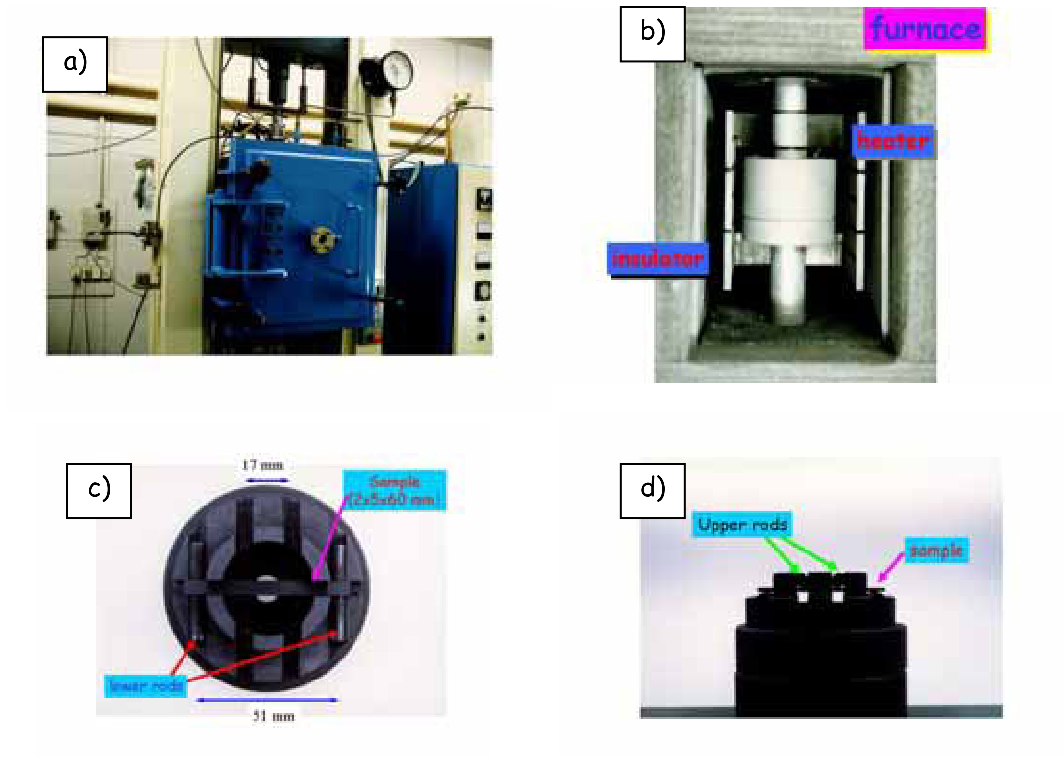

Figure 1. Photos of a) view of test machine equipment, b) furnace inside and bending zig (c: top and d: side).

observed at the test temperature from 2200 to 2400ºC. In the case of GC10-M with fine polished surface, on the other hand, the strength t the ambient temperature is slightly larger value than GC10-N, *ca*. 120 MPa. It is characteristic that the strength increases with increasing in the test temperature of the range from 1000 to 1800ºC, of which the average value is 1.5 times higher than that at room temperature. Such increment of strength with increasing in the test temperature of the range from 1000 to 1800ºC is almost the same situation as the isotropic graphite materials [1].

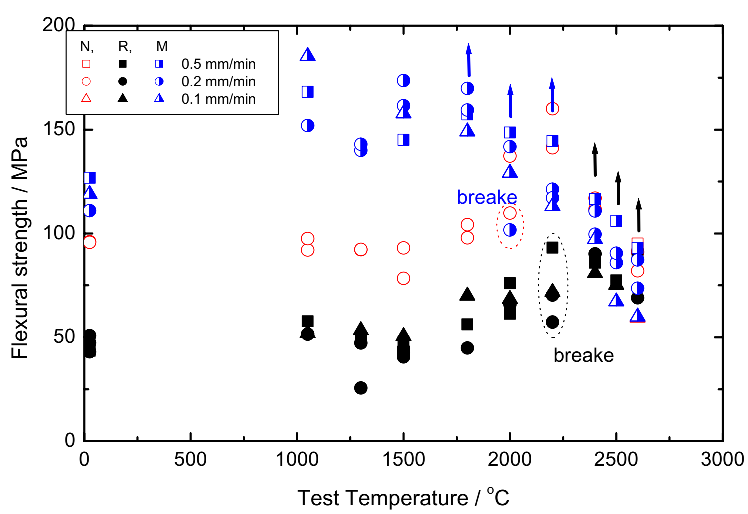

Figure 2. Plots of flexural strength of glassy carbons (GC10-N, -R and -M) against test temperature.

It is known that polycrystalline graphite materials include lots of micro-cracks. The micro-cracks are caused by anisotropy in thermal expansion coefficient of graphite crystallites and/or by frozen-in stresses with cooling from graphitizing temperature. Such micro-crack is so-called as "Mrozowski's crack" [2]. The thermal closure of these micro-cracks has formed the basis of expansions for increase in modulus of graphite with temperature [3]. However, the reason why that the increment of the strength with increasing in the test temperature of the range from 1000 to 1800ºC is observed in the case of only fine-polished glassy carbon (GC10-M) can not be understood. It may be assumed to be influenced by adsorption of moisture or oxygen on the surface at ambient temperature.

The glassy carbon is a typical brittle material. The strength of glassy carbon is governed with surface damage, so that the strength of glassy carbon affects on its surface roughness. In the case of GC10-R, the specimen is broken at the test temperature of 2200ºC. On the other hand, GC10-M is seldom failed at the test temperature above 1800ºC

The all specimens at test temperatures above 2400ºC can not be failed in brittle. The plots against the test temperatures above 2400ºC in **Figure 1** are the maximum stress at these tests which were estimated from the maximum load when test displacement reached a limited position (u = 3.5 mm). It is characteristic that the maximum stress of the present glassy carbon specimens above 2400ºC is almost the same value, being independent of the surface roughness.

The modulus of the glassy carbon at the temperature above 1000ºC drastically decreased with the elevating the test temperature. The average value of modulus reduces from 20 GPa at room temperature to 7 GPa at 2600ºC (**Figure 3**).

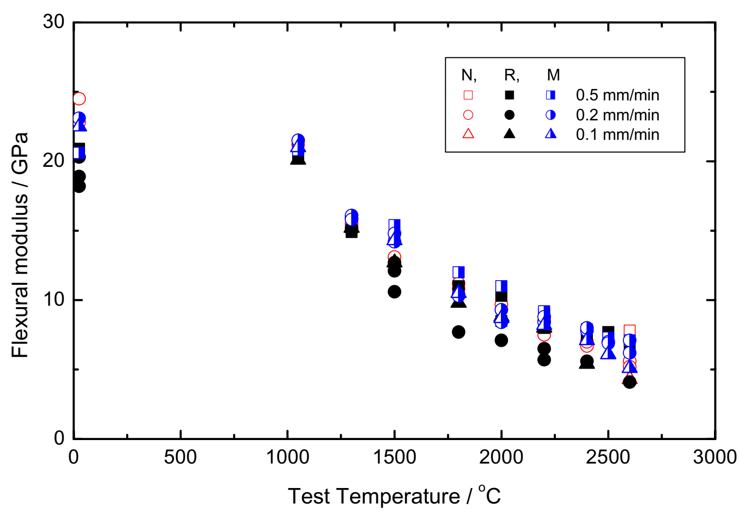

Figure 3. Plots of flexural modulus of glassy carbons (GC10-N, -R and -M) against test temperature.

References

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