MICROSTRUCTURE EFFECT ON MECHANICAL PROPERTIES OF FLEXIBLE GRAPHITE SHEET

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Introduction

Flexible graphite is applied in many industrial fields, but its use is limited by its lower strength. It is very important for improving the properties of flexible graphite sheet(FGS) to explore the relationship between the microstructure and mechanical properties of FGS. Here we report the results of a study about microstructure effect on the mechanical properties in FGS.

Experimental

FGS was made from natural graphite flakes with 99%wt carbon content and 0.3mm of average size. H_2SO_4 was electrochemically intercalated into graphite, and the expandable graphite with different exfoliation volume was obtained by controlling the intercalation current and duration.

Expandable graphite was exfoliated at 1000℃ for 15 seconds, then the exfoliated graphite(EG) was compressed to form sheets with different density.

Smooth tensile test was performed in a universal test machine. The essential fracture work(We) developed by Mai and Cottereu[1] was evaluated by use of a set of the double-edge pre-cracked samples.

Pore structure of the EG and FGS was characterized by SEM, mercury porometry and SAXS. The deformation texture of FGS was measured by XRD.

Results and Discussion

Figure 1 Shows that the tensile strength(σ)increases with the exfoliation volume of EG. Table 1 lists the σ and We of FGS with different density. The σ increases with density, which consistents with previous results[2]. The We also increases with the density, which indicates that, the higher the density, and the larger the resistance to crack propagation in the FGS.

FGS contains two phases of gas and solid. The relationships between porosity(P) and density(ρ) of FGS is as follows: $P=(2.26-\rho)/2.26$, where 2.26 is theoretic density of graphite[3]. Therefore, it is believed that the effect of density on the mechanical properties of FGS is the effect of pores in it in principle. There are three effects of pores on the mechanical properties, (1) the present of pores reduces the bearing matter, inducing the increase of the true stress; (2) the pores would cause the stress concentration, which degree is related to the size and shape of pores; (3) the pores could offer some space for the plastic deformation.

Table 1 lists the data of the tensile strength(σ') and essential fracture work(We') calculated by deducting the pore area. They increase still with the increase of density, which shows that the pore effect is not only the first one. From the data in table 1, it can be calculated when the porosity decreases from 65% to 38%. We' and σ' increases 14% and 26%, respectively, which proves when there is macro stress concentration at the crack tip, the effect of the micro stress concentration induced by pores on the mechanical properties is smaller.

Figure 2 shows the mean pore size(r_a) and the pore size of the maximum probability(r_p) in different EG. It can be seen that the pore size is similar, but the pore number is different in them. The lager the exfoliation volume, the more the pore number. Therefore, the pore size and number in the FGS made from different EG and with the same density is different. In the FGS made from EG with large exfoliation volume, because the pore number is more and the porosity is certain, the pore size is relatively small, which means in the FGS the stress distribution is more even, so the tensile strength is higher.

Figure 3 exhibits that the pore size in the FGS decreases with increasing the density. Figure 4 shows that the angular spread of basal plane orientation decreases with the density, but it tends to a certain value when the density is more than 0.6 g/cm^3. From the Fig.3-4 it can be seen that the increase of the density causes also the decreases of the pore size and the turning of the basal plane as well as the decrease of the porosity, which proves that the third effect of the pores on the mechanical properties is in present, too. The morphology of cleaved surface of FGS observed by Atom Force Microscopy, which is very rough[4]. According to the model proposed in our previous work[5], the friction force would increase due to the decrease of the pore size and angular spread of basal plane orientation, so that the strength and essential fracture work could increase with the density.

Conclusions

1. The pore effect on the mechanical properties in FGS includes decreasing the bearing area, inducing the stress concentration and providing the plastic deformation spaces.
2. The FGS made from larger exfoliation volume graphite has higher strength, which results from that more pore number and less pore size induces more even stress distribution.
3. As increasing of the density the porosity, pore size and angular of basal plane orientation decrease at all, inducing the increase of the friction force, so that the strength and essential fracture work increase.

References

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Acknowledgement

This project was supported by a National Science Foundation Committee of China under Grant No.59582006 and the Hong Kong University of Science and Technology under RIG Grant PR93194.EG07.

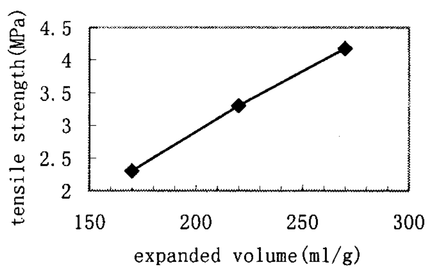

Fig.1 The Effect of exfoliation volume on tensile strength (ρ =0.8g/cm^3)

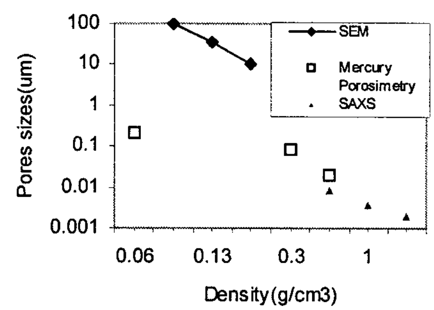

Fig.3 Mean pore diameter variance of FG with its density

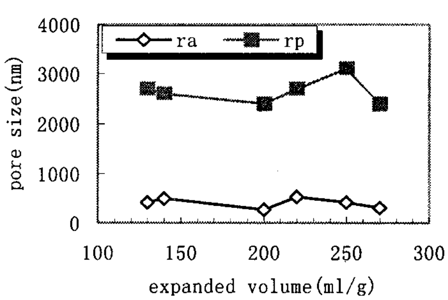

Fig.2 The pore size of EG with different exfoliation volume

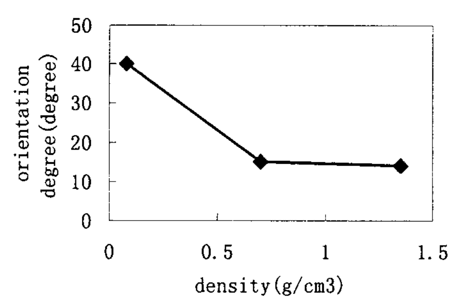

Fig.4 The relationship between orientation degree of (002) plane and density of FGS

Table 1 Tensile properties of FGS with different density

ρ (g/ cm^3)	P(%)	We(J/m^2)	We' (J/m^2)	σ (Mpa)	σ ' (Mpa)
0.8	65	51	146	2.24	6.4
1.0	56	70	159	2.96	6.7
1.2	47	90	170	3.75	7.1
1.4	38	104	168	5.42	8.7