THE EFFECT OF THE TYPE AND AMOUNT OF THE GRAIN BOUNDARY PHASE IN S-TYPE POLYCRYSTALLINE DIAMOND ON ITS PHYSICAL PROPERTIES

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The sinter-type polycrystalline diamond has two subkinds: with or without additives. This paper concerns the former, dealing with the effect of the type and amount of grain boundary phase on the material's relative wear resistance, strength and thermostability. It was discovered by experiment that the relative wear resistance and strength are dependent on the amount of intermediate transiting phases formed in the grain boundary phase and that the thermostability is dependent on the type of the grain boundary phase.

1. Introduction

Natural polycrystalline diamond (PCD) is a rarer form of diamond, found only in a limited number of mines. Ballas is a form of diamond with a globular shape, in which the crystallites are arranged radially. It has grown from its centre to the surface. Carbonado is an aggregate of randomly oriented small diamond crystal blocks.

Because of its better impact resistance without cleavage and some other unique features, man has been trying since the fifties to create PCD which can match with natural carbonado and ballas in terms of structure and properties under ultra-high pressure and high temperature conditions.

Ballas-like diamond was synthesized by Kalashnikov *et al.*[1]. The synthesizing conditions, however, were not described. Carbonado-like diamond has been prepared by sintering and other methods[2)-5)]. Similar products had been achieved in the United States, South Africa and the U.S.S.R., as well as in China by the sixties, and found wide applications during the mid seventies.

From the viewpoint of the manufacturing process and product structure, the achieved PCD products, according to the author, may be classified into three basic types[6], which are the Sinter-Type (S-Type), Growth-Type (G-Type) and Growth-Sinter-Type (G-S-Type). The S-Type PCD has two subkinds, with and without additives. This paper concerns the former, dealing with the effect of the type and amount of grain boundary phase on the material's relative wear resistance, strength and thermostability.

2. Description of experiment

For the above-mentioned purpose the different sample groups were examined by means of SEM, X-ray diffraction and chemical analysis. There were three sample groups: A was JRS, made in China; B was a Compax-type product made by two famous companies; C was a triangular product made by two famous companies, of which C-II was made in 1984 and C-III was made in 1986.

The relative wear resistance (Q) is defined as the wear ratio of a medium-hard SiC grinding wheel to PCD by weight loss. Thermostability means the temperature at which the Q-value of PCD drops sharply after being treated under high temperatures in a reduction atmosphere. The measurement of compression strength is carried out by a press, in which a hardened steel disc and a tungsten carbide disc are placed on both end faces of the PCD sample, then the load increases until the sample is broken.

3. Experimental results

1) Grain boundary phases and composition examined by X-ray diffraction and SEM are shown in Table 1.

2) The thermostabilities of samples A, B and C are shown in Fig. 1.

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Table 1. Grain boundary phases and composition examined by X-ray diffraction and SEM

Sample	Composition except C	Grain boundary phases
A	Si, Ni, Ti	β-SiC, Si–Ni, Ti–Si
	Si, Co	β-SiC, Si–Co
B	Co	β-Co, Co–WC
C I	Co, Al, Si	β-Co, Al_2O_3?
II	Co, W, Si	
III	Co, Si, Cu	β-SiC, Si–Co

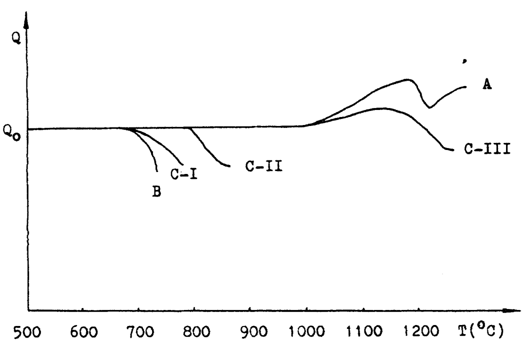

Fig. 1. The thermostabilities of samples A, B and C.

Table 2. The correlation between the amount of the intermediate transiting phases and Q, σ_p of sample A

	a	b	c	d
$\frac{Si_{(SiC)}}{Si_{(total)}} \times 100\%$	24.7	30	34	46.7
$Q \times 10^4$	0.5	0.7	0.7	1.2
σ_p	0.9–1	1.2–1.23	1.2	1.3

$Si_{(SiC)}$ means the amount of the intermediate transiting phase β-SiC.
$Si_{(total)}$ means the total amount of all additives.
σ_p means the compression strength of PCD.

3) The correlation between the amount of the intermediate transiting phases, Q-values and σ_p-values of sample A are shown in Table 2, Fig. 2 and Fig. 3.

4. Discussion

1) Samples A, B and C were the S-type, G-type and G-S-type PCD products respectively, as shown in Fig. 1. The thermostabilities were 1200°C (A), 700°C (B), 700°C (C-I), 800°C (C-II) and 1200°C

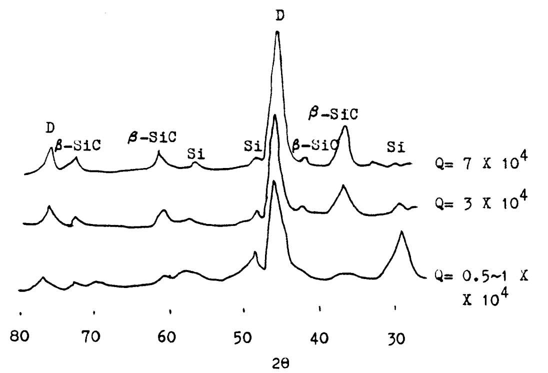

Fig. 2. X-ray diffraction of PCDs with different Q-values.

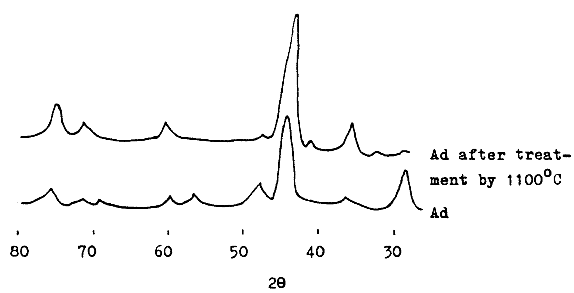

Fig. 3. X-ray diffraction of sample Ad before and after heat-treatment at 1100°C.

(C-III). The major difference of sample A from B and C-I is that interestingly enough, its Q-value slightly increases after a heating treatment.

2) Table 1 has shown that the Q-values and σ_p-values increased with an increasing amount of intermediate transiting phase (β-SiC) formed.

3) What is the cause of such big differences in thermostability among samples A, B and C? This is another problem worth discussing. From 2) and Fig. 3 it can be deduced that the thermostability may have something to do with the properties of the grain boundary phase. The grain boundary phase of sample A is a refractory carbide, which is stable or even growing during its heating treatment and plays a protective role in diamond, while that in sample B is an unstable phase. The cobalt content is not only a catalyst solvent under ultra-high pressure and high temperature for synthesizing diamond, but also promotes the conversion of diamond back into graphite under high temperature conditions; owing to the expansion coefficient of diamond being different from cobalt, the PCD

strength decreases during heating treatment. This is supposed to be the major reason for the lower thermostability of sample B. As for sample C, the grain boundary phases of C-I and C-III belong to the unstable phase and stable refractory phase respectively, so that the thermostability of C-I and C-III are similar to sample B and sample A respectively.

5. Conclusion

1) The thermostability of PCD is dependent on the type and properties of the grain boundary phase. When it is an intermediate transiting phase and bounded chemically, and refractory such as carbides and other refractory phases, the thermostability of PCD will be excellent. But if the grain boundary phase contains dominantly some element of group VIII by which diamond is easily converted back to graphite, good thermostability of PCD can hardly be expected.

2) The relative wear resistance (Q) and compression strength (σ_p) are dependent on the amount of intermediate transiting phases formed in the grain boundary area in S-type PCD, which explains why the thermostability of sample A-d increased after heating treatment.

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