



Friction and wear behavior of polytetrafluoroethylene composites filled with Ti_3SiC_2



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ABSTRACT

In this work, polytetrafluoroethylene (PTFE) composites filled with Ti_3SiC_2 or graphite were prepared through powder metallurgy. The effects of different filling components, loads and sliding velocities on the friction performance of Ti_3SiC_2 /PTFE composites were studied. Ti_3SiC_2 /PTFE composites exhibit better wear resistance than graphite/PTFE composites due to the better mechanical properties of Ti_3SiC_2 . The wear resistance was found to improve around 100× over unfilled PTFE with the addition of 1 wt.% Ti_3SiC_2 . In addition, the 10 wt.% sample had the lowest wear rate of $K = 2.1 \times 10^{-6} \text{ mm}^3/\text{Nm}$ and the lowest steady friction coefficient with $\mu = 0.155$ at the condition of 90 N–0.4 m/s. Ti_3SiC_2 was proved to promote the formation of a thin and uniform transfer film on counterpart surface and a protection oxide film on worn surface, which are the key roles for improving wear resistance.

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1. Introduction

Polytetrafluoroethylene (PTFE) has been widely used in aerospace, chemical, medical, automotive and electronics and other fields due to its excellent thermal stability, chemical stability and good friction performance. However, the disadvantages of pure PTFE, including fairly low thermal conductivity, low hardness and poor wear resistance, limit its application. As a result, over the years, many scholars studied a variety of modified PTFE, in order to improve the comprehensive performance of PTFE and expand its application in various fields.

Among all these tries, filling modification is a convenient and effective way. Adding micro- or nanoscale fillers can significantly improve the thermal conductivity, hardness and wear resistance, and reduce the wear rate of 1–3 orders of magnitude [1–8]. For example, adding ultra kaolin [1] or glass fiber [2] to PTFE reduced the wear rate of 2 orders of magnitude, while some nanoscale fillers such as nanoalumina [5,7] or graphene [8] achieved over a thousand times reduction of wear rate. As a typical material of all the fillers, graphite can substantially improve the thermal conductivity, dimensional stability and compression creep of PTFE, because it is a good solid lubricant and has high

thermal conductivity. For example, the wear rate of 2 wt.% expanded graphite filled PTFE nanocomposite were reduced approximately 162 times [9]. On the other hand, ternary Ti_3SiC_2 ceramics have excellent thermal conductivity, low expansion coefficient, good self-lubrication similar to graphite and higher strength and hardness than graphite. Huang et al. [10–12] reported that when Ti_3SiC_2 material was slid against with low carbon steel under dry conditions, the friction coefficient and the wear rate are 0.25–0.35 and $1.5\text{--}3.0 \times 10^{-6} \text{ mm}^3/\text{Nm}$, respectively. Because a protective oxide film can be generated over the friction surface of Ti_3SiC_2 at high temperature and high speed, which shows great lubrication effect, thereby significantly reducing the friction coefficient and wear rate of the material. Moreover, Ren [13] studied the friction properties of Ti_3SiC_2 in artificial seawater, the result shows that Ti_3SiC_2 has good tribological properties and corrosion resistance in the seawater environment. Thus, as a potential filling candidate, Ti_3SiC_2 is expected to achieve a lower wear rate and better comprehensive performance for PTFE based composites. In this paper, Ti_3SiC_2 filled PTFE composites material was prepared by the mechanical blending – cold pressing molding – sintering process. Graphite/PTFE composites were also prepared through the same process for comparison. Then the tribological properties of the composites were examined under dry sliding condition. Compared to PTFE matrix, the wear resistance of the composites has a great improvement.

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2. Materials and methods

2.1. Materials preparation

The M-18 PTFE with an average size of 100 μm was bought from Daikin America INC. Ti₃SiC₂ powders were synthesized by high-temperature self-propagating synthesis using elemental Ti, Si, C, Al as raw materials according to the atom proportion of 3/1.5/2/0.2. Excessive Si was added to supply its loss on high temperature during the reaction process, while Al can help the formation of Ti₃SiC₂ [14,15]. It can be seen from Fig. 1 that the as-synthesized powders are mainly composed of Ti₃SiC₂, while a little TiC phase can be detected. The sheet-like Ti₃SiC₂ grains are around 0.3–3 μm, which gathered together to form small particles (Fig. 2). Different mass fraction of Ti₃SiC₂ or graphite (approximately 30 μm) as fillers and PTFE powders were added into plastic containers subsequently loaded into a mixer. The mixed powders were cold-pressed at 40 MPa for 3 min in a 8 mm diameter cylindrical die to yield cylindrical green compacts. The compacts were then sintered by heating at a rate of 100 °C/h to 360 °C where they were held for 3 h followed by cooling to room temperature. The as-sintered samples were machined into φ6 mm × 8 mm pins for following tribological test.

2.2. Tribological test

The tribological test was conducted on a MG-2000 pin-on-disk High-temperature tribometer. The pins, which were the

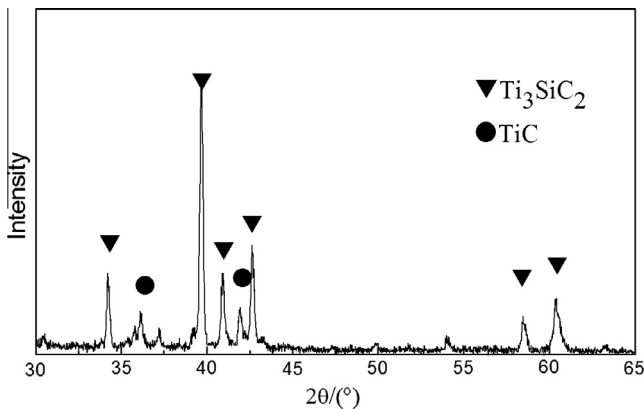


Fig. 1. XRD pattern of Ti₃SiC₂ powders.



Fig. 2. SEM morphology of Ti₃SiC₂ powders.

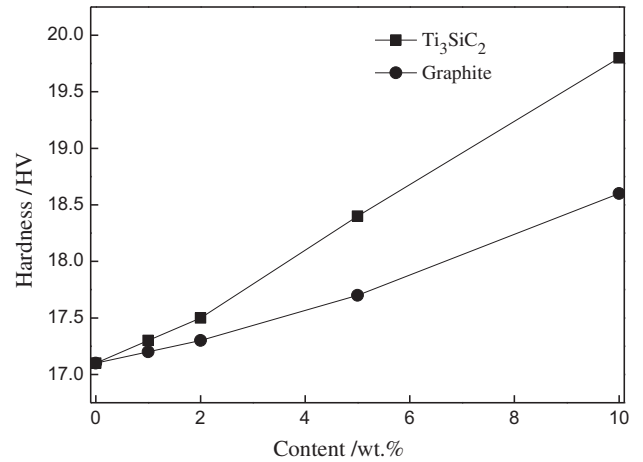


Fig. 3. The variation of Vicker's hardness with varying weight fractions of Ti₃SiC₂ or graphite.

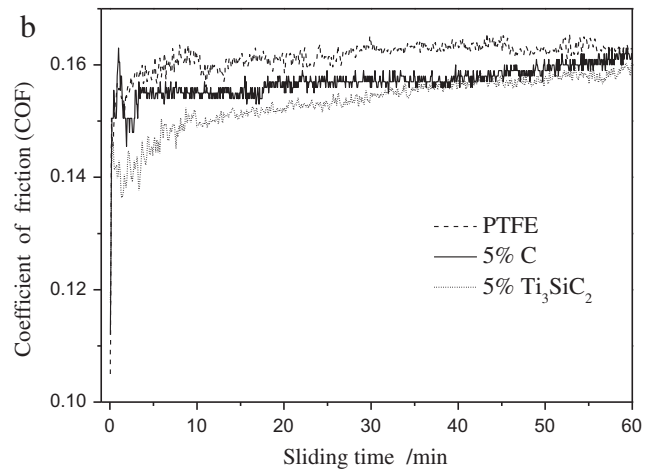
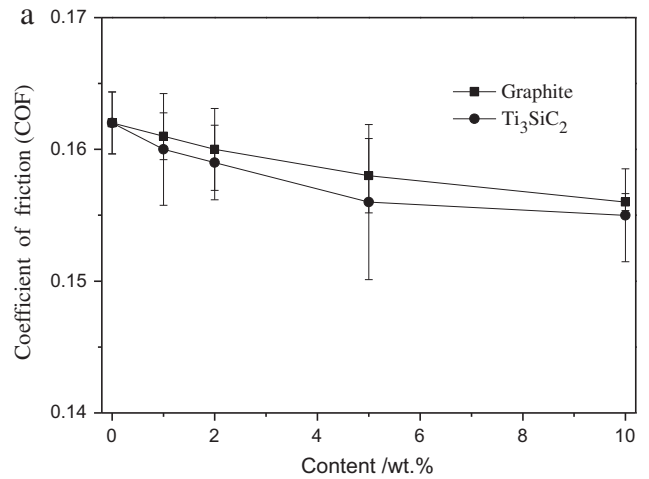


Fig. 4. (a) The variation of COF with varying weight fractions of Ti₃SiC₂ or graphite at the condition of 90 N–0.4 m/s. (b) The variation of COF of different materials with sliding time.

as-prepared materials, were cleaned with acetone and then dried in hot air before test. The counterpart disk was 45 carbon steel, which was polished mechanically with emery papers down to 1500 grad. The test temperature was room temperature. The sliding speed and applied load were 0.2–0.8 m/s and 60–120 N

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