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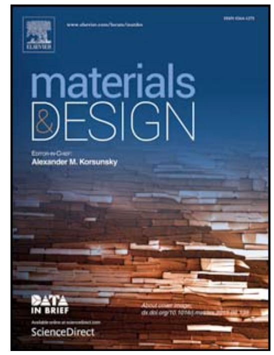

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Polyimide/mesoporous silica nanocomposites: characterization of mechanical and thermal properties and tribochemistry in dry sliding condition

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Abstract

Mesoporous silica (MPS) with tunable mesopore channels can be used to reinforce polymers and has great potential in tribological applications, which is rarely investigated by research community. In this study, comprehensive properties of polyimide (PI)/MPS nanocomposites were investigated. In particular, the tribochemistry of PI/MPS nanocomposites in dry sliding against bearing steel was explicitly studied by the combining use of X-ray photoelectron spectroscopy (XPS) and Raman analysis. The results demonstrated a slightly decreased tensile strength but increased modulus, microhardness and thermal stability of the PI/MPS nanocomposites. The incorporation of 1.5 wt.% MPS increased the anti-wear resistance of PI by more than 14-fold. This was highly associated with the formation of high-quality transfer film on the bearing steel counterpart surface, of which the relevant tribochemistry was thoroughly revealed by XPS analysis on the transfer film and Raman analysis on the worn surfaces. This study confirmed the high efficiency of using MPS to reinforce PI polymer for tribological applications and elaborated tribochemistry to further understand the tribochemical process in polymer-metal rubbing systems.

Keywords

Mesoporous materials, Polymer-matrix composites, X-ray photoelectron spectroscopy (XPS), Raman, Tribochemistry

1. Introduction

With the development of industries, the needs for high-performance friction materials continue to grow. For example, the global friction products market is estimated to grow at a compound average growth rate of 6.07% over the period 2014-2019, according to Technavio's report [1]. Such urgent need demands high-performance and low-cost friction materials. Polyimide (PI) is a versatile engineering plastic with its important application for non-lubrication friction, especially under harsh environment. In essence, excellent mechanical, thermal and tribological properties of PI composites are required in order to resist the heavy load or elevated temperature. Mesoporous molecular sieves have attracted much attention since their first discovery [2-5]. Mesoporous materials benefit from two advantages including extremely high specific surface area (normally >500m^2/g) and interconnected mesoporous structures. The former provides reaction interfaces for mesoporous materials and others, whereas the latter facilitates the penetration of polymeric molecules into particulates in the formation of much stronger physical or chemical bonding, as evidenced in [6-9]. PI composites reinforced with mesoporous silica, typically PI composite films, are of great interest among the wide research community. Such PI composite films can be utilized in multiple applications for microelectrical devices [10] and selective separation [11]. However, the reinforcing effect of mesoporous on the mechanical and thermal properties of PI films is still uncertain. For example, Cheng et. al [12] synthesized PI/mesoporous silica nanocomposites with improvements of storage modulus, tensile strength and glass transition temperature (T_g). Nevertheless, with the same PI matrix (ODPA-BAPP) but a different kind of mesoporous silica, the modulus and tensile strength of PI/mesoporous silica