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POSS grafted hybrid-fabric composites with a biomimic middle layer for simultaneously improved UV resistance and tribological properties

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ABSTRACT

Poor interfacial adhesion and inferior UV resistance severely inhibit the development of hybrid Meta-aramid/Polytetrafluoroethylene (Nomex/PTFE) fabric composites for distinguished solid self-lubrication materials, especially under high exterior load and long-term UV irradiation conditions. Herein, glycidyl polyhedral oligomeric silesquioxanes (POSS) nanoparticles are covalently grafted onto the hybrid Nomex/PTFE fabric with a polydopamine/polyethylenimine (PDA/PEI) intermediate layer. The microstructure and chemical characteristics of Nomex and PTFE fibers before and after modification are investigated and the results manifest an obvious increase in surface functional groups and roughness, as well as resin compatibility. Tensile and peeling testing results show that the obtained fabric composites, denoted as hybrid-fabric@PDA/PEI-POSS composites, exhibit 24.3% and 46.8% enhancements in tensile and interfacial bonding strength without discernable decrease in pristine hybrid-fabric strength. In addition, the PDA/PEI-POSS hierarchical coating imparts the hybrid-fabric with excellent UV-shielding properties. As a result, the tribological performance of hybrid-fabric@PDA/PEI-POSS composites presents an obvious improvement under high load and UV irradiation conditions.

1. Introduction

Hybrid Nomex/PTFE fabric reinforced resin composites have demonstrated wide potential applications in frictional components such as bears, soft seals and piston rings on account of its combining the superior strength of Nomex fibers and distinguished self-lubrication of PTFE fibers [1–4]. However, the smooth and chemically inert surface of Nomex and PTFE fibers makes them difficult to form firm interfacial adhesion and good compatibility with resin matrix [5,6]. In addition, Nomex fibers consisting of highly aligned long chains of poly-(isophthaloylmetaphenylenediamine) (PMIA) are susceptible to damage from ultraviolet (UV) irradiation, which can cleave amide bonds and cause structural degradation of Nomex fibers [7,8]. These fatal shortcomings limit greatly the exerting of above excellent properties during actual applications. So far, although various surface modification techniques, including chemical etching [9], plasma treatment [10], high-energy irradiation [11] and chemical grafting [12], have been introduced to improve the surface activity of reinforced fibers, these conventional treatment methods with oxidation or etching procedure would lead to the deterioration in fiber strength to some extent. Meanwhile, less attention was paid on improving the UV resistance of Nomex fibers. Moreover, the PTFE fiber due to its excessive chemical stability shows highly inert to usual chemical etching and grafting. Hence, building a suitable approach, which can simultaneously overcome poor surface activity and inferior UV resistance without compromising fabric strength, has become the key issue for improving the properties of hybrid Nomex/PTFE fabric composites.

Recently, owning to unique structures, nanoscale size and superior properties, nanomaterials have been widely used as interphase reinforcements in fiber reinforced composites (FRC) to improve interfacial adhesion, and thus to enhance mechanical,

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thermal and tribological properties [13–16]. Noteworthy, polyhedral oligomeric silesquioxanes (POSS) possesses the unique cage-like molecular structure with an internal inorganic silicon-oxygen framework surrounded by organic substituents which provide them with high polarity and compatibility compared to other inorganic nanomaterials. Various researches have presented that the introduction of POSS nanoparticles can improve mechanical properties, anti-hydrothermal ageing and thermo-oxidative stability of resulting FRC [17–20]. The tribo-performance evaluation of POSS modified FRC, however, has not be reported. Moreover, the study for grafting POSS onto hybrid-fabric also accompanies with big challenge, as there are no reactive sites available for reaction.

Inspired by the remarkable adhesive behavior and intrinsic capacity for further functionality, dopamine has attracted extensive interest in surface modifications or pretreatments [21,22]. Additionally, PDA shares outstanding UV-shielding properties with eumelanin due to their similar structures and chemical functionalities [23]. Although DA could adhere on almost any substrates through a facile oxidation process, the preparation procedure is time-consuming and DA oligomers tend to form aggregates via non-covalent interactions resulting in loose and heterogeneous coating, which would greatly weaken the adhesion strength and UV-shielding properties of resulting PDA [24]. Recently, the surface modification strategy by co-deposition of dopamine with polyethyleneimine (PEI) to catalyze the polymerization of dopamine and disintegrate the large polyphenol aggregates has been proposed

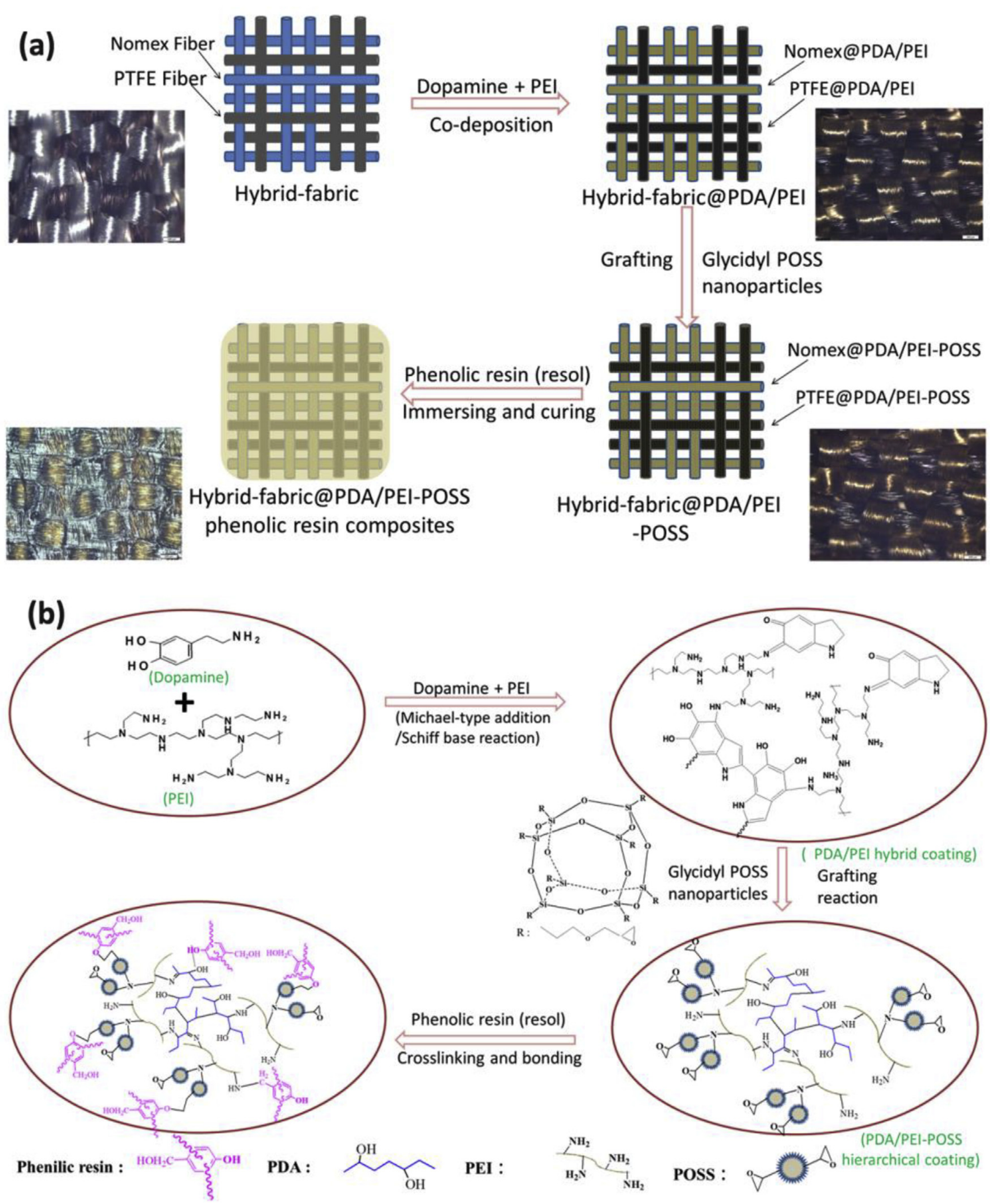

Fig. 1. Schematic illustration of the preparation procedure (a) and reaction mechanism (b) for the Hybrid-fabric@PDA/PEI-POSS composites.