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Thermal and combustion behavior of furan resin/silica nanocomposites

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ABSTRACT

In this paper, we report the development of furan resin nanocomposites, filled with silica nanoparticles. In order to have a dispersion procedure, which could be easily up-scalable to the industrial level, a commercially available water-based suspension of silica particles was used. This was possible thanks to the fact that water is a good solvent of furan resin. Different treatments with silanes were performed in order to improve the interaction between the silica particles and the furan matrix. As a result, the thermal oxidative resistance of the furan resin is improved with also a minor improvement of fire reaction, which is already quite substantial in the pristine resin.

1. Introduction

Furan resin from furfuryl alcohol polymerization, extensively studied by Gandini and Belgacem [1] and Hoydonckx et al. [2], is a very promising thermosetting material, since it comes from renewable resources and has a fire reaction as good as phenolics, which are the less flammable among common polymer materials [1,2]. Indeed, since the global tendency nowadays is to use renewable resources for the development of new polymeric materials, furan resins can be considered an interesting alternative to fossil-based polymers. As a matter of fact, furfuryl alcohol can be easily obtained from a wide range of agricultural residues containing pentoses. Therefore, it is possible to obtain a material with excellent thermal behavior and reaction to fire, as phenolic resins, but avoiding the contaminant formaldehyde emissions involved in phenolic resins synthesis and use [3]. For this reason, furan resin can be considered a very promising environmentally friendly thermosetting matrix to substitute phenolics for composites production.

In the last decades, the addition of nano-sized particles to a polymer matrix has led to materials with radically improved properties [4–22]. In particular, several nanofillers have shown to produce a significant improvement of the reaction to fire of the polymer matrix both thermoplastics and thermosets, which they are embedded in [6–17]. As examples, as far as thermosetting matrices and reaction to fire are concerned, Schartel et al. [14] added nano-sized layered silicates to an epoxy matrix and focused their study on the formation of the inorganic-carbonaceous fire protection layer produced by the nanofiller. Natali et al. [15] developed phenolic nanocomposites filled with silica particles and the produced materials showed both homogeneous dispersion and improved thermal stability. Furthermore, there is plenty of literature focused on the use of thermosetting nanocomposites as advanced matrices for fiber reinforced composites, which has been summarized in [16], in order to confer to lightweight structural

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Table 1
Studied materials.

Studied materials	Code
Neat furan	Neat furan
Furan + Ludox AS-40 not functionalized	F/AS-40
Furan + Ludox PT40-AS not functionalized	F/PT40-AS
Furan + Ludox AS-40 functionalized with isocyanate	F/AS-40 isocy
Furan + Ludox PT40-AS functionalized with isocyanate	F/PT40-AS isocy
Furan + Ludox AS-40 functionalized with amino	F/AS-40 amino
Furan + Ludox PT40-AS functionalized with amino	F/PT40-AS amino

materials enhanced properties and/or multifunctional features (see also as examples [17,18]).

Limited literature is available on furan resin nanocomposites. Rivero et al. [3,21] studied the cure kinetics of furan-based nanocomposites filled with different type of montmorillonite, and Ballav et al. [22] developed two different furan nanocomposites filled with Al_2O_3 and montmorillonite produced by in-situ polymerization. Finally, Guigo et al. [23] studied the thermal degradation of furan/SiO_2 hybrids obtained by sol–gel process.

In this paper, a furan nanocomposite filled with silica nanoparticles was developed and its thermal and combustion behavior studied. The nanocomposite mixture was obtained with the support of a commercial water-based silica colloidal suspension that was mechanically mixed with the furan prepolymer. The used raw furan system together with the use of liquid suspension of the filler lead to a processing that can be easily up-scaled, and represent a unique opportunity to reach the industrial maturity of this materials.

2. Materials and methods

The utilized furan resin was developed by TransFurans Chemicals. It consists in polyfurfuryl alcohol dissolved in water. The final resin had a total water content of 5%, viscosity of 2000cps @ 25 °C and a density of 1.2 g/ml. The

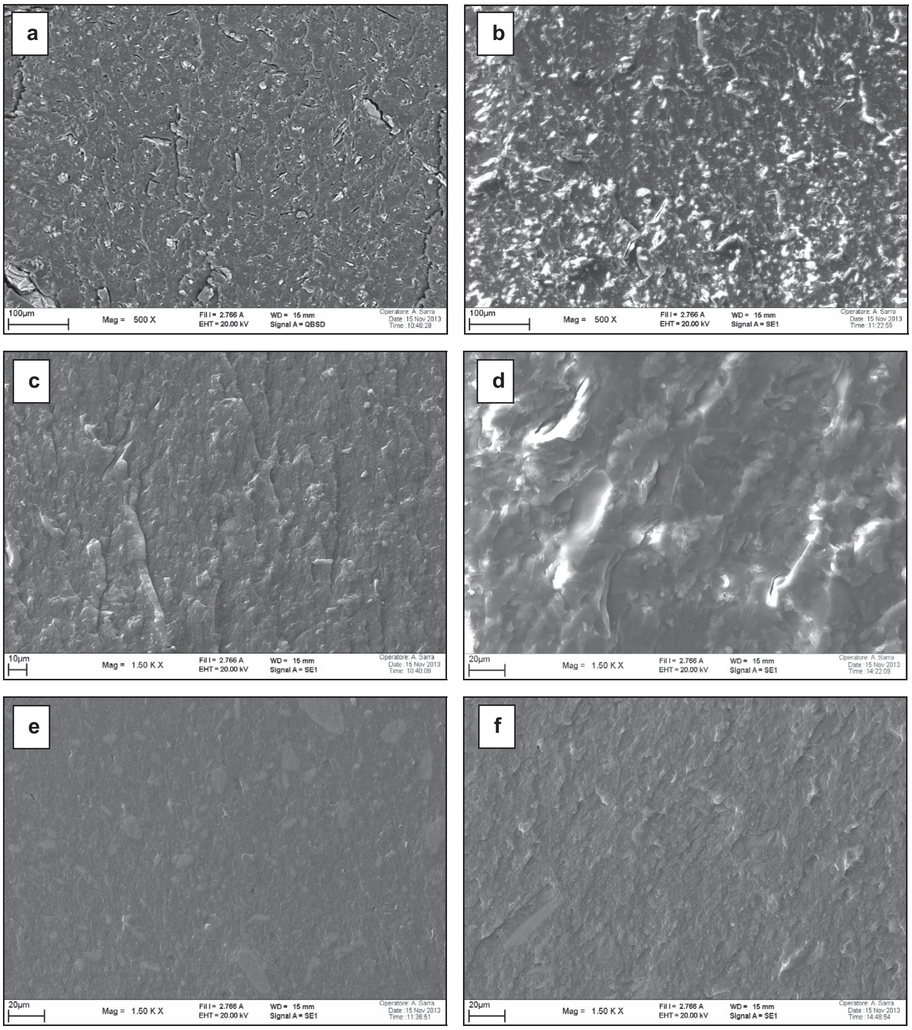

Fig. 1. SEM images of the studied materials. (a) F/AS-40, (b) F/PT40-AS, (c) F/AS-40 isocy, (d) F/PT40-AS isocy, (e) F/AS-40 amino and (f) F/PT40-AS amino.