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Featured Letter

Layer-by-Layer nanostructured assemblies for the fire protection of fabrics

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ABSTRACT

This paper discusses the recent findings on the use of the Layer-by-Layer technique for the surface nanostructuration of different fabrics in order to achieve flame retardant features. For this purpose, the almost unlimited choice of Layer-by-Layer constituents (nanoparticles and organic/polymer layers) and the broad tuning of deposition parameters can be successfully exploited. First, a general description of the proposed approach and of the structure of inorganic or hybrid organic–inorganic nanoassemblies, able to confer flame retardancy properties to both synthetic and natural fabrics, will be presented. Then the recent evolution of the coating composition toward the design of sustainable bio-based Layer-by-Layer nanoarchitectures will be also considered. Finally, some possible solutions for overcoming the current limitations of the proposed approach will be summarized.

1. Introduction

Among the surface engineering approaches, the Layer by Layer (LbL) technique has arisen as a new method for obtaining molecularly-controlled nanostructured thin films and coatings. Despite that the pioneering work discussing the principles and potentials of this method was published in 1966 [1], its exploitation was assessed only in the early 1990s by Decher, who succeeded in developing a practical method for the deposition of polyanions and polycations [2]. Nowadays, LbL processes can be employed for fabricating nanostructured assemblies on different substrates, aiming to: i) define and provide the surface functionality, through which every object/substrate can interact with the surrounding environment, ii) design and fabricate surface-based devices (membrane reactors [3], photonic devices like LED [4] or complex waveguides).

Generally speaking, the LbL requires an alternate adsorption of chemical species on a chosen substrate exploiting one interaction, which occurs between the selected species, as the driving force for the growth of multilayered assembly: it is very common to build up LbL architectures by using the electrostatic attraction, although other interactions could be used as well: among them, it is worthy to mention hydrogen or covalent bonds, donor/acceptor, stereocomplex formation or specific recognition [5–8].

The deposition process involving electrostatic interactions is based on the alternate dipping of the substrate into oppositely charged polyelectrolyte water solutions or nanoparticle water suspensions; thus, a total surface charge reversal after each immersion step is achieved, resulting in the building up of a structure of positively and negatively charged layers piled up on the substrate surface. A schematic representation of the LbL process is depicted in Fig. 1. The size and topology of the treated substrate do not affect the LbL process that can be applied to almost any solvent-accessible surface, ranging from submicron objects [9] up to the inner surfaces of pipes or even large surface items.

The components exploitable for creating the Layer-by-Layer assembly can be selected from a wide range of materials: cationic or anionic polyelectrolytes, metallic or oxidic colloids, layered silicates, etc., [10–12]. Furthermore, several experimental parameters, like chemical structure [13] and molecular weight [14] of the used polyelectrolytes/nano-objects, pH [15], temperature [16], types of counterions [17], ionic strength [18], adsorption time [19], drying step [20] may affect the formation of the final assembly.

The use of the LbL technique has grown year by year, widening the potential application fields [21]: in particular, this approach has become an effective method for providing polymeric materials with flame retardant (FR) features. Undeniably, flame retardancy has become of extreme importance as the easy flammability of polymers and the resulting fire hazards still represent severe treats to human safety [22]. Fabric flammability is a typical surface property, in which traditional bulk addition of so-called fire retardant additives shows poor effectiveness, in some cases demanding up to 60 wt% loading, with worsening effects on materials properties, and determining processing difficulties.

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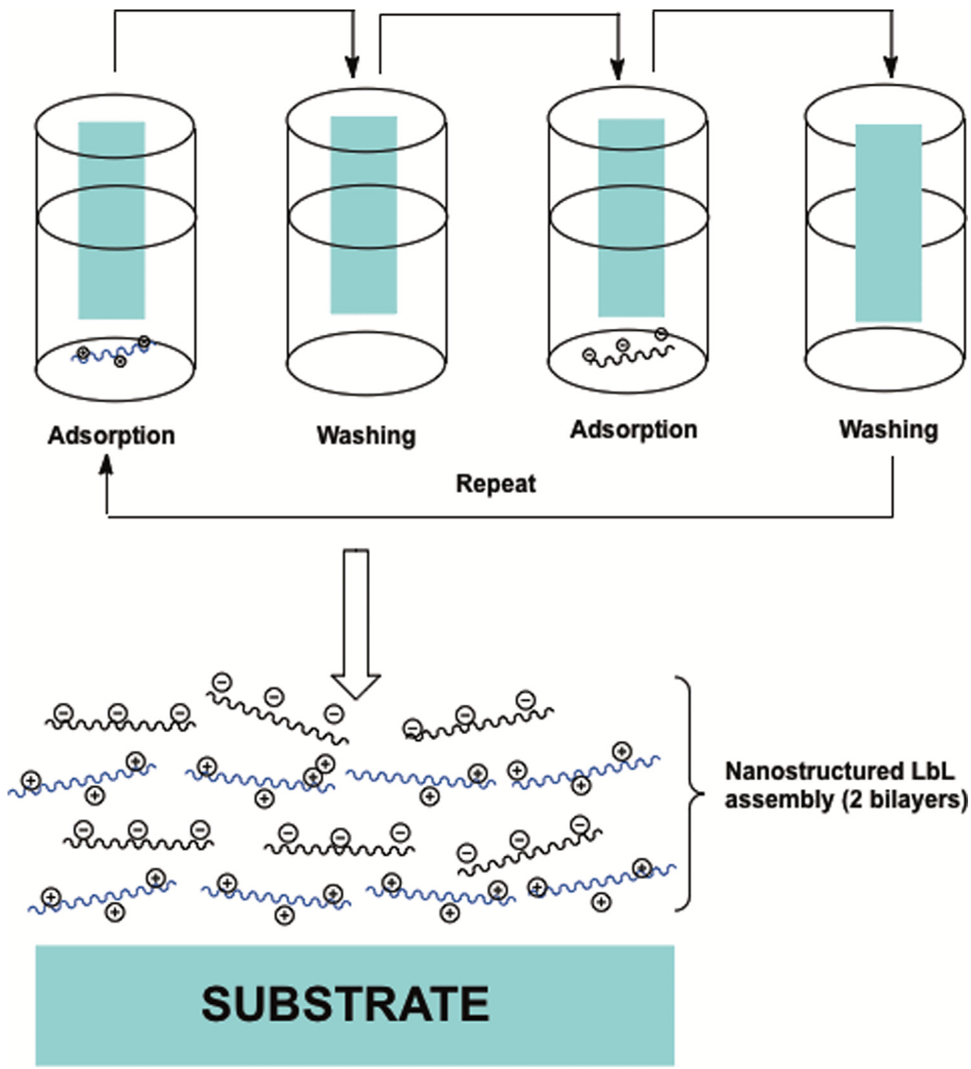

Fig. 1. General scheme of the LbL process.

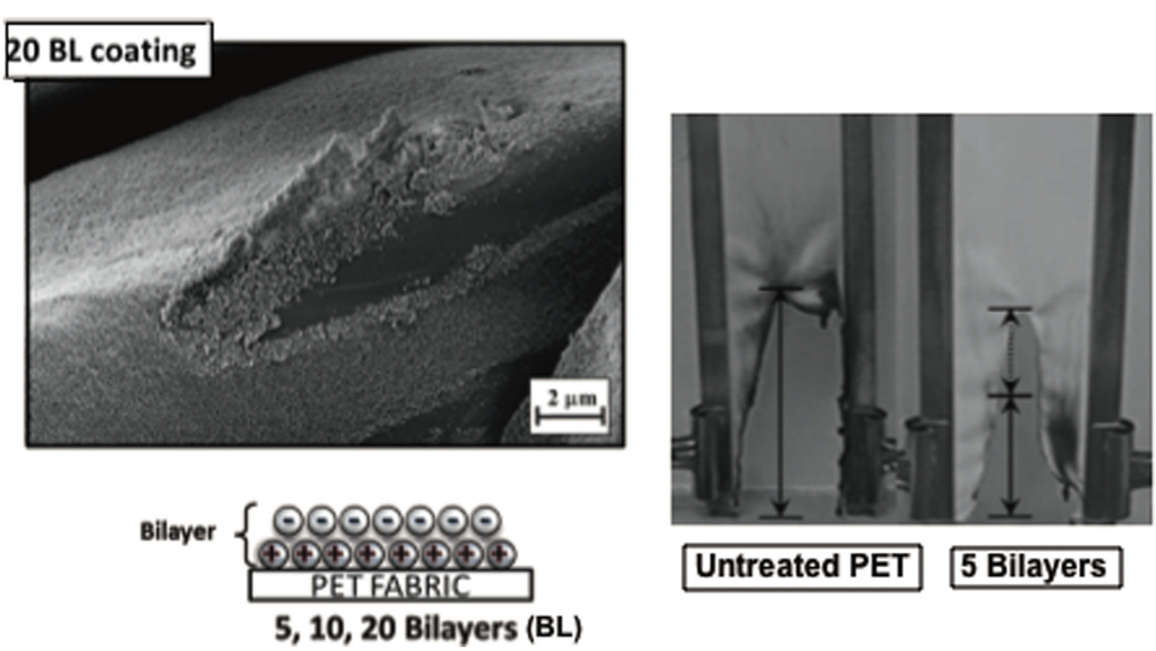

Fig. 2. FE-SEM magnification of the 20 BL silica/silica assembly deposited on PET fabrics and images of uncoated and LBL-coated fabrics following the vertical flame testing (from Ref. [24]).