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Invention Article

Graphene as effective anti-fading agent for the protection of artworks

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ABSTRACT

Since all art materials in time are prone to degradation due to environmental conditions, a solution is needed to delay or even to prevent such an interference. Graphene, the pioneer of 2D materials, seems to pave the way to this end either as a protective layer on artworks or as an inclusion in paints, dyes, pigments acting as protective additive, respectively. Regarding the former, the proposed invention provides a method for applying a protective graphene coating onto a surface, such a two- or three-dimensional artwork or other coloured surface. The steps followed within this method are: Deposition of Chemical Vapor Deposition (CVD) produced graphene onto a supporting substrate in order to produce a graphene/substrate composite; Removal the graphene membrane from the supporting substrate; and Deposition the graphene membrane onto the surface of interest All the pre-mentioned steps are performed following the roll-to-roll method (Choi et al., 2015), with the assistance of a tailor-made laminator. However, the direct deposition of graphene onto artworks may not be straightforward due to the wet transfer and hot lamination conditions that can be catastrophic for fragile painted substrates. The novel strategy designed exploits the high-quality CVD monolayer graphene and uses a pressure-sensitive adhesive film (PSAF) in the transfer process that has been demonstrated to enable graphene wetting on the final target-substrate (Kim et al., 2015), thus maximizing the contact area and van der Waals interactions. The low work of adhesion between graphene and the PSAF, compared to the corresponding between graphene and the destination surface, promotes the transfer that can be performed at mild pressure and temperature conditions, without using a surface modifier or adhesives (Martins et al. 2013). Additionally, the proposed roll-to-roll method does not affect the mechanical integrity of the typical paper substrates used in graphic arts. As for the protective additive case, graphene is employed in the form of an aqueous dispersion in media such as paints, dyes, inks, pigments and/or varnishes used for artistic purposes in order to create indelible colours to capable to prevent degradation, attributed to UV radiation, moisture and oxidizing agents. The method presents a new approach for obtaining aqueous dispersions for the hydrophobic graphene and thus, protecting artworks and painted indoor/outdoor wall surfaces taking advantage of the optical and barrier properties of graphene.

Specifications Table

Subject code	2501 (Materials Science)
Specific subject area	Protection and conservation of cultural heritage with novel two-dimensional nanomaterials such as a graphene
Industry code	C Chemistry; metallurgy
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Intended use	The main intention strategy is to license the patented outputs to one or more existing companies, either European and/or national industries, or already-funded start-ups operating in industrial areas. Also, collaborations with enterprises and/or leaders in the production of paints and coatings for the development of graphene-based innovative paints are within the agenda of the group. Such a development would lead to the production of decorative paints with reduced color fading and an extended lifetime. Up to now, there are discussions with several companies, which have expressed their strong support for this invention.
Related research article	-
Related other sources: (datasets, software, diagrams, plans, etc.)	-

1. Invention description

Since its rediscovery and isolation in 2004, graphene has been touted as the "wonder material" of science due to its outstanding chemical resistance, ability to conduct heat and electricity and excellent physical/mechanical properties [4]. Graphene is one of several allotropes of carbon and can be considered the ultimate aromatic hydrocarbon – existing as an infinite monolayer of carbon atoms joined together in a two-dimensional, hexagonal sheet-like structure that gives rise to its many unique properties. Graphene shows protective abilities and, the properties of the hexagonal lattice arrangement of carbon atoms make it act as a flexible barrier to oxygen and other gases, damaging wavelengths of light and water vapor when applied to a surface [5]. The current invention aims to the development of an invisible veil, such as, a graphene membrane of atomic thickness, that can provide protection for old and contemporary paintings against UV radiation, humidity, oxygen or any other chemical penetration. It also aims to the creation of colour paints and varnishes with dispersed graphene flakes so as to bestow enhanced UV, oxidation and humidity resistance.

The coverage of paintings with invisible veils is achieved through production, shaping and transfer of wrinkle-free graphene sheets of various sizes to various surfaces such as polymers, but also on canvas or paper substrates used by artists. We employ the Chemical Vapor Deposition (CVD) method to produce monolayer graphene [6]. Using raw materials such as methane gas (CH_4), we can grow high quality graphene on a variety of carrier or support substrates such as metals (Cu, Ni etc.) and non-metals [7,8]. Transfer process, where a deposited graphene is removed from a carrier/support layer (PET/Silicone film, Figure (a)) and deposited on a second different surface (artwork) [1] has also been developed. A novel roll-to-roll process for dry transfer of CVD graphene membranes (both monolayer and few-layers) on the surface of art materials (Figure a) has been implemented. Also, the application of nanographene materials to paints/dyes/inks as additives for the formulation of novel varnishes (Figure b) is performed using graphene powders, and then, bath sonication (Patent granted from the Hellenic Industrial Property Organisation, No. 1009757).

Both the graphene-coated samples and the novel paints have been subjected to UV and visible radiation and accelerated weathering conditions. As a result graphene seems to lower the index for colorimetric change, Delta E, by about 70% [9]. Up to now, performed colorimetric measurements have been performed to totally 3 artworks, 2 of them donated by a Greek artist (Ms. Matina Stavropoulou), and the results obtained regarding optical differences are very encouraging.

Finally, the transparent protective graphene veil can be easily removed [9] so it does not constitute an irreversible intervention on the art object. Moreover, for such an application the price of graphene does not hamper its business potential since the quantities are minimal Fig. 1.

2. Background (optional)

Anti-fading paints currently available on the market are based on organic and inorganic pigments (e.g. titanium dioxide) rather than on 2D materials (e.g. graphene), which is the aim of the current patent. Furthermore, such commercial products are generally varnishes/coatings that "seal" the surface of the paintings thus keeping out dirt, dust, moisture and other contaminants. Invisible multi-functional anti-fading solutions that can be directly applied to the artwork or can be integrated in the paints themselves, have not been proposed to the market yet. Commercial protective films for paint protection (including those aimed at automotive application) are considered as "too thick/ unsuitable" for application to artworks as proposed herein due to their visual appearance and that their application/removal could destroy valuable items.

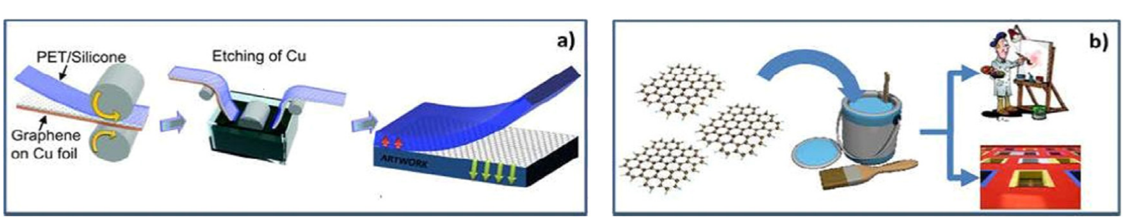

Fig. 1. Creation of multi-functional graphene coatings and paints through different procedures: (a) direct application of large-size CVD graphene on existing artworks and (b) addition of microscopic graphene flakes to artists' colour paints and to architectural paints.

3. Application potential

According to Coatings World, the global top coatings companies had a combined turnover in excess of $58 Billion (2017) with key organisations including AkzoNobel N.V. (Netherlands), PPG Industries (U.S.), Axalta Coatings Systems (U.S)., The Sherwin-Williams Company (U.S.), RPM International (U.S.) and NEI Corporation (U.S) among 84 companies. Also, it is worth highlighting that there are some smaller companies that are emerging such as Applied Graphene Materials PlC and HMG Paints.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Maria Kotsidi: Data curation. **George Gorgolis:** Writing – original draft, Writing – review & editing. **Maria-Giovanna Pastore Carbone:** Visualization, Investigation. **George Anagnostopoulos:** Validation. **George Paterakis:** Visualization, Investigation. **Giovanna Poggi:** Data curation. **Piero Baglioni:** Supervision. **Costas Galiotis:** Conceptualization, Methodology, Supervision, Writing – review & editing.

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