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Application of Carbon Nanotubes in Preservation, Conservation and Restoration of Manuscripts and Artefacts

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Abstract

The manuscripts and artefacts are threatened by degradation due to the environmental factors and the harmful components used in technique of papermaking. It is thus becomes important to develop a proper consolidating agent, which can effectively preserve, conserve and restore these historical manuscripts and artefacts. Carbon Nanotubes (CNTs) are the new developed tubular nanomaterial employed in the process of conservation of manuscripts. The nanomaterial like metal nanoparticle (Aluminium and Gold), metal oxides (silicon and Titanium) are the typically used nanotechnology in conservation processes of the manuscripts, but the CNTs has shown unique properties like electrical, thermal, optical and mechanical properties, which makes it significant candidate to be employed in the preservation process of the manuscripts. The CNTs effectively restores preserves and conserves the manuscripts and artefacts without affecting the original appearance of the manuscripts. This study provides recent development in the application of CNTs in the preservation and conservation of manuscripts and artefacts.

Key Words: Manuscripts, Artefacts, Consolidate, Preservation, Restoration, Carbon nanotubes (CNTs), Nanoparticle

Introduction

Manuscripts are handwritten documents written on paper, wood, plant leaves, metals, stones and clothes having cultural, historical and scientific values dating back at least seventy – five years and carry significant scientific, historical or aesthetic value and India has the largest number of manuscripts (Londhe et al., 2011), whereas an artefact is an object created or modified or recovered archaeologically by a human being, which has historical and cultural significance (Dumitriu and Ion 2011). These manuscripts and artefacts are continually prone to degradation, as they are constantly subjected to degrading factors like biological and chemical factors, which deteriorate the artefacts and manuscripts by affecting their structural integrity and mechanical strength (Ion et al., 2013 and Mourdikoudi et al., 2018).

In recent years nanomaterials have attracted the attention of researchers to conserve the

cultural heritage because of their unique properties. So far scientists have used several nanomaterials like gold, silver, copper and platinum nanoparticles and nano metal oxides and hydroxides (ZnO, $Ca(OH)_2$, MgO and $Mg(OH)_2$) to conserve, preserve and restore the cultural heritages (nature, 2022, Kwiatkowska et al., 2014 and Ali et al., 2021). The nanomaterials have characteristics like self-cleaning, improving the surface of materials where applied and reducing bio deterioration (Weichelt et al., 2011). Studies have shown that when nanoparticles of titanium dioxide (TiO_2) and silicon dioxide (SiO_2) were used in treating artefacts. The nanaomaterials have nanoscale particle size (1 – 100nm), which gives them a larger surface area that helps them to penetrate into the surface of the treated object and increase the resistance of the object (Khan et al., 2019). From various researches it has been reported that the nanoparticle of ZnO and TiO_2 have properties like antifungal and antibacterial, which makes them a good consolidator for wood origin manuscripts and wood artefacts (Szurkalo et al. 2017). The manuscripts and artefacts treated using nanomaterials all over the world are shown in the figure 1.

Figure-1: World distribution and cultural heritage treated with nanomaterials; reuse from the open access www.ars.els-cdn.com

(a) Palacio da Pena Walls (Fonseca et al., 2010) in Portugal.
(b) Enameled tiles at Pombal Palace; Marquis, (Coutinho et al., 2016) in Portugal.
(c) Paper sheet from the archive of the Royal Botanic Garden (Spain)(Castillo et al., 2019).
(d) (d) Plaster wall from the Fiesole archaeological area, Italy (Pinna, D. et al., 2018)
(e) Church of San Leonardo di Siponto, Italy (Van der Werfet al., 2015).
(f) Villa dei papyri, all three from Italy (Ruffoloet al., 2017).
(g) Cathedral of Seville (Spain) (Becerra et al., 2018).
(h) Old manuscript from Iran (Afsharpour et al. 2017).
(i) Teotihuacan Monument, Mexico (Carrillo-González et al., 2016).
(j) Pre-Colombian wool from La Plata Museum in Argentina (Pietrzak et al., 2017).

(k) ConcordiaTemple, Italy (Schifano et al., 2020).
(l) Wall paintings at Valley of the Kings, Egypt (Gambino et al., 2017)
(m) Funerary mask, Egypt (Helmi et al., 2015).
(n) Amir Altinbugha al-Maridani Mosque's columns, Egypt (Aldosari et al., 2019).

Presently researchers are focusing on developing new nanomaterials for application in the conservation of cultural heritage, which can more efficiently consolidate the treated object and they have found that tubular nanomaterials like carbon nanotubes (CNTs), titanium dioxide nanotubes (TiO_2 NTs) and Zinc oxide nanotube (ZnO NTs) have shown properties that make them apply for various application and to be used as consolidates for heritages (Yahyazadeh and Khoshandam 2017). The tubular nanomaterials along with their unique physical and chemical properties have ability to present multiwall, which make them ideal for different applications (Dimitrov et al., 2011). Among all these tubular nanomaterials CNTs have gained adequate attention, as it has shown excellent ability to be used as consolidate for manuscripts and artefacts, due to their interior voids and exterior surface (Saleh et al., 2019).

Structure of CNTs

In 1991 Sumio Iijima discovered CNTs, using the action of a catalyst on the species of gaseous, which form from the decomposition of hydrocarbons. Subsequently, as a by-product from the fullerenes of an electric arc, multi-walled carbon nanotubes (MWNTs) were formed, where catalysts were not involved. After two years, as result of several attempts to use various metals to fill CNTs, single-walled nanotubes were discovered (Scoville et al., 2020).
CNTs are molecules, which is a hexagonal arrangement of hybridized carbon atoms, formed by rolling one or more graphene sheets having diameter in nanometers (Kumari et al., 2022). Generally these nanotubes are in fullerene (hemispherical arrangement coated at both the ends) (Holban et al., 2016). The figure 2 shows CNTs.

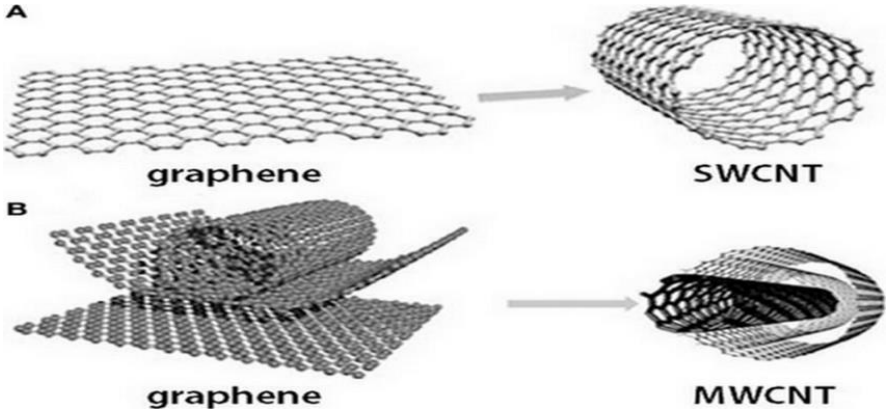

Figure-2: Carbone nanotubes; reused from open source: www.researchgate.net

Significant Properties of CNTs for Cultural Heritage Preservation

CNTs have various unique properties, which make them desirable candidates to be used as consolidate for heritages. The properties that play a vital role in heritage preservation are

discussed below:

Mechanical and Elastic Properties: CNTs are more rigid as compared to steel and are resistant to the physical force, as when force is applied on a nanotube though it bents but no damage is made to the top of the nanotube (Yakobson and Avouris, 2001). CNTs exhibit excellent tensile strength and elasticity as compared to graphene, as such CNTs are known for their very high mechanical strength (Zhang et al., 2017). The manuscripts and artefacts, when treated with CNTs (MWNTs or SWNTs) gain high mechanical strength, which help in increasing the life of the object or material used in making these heritages (Flores et al., 2019 and Farsheh et al., 2011).

Optical properties: The CNTs are resistant to ultra violet radiation (UV radiation), as when CNTs are exposed to UV radiation, there is no direct effect of the radiation on the characteristic of the CNTs (Najafi and Shin 2005). Studies show that when CNTs are added to polymeric matrix, the radiations with high energy were dissolute into the network of CNT composite, resulting in increasing the resistivity of the polymer matrix against UV radiation (Nguyen et al., 2017). The resistivity against UV radiation makes CNTs a good consolidate for application on cultural heritage, as they can protect against photo-degradation.

Hydrophobic properties: The CNTs are hydrophobic in nature. Studies have reported that when MWNTs are applied on a surface, super hydrophobic surface is obtained (Eseev et al., 2019). The surface of CNTs has high adsorbing property, as it can absorb poly (dimethyl siloxane) fluid and hence attain the highly hydrophobic character (Sulym et al., 2019). The CNTs when present in polymer matrix significantly decrease the water adsorption by polymer matrix, as CNTs has a non-polar hydrophobic structure (Ray et al., 2012). The hydrophobicity of the CNTs can be utilized in conserving artefacts, as when CNTs will be applied on the surface of artefacts, and then there will be minimum adsorption of water on the surface of artefacts, which will help in increasing the life of artefacts, as there will be decrease in the deterioration due to water.

CNTs Used in Conservation and Restoration of Artefacts

CNTs are used in developing thin heaters to preserve artefacts. Scientists designed light weight, flexible and transparent heater using CNTs, for art preservation. The figure 2 shows the SEM image of the thin heater with hybrid textile (Meyer et al. 2013).

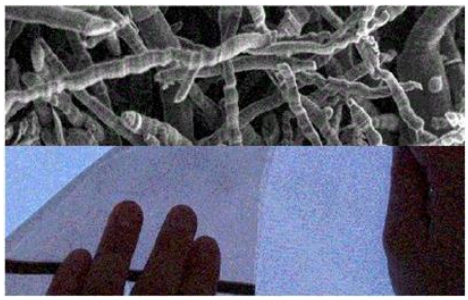

Figure-2: SEM image of CNTs thin heater with hybrid textile (Meyer et al. 2013)

CNTs embedded in epoxy resin, were used as a coating on wood structures and it was observed that the application of CNTs increased the mechanical strength of the object significantly, as such when these coatings will be applied on the surface of the wood origin manuscripts, it will enhance the mechanical strength of the manuscript and hence increase its life (Cestari et al., 2009).

The CNTs has shown excellent result, when added to the polymeric matrix, as such scientists are trying to develop functionalized CNTs with metal oxides (Chen and Lu 2010). Some of the functionalized CNTs with metal oxides and their properties are discussed in table 1.

Table 1. Functionalized CNTs and their properties

Structure	**Properties**	**References**
MWCNT-TiO_2	Photocatalytic activity	Ramoraswiet al. 2015
MWCNT-ZnO	Bolometric sensor	García-Valdivieso et al., 2018
MWCNT-Fe_3O_4	Magnetic sensor	He et al., 2011
MWCNT-CuO	Glucose sensor	Zhang et al., 2015
MWCNT-Ag/TiO_2	Antimicrobial agent	Mohamed et al., 2015

Currently, the functionalized CNTs are not employed in the preservation of heritages, but it has shown properties like excellent mechanical strength, good optical and electrical properties as compared to non-functionalized CNTs, which makes a higher probability of functionalized CNTs to be used as consolidators for various artefacts and manuscripts.

Historical evidence of CNTs application in the preservation of Artefacts

Scientists have confirmed that the unique black coating found on the ancient pottery shards from the archaeological site of Keeladi in Tamil Nadu, India dated back to 600 BC, is the oldest known man-made nanomaterials. It is divulged that these coatings can last for more than 2600 years and are made of CNTs. The images of pottery shards and artefacts are shown in figure 3. Scientists have put forward a simple clarification for the findings that the extracts that were used in the coating of these pots must have resulted in CNTs, formation at high temperatures (News Article, The Hindu, 21 Nov. 2020 and News Article, The Sentinel, 22 Nov. 2020).

Figure-3: Various artifacts on display at Keeladi Exhibition at Wolrd Tamil Sangam in Madurai

These historical evidences prove that the CNTs are great options in near future to be used as consolidate for the manuscripts and artefacts preservation, conservation and restoration for a long period.

Conclusion

In the past couple of decades, the conservation of manuscripts has gained interest and significance throughout the world, because there is a need to preserve the originality of the manuscripts, artefacts and the history of mankind. Due to the age of these manuscripts, external degradation factors resulted in the deterioration and degradation of these heritage manuscripts. For example, wood materials and papers are prone to many degradation factors like biological and chemical factors that can cause serious damage to the manuscript materials by affecting the structural purity and mechanical strength of these materials.

Studies have shown the successful introduction of CNTs into a polymeric matrix of CNTs and its attachment on the surface of CNTs, it has been put in different applications along with successful conservation restoration of object and its introduction has remarkably increased the UV resistance and mechanical properties of treated object. CNTs applications and functionalization on objects have improved the mechanical, optical or electrical properties of treated object as compared to the nanotubes without functionalization. Consequently CNTs have brought significant improvement in the consolidators for the manuscripts and the historical artefacts. The studies so far done on the application of CNTs in the conservation, preservation of manuscripts and artefacts has shown excellent potential to be used as consolidation of cultural heritage.

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