Importance of using Nanomaterials in Preservation of Oil Paintings for Achieving Required Sustainability

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Abstract:
New nano-materials and responsive systems have been developed and experimented for using it in preservation of artworks. as same as cleaning, deacidification and consolidation. The main goal of this study was to learn the importance of applications of nanomaterial's in preservation efficiency on oil paintings. This study will focus on Nanoscience to discover new behaviors and properties of materials at the atomic scale to create materials, devices, or systems with new properties and/or functions, will present types of nanomaterials " Carbon-based Materials - Metal-based Materials - Dendrimers - Composites " after that will present nanomaterials properties as a" structure - thermal - chemical - electrical - magnetic - electronics-biological " . the experiments in this study showing applications for nanomaterials in the preservation of oil paintings as a unique property of nanomaterials encourage and achieving sustainability concepts in the preservation of cultural heritage. Confirmed this study's effectiveness of using nanomaterials components in preservation and conservation of oil paintings within process (Cleaning – Consolidation - PH Treatment). It was observed that there are Highly viscoelastic HVPDs and magnetic gels are very promising materials for cleaning movable artworks surfaces, Silver NPs achieved better results than zinc oxide NPs. Application of 1.0 or 2.0 mM silver NPs exhibited the best preservation effect on achieving 100% microbial inhibition (bacteria and fungi, respectively), acidic character of CCNF and CNC may not induce any problems during Treatment Process

Keywords:
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Introduction

The field of protection and preservation of cultural and artistic heritage is one of the most important priorities of the sustainability approach, which many countries and international organizations seek to apply it to ensure its survival and resistance to all factors and aspects of damage that may cause its extinction. Nanoscience has become one of the most import modern methods and materials for preservation of cultural heritage, is The first application of nanoscience to the conservation of artefacts dates back to the end of the 1980s in Florence, Italy, with cleaning the surface of works of art is an irreversible and delicate intervention involving the removal of undesired materials layer by layer **(Pisupati S. S., 2014).** Using Nano-materials for the conservation and preservation of movable and immovable artworks, new nano-materials and responsive systems have been developed and experimented for the preservation of artworks. The main challenge of nano for art is the combination of functional materials arising from the recent developments in nano-science with innovative techniques in the restoration of works of art, as same as cleaning, deacidification and consolidation of movable artworks (paper, parchment, canvas paintings) **(Baglioni 2012).**

Methods & Materials

1. **Definition of Nanotechnology**

The concept of a ‘‘nanometer’’ was first proposed by Richard Zsigmondy (the 1925 Nobel Prize Laureate in chemistry) for characterizing particle size. And he used an ultramicroscope in 1914 to study colloidal gold and other nanomaterials **(Hulla 2015) .** Nanotechnology is one of the leading scientific fields today since it combines knowledge from the fields of physics, chemistry, biology, medicine, informatics, and engineering **(Logothetidis 2012)**. Nanoscience involves research to discover new behaviors and properties of materials with dimensions at the nanoscale which as the size ranges from approximately 1 to 100 nanometers 'nm' **(Göran 2010)**. dimensions between approximately 1 and 100 nm are known as the nano-scale **(Wolfgang 2010)**. The nanometer is a metric unit of length and denotes one billionth of a meter or 10-9 m **(Buzea 2007).** Also, nanotechnology can be defined as a manipulation of matter at the atomic scale to create materials, devices, or systems with new properties and/or functions **(Michael 2002).**

2. **Types of Nanomaterial**

Nanomaterials can be categorized into three types according to their source: natural, incidental and engineered **(Mary 2014)**. Engineered nanomaterials are resources designed at the molecular (nanometer) level to take advantage of their small size and novel properties which are generally not seen in their conventional, bulk (micrometre) counterparts **(Pisupati S. S., 2014).** Most current nanomaterials could be organized into four types:

2. 1. Carbon-based Materials. These nanomaterials are composed mostly of carbon, most commonly taking the form of hollow spheres, or tubes. Spherical and ellipsoidal carbon nanomaterials are referred to as fullerenes, while cylindrical ones are called nanotubes. have many potential applications, including improved films and coatings, stronger and lighter material

2. 2. Metal-based Materials. These nanomaterials include quantum dots, nanogold, nanosilver and metal oxides, such as titanium dioxide. A quantum dot is a closely packed semiconductor crystal comprised of hundreds or thousands of atoms, and whose size is on the order of a few nanometers to a few hundred nanometers. Changing the size of quantum dots changes their optical properties.

2. 3. Dendrimers. These nanomaterials are nanosized polymers built from branched units. The surface of a dendrimer has numerous chain ends, which can be tailored to perform specific chemical functions. This property could also be useful for catalysis.

2. 4. Composites combine nanoparticles with other nanoparticles or with larger, bulktype materials. Nanoparticles, such as nanosized clays, are already being added to products ranging from auto parts to packaging materials, to enhance mechanical, thermal, barrier and flame-retardant properties. **(Jeff 2007).**

3. Nanomaterials Properties

Nanoparticles are attractive from a scientific perspective because they may exhibit completely new or improved properties based on their respective specific characteristics (particle size, size distribution, morphology, phase, etc.)

3. 1. Structural Properties

The crystal structure of nanomaterials may or may not same as its bulk one, but has different lattice parameters. For example, Indium of size less than 6.5nm is face-centered cubic rather than face-centered tetrahedral for size greater than 6.5nm. Also, the interatomic spacing in nanomaterials decreases than bulk due to longrange electrostatic forces and the short-range core-core repulsion **(Alagarasi 2011).**

3.2. Thermal Properties

It is known that polycrystalline materials exhibit lower thermal conductivity than low – defect single crystals of the same material. Several investigators realized recently that this could result in significantly reduced thermal conductivities in nanostructured materials, which could lead to improvements for applications such as thermal barrier coatings, the large increase in surface energy and the change in inter-atomic spacing as a function of nanoparticle size have a marked effect on material properties **(Douglas 2008).**

3.3. Chemical Properties

One of the important factors for the chemical applications of nanomaterials is the increment of their surface area which increases the chemical activity of the material. Due to their enhanced chemical activity, nanostructural materials can be used as catalysts to react with such noxious and toxic gases as carbon monoxide and nitrogen oxide to prevent environmental pollution. Additionally, nanoparticles often exhibit new chemistries as distinct from their larger particulate counterparts; for example, many new materials are insoluble in water when in the form of \ micron-sized particles but will dissolve easily when in a nanostructured form **(Pokropivny, 2007).**

3.4. Electrical Properties

The electrical properties of nanomaterials vary from metallic to semiconducting materials. It depends on the diameter of the nanomaterials. The very high electrical conductivity of nanomaterial is also due to minimum defects in the structure **(Arivalagan, 2011).**

3.5. Magnetic Properties

Magnetic nanomaterials have multifunction applications, including ferrofluids, colour imaging, bio-processing, refrigeration as well as high storage density magnetic memory media. Due to a large proportion of surface atoms which have a different local environment. Ferromagnetic materials in bulk form have multiple magnetic domains, whereas nanoparticle often has one domain as in exhibit superparamagnetism phenomena. Also, Giant magnetoresistance is a phenomenon observed in nanoscale multilayer consisting of a strong ferromagnet and a weaker magnetic or non-magnetic buffer **(Pokropivny, 2007).**

3.6. Optical Properties

In bulk materials, optical emission and absorption depends on the transition between the valence band and conduction band. Large changes in optical properties such as colour is seen in low dimensional semiconductor and metal. Semiconductor nanoparticles in the form of quantum dots show size-dependent behaviour in the frequency and intensity of light emission as well as modified non-linear optical properties and enhanced gain for certain emission energy or wavelength **(Charles, 2003).**

3.7. Electronic Properties

The electronic properties changes occur in the low dimensional material are related to the wave-like property of the electron and scarcity of the scattering centres. electronic transport is determined by scattering with phonons impurities or other carriers. However, if the system becomes sufficiently small, all scattering centres will disappear and the electronic transport becomes purely ballistic transport **(Pokropivny, 2007).**

3.8. Biological Systems

Biological systems contain many examples of nanophase materials and nanoscale systems. Biomineralization of nanocrystallites in a protein matrix is highly important and using in produce materials with well-defined characteristics such as particle size, crystallographic structure, morphology and architecture. Generally, which makes them ideal for the assembling of nanosized building blocks **(Andrea, 2013).**

4. Applications of Nanomaterials in Preservation of Oil Paintings

The unique properties of nanomaterials encourage belief that they can be applied in a wide range of fields. There is no comprehensive review of nanotechnology applications, likely due to the rapid development of this field. This brief part is necessary in order to broaden understanding of the importance that nanomaterials have and will play in the future of oil paintings preservation **(Valeriy, 2013).** researches have focused on developing suitable materials for consolidating and protecting materials, as well as structures and many materials, have been used with varying degrees of success **(Santina, 2014).** there are already many specific research projects and applications for different materials, such as paper, canvas, stone, wall paintings, wood, etc. Nanoparticles have been used in different conservation operations **(Baglioni, 2009).**

4.1. Cleaning

nanomaterials have been used to remove dirt and grime from easel paintings. They provide an alternative to hydrocarbon-containing organic solvents like petroleum ether and white spirit, they also have the benefit of being highly efficient in the cleaning process. This is because the high surface area of the nanodroplets of the organic solvent increases their interaction with surfaces. figure (1) explain this action.

4.1.1. HVPD: In the case of oil paintings, in cleaning procedures of the painted surface is mainly related to the use of solvent gels coupled with a wide range of solvents without affecting the underlying artwork's surface and bulk layers, Provided new formulations of highly elastic viscous poly (vinylalcohol) polymeric dispersion (HVPD) for conservation applications. Enables the modulation of the HVPD adhesion to the art object by controlling the HVPD structure and its degree of cross-linking . and Other new useful formulations for chemical gels include the recent development of nanomagnetic sponges by Bonini et al., By adding magnetic nanoparticles to the gel's polymeric network, it is possible to make the gel responsive to an external magnetic field, allowing the complete removal of the cleaning gel from the painted surface without leaving residues and avoiding additional contact between the conservator and the artwork. This mechanism is shown in figure (2). highly viscoelastic HVPDs and magnetic gels are very promising materials for cleaning artworks surfaces, Progress beyond the state-of-the-art in the Nano of Art **(Baglioni, 2012).** Also, the oil-in-water (o / w) microemulsions can be associated with nanomagnetic sponges to obtain a gel-like system for the cleaning of painted surfaces without undesired residuals on the works of art. The nanomagnetic gel (i.e., the sponge loaded with a microemulsion or micellar solution) can be shaped as desired and applied to a specific area with fine spatial control of the area.

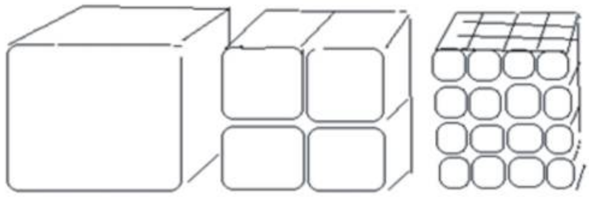

Fig., (1): An example of how smaller particles (right) have more surface area than bigger particles (left). Solvent on the surface of nanodroplets will have more surface area to interact with the dirt on a painting than conventional solvent materials.

(Source by Julie Sandeen)

4.1.2. Titanium dioxide Nanoparticles TiO2 NPs: While the previously described treatments act mainly against the results of acid production due to chemical or biological processes, several research groups have also investigated the use of inorganic nanoparticles to tackle bacteria directly, reducing their impact on the wooden panel. Most of the attention has been directed toward titanium dioxide Nanoparticles, well known for its photoinduced biocidal and fungicidal properties. Upon irradiation in the presence of oxygen and moisture. The use of TiO2 NPs may provide a solution to this issue, De Filpo et al., Have recently examined the use of TiO2 NPs as anti fungals on several different wood species commonly used in artistic works of cultural importance. treatment with TiO2 NPs were tested against two species of rot fungus; Hypocrea lixii (white rot) and Mucor circinelloides (brown rot). Regardless of the species and its natural resistance, no fungal growth was observed on any treated sample. These results confirmed, the enhanced fungal resistance conferred on the wood by the TiO2, despite previous reports suggesting that TiO2 was not as active against fungi as bacteria. No additional UV irradiation was provided to the samples other than simple daylight, indicating that the UV component of solar radiation is sufficient to activate the anti-fungal properties of the NPs. This is a huge advantage for more widespread use, Thus, hindering biologically mediated decay processes **(Zarah, 2019).**

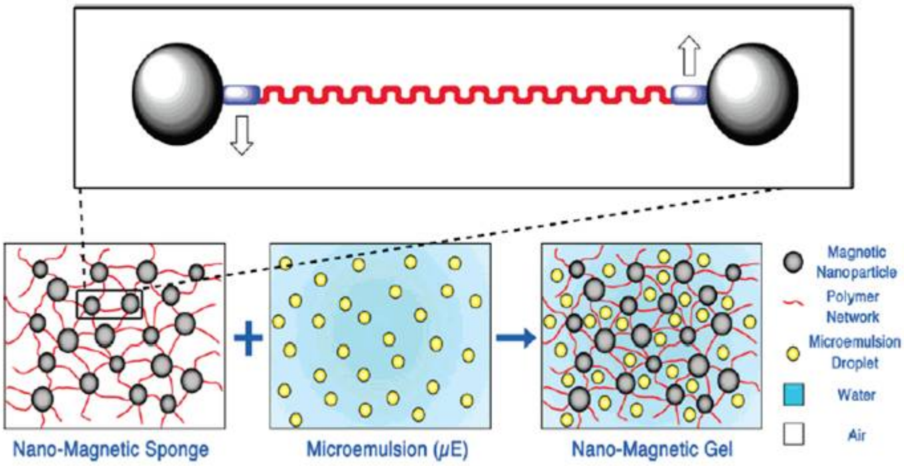

Fig., (2) Showing Nonmagnetic Gel work mechanism

4.1.3. Silver NPs (Ag-NPs) and zinc oxide NPs (ZnO-NPs) were used at different concentration (1 mM and 2 mM) as treatment solutions. While, ZnO-NPs was biosynthesized using endophytic fungal strain Penicillium chrysogenum Pc_25. Isolation and identification of endophytic fungal strain. papers treated with different nanoparticles (Ag-NPs and ZnO-NPs, biosynthesized by Penicillium chrysogenum strain Pc_25. Filter paper was used in experiment. ZnO-NPs (1 mM) exhibited complete inhibition (100%) against subtilis strain, Ag-NPs exhibited higher inhibition activity on P. chrysogenum strain than ZnO-NPs. However, low NPs concentrations (1 mM Ag-NPs and 1 mM ZnO-NPs) inhibited the growth of P. chrysogenum strain by 59.9% and 51.9%. was completely inhibited (100.0% growth inhibition) using 2 mM Ag-NPs **(Amr, 2019).**

4.2. PH Aspect Treatment

4.2.1. Mg(OH)2 - Ca(OH)2 NPs : Experiments have shown that alcoholic dispersions of calcium and magnesium hydroxide nanoparticles can be used for the neutralization of PH and can generate an alkaline reserve of carbonate (after the reaction of the hydroxide with CO_2 from air) that prevents further degradation. in addition, the nanosized particles that grant a good penetration inside the papers and quick carbonation due to their high surface reactivity. Moreover, are used to stabilize the alkaline nanoparticles. This means that the decrease of the degradation rate of oxidation through Fenton reactions could be provided by precise control of acidity/alkalinity **(Baglioni, 2012).**

Alkaline nanosized particles, used as nonaqueous dispersions, have been found particularly efficient for the preservation of cellulose-based materials that degrade through an acid-catalyzed process, which leads to chemical disruption of the cellulose polymer. It has been shown that acid-catalyzed hydrolysis is the main chemical route for cellulose depolymerization. Mg (OH) 2 and Ca (OH) 2 are excellent de-acidifying agents since they ensure a fair physicochemical compatibility with the support, Mg (OH) 2 and Ca (OH) 2 nanoparticles dispersions in alcohols, but the method is not restricted to these solvents and other less polar solvents can be employed as well, maybe applied on papers by spraying **(Sequeiraa, 2006)**

4.2.2. SiO2 NPs : Treating canvas surface with combinations of silica nanoparticles, silane hydrophobes, and silane crosslinkers to obtain durable hydrophobicity. Performance analysis was done by measuring the contact angle of water on the treated fabric surface. canvas fabrics with good hydrophobicity (contact angle = 139.1 °) and excellent durability (e.g. 95% recovery of contact angle after treatment) **.**

4.3. Consolidation

CNF - CCNF :in the form of an aqueous suspension was used by Stora Enso AB (Sweden). The CNF was produced from softwood pulp (ca. 75% of pine and 25% of spruce, containing 85% of cellulose, 15% of hemicellulose, and traces of lignin). CCNF, also in the form of an aqueous suspension, was used by RISE Bioeconomy

(Sweden). The CCNF was produced from a softwood sulphite dissolving pulp) by carboxymethyl, in order to achieve similar viscosity, aqueous suspensions of CNF, CCNF and CNC were prepared by dilution with deionized water at concentrations of 1.00, 0.25 and 3.00 wt.%, Respectively, rpm). These suspensions were homogeneously spread on the surface of the canvas using a plastic serigraphy squeegee. The coatings were deposited in 1--3 passes with an interval of 20 min to allow some water to evaporate, measured by gravimetry. After drying, one batch of CCNF canvas, with different amounts of deposited nanocellulose, was treated with a 0.5 M $CaCl_2$ aqueous solution (ca. 2 g of solution per m^2) to cross-link the nanofibrils, which was applied by spraying with Airbrush Compressor . One batch of samples was prepared by mixing CCNF suspensions with TBAOH (5/1 wt / wt dry) to reduce the hydrophilicity of the cellulose. Table 1 shows the increase of the canvas basis weight after brushing **(Oleksandr, 2018).**

Table 1 List of treatments used for aged canvas consolidation and basis weight after coating.

Sample name	Description	Basis weight uptake (%) with number of coatings		
		1	2	3
CNF	Canvas coated with cellulose nanofibril suspension at 1 wt.%	2.5	5.0	7.2
CCNF	Canvas coated with carboxymethylated cellulose nanofibril suspension at 0.25 wt.%	0.6	1.2	1.8
CNC	Canvas coated with cellulose nanocrystal suspension at 3 wt.%	7.4	14.8	22.2

Source: Oleksandr N., et al, Op., Cit

Conclusions

- Highly viscoelastic HVPDs and magnetic gels are very promising materials for cleaning movable artworks surfaces
- Progress beyond in the Nano of Art. order to gain the proper pH adjustment and to avoid alkalinity
- Silver NPs achieved better results than zinc oxide NPs for paper preservation. Application of 1.0 or 2.0 mM silver NPs exhibited the best preservation effect on the paper models achieving 100% microbial inhibition (bacteria and fungi, respectively).
- The stiffening effect of CNF, CCNF and CNC is much higher than that achieved using traditional wax-resin formulation (Beva 371). Despite the high porosity of the canvas, acidic character of CCNF and CNC may not induce any problems.

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