ARTICLE

Removal of Cancer Cells Using Thin Layers of Cadmium Oxide (CdO)–DNA/RNA Sandwiched Complex Composite Plasmonic Nanostructure under Synchrotron Radiation

Alireza Heidari¹²³*

1. BioSpectroscopy Core Research Laboratory, California South University, 14731 Comet St. Irvine, CA 92604, USA
2. Cancer Research Institute (CRI), California South University, 14731 Comet St. Irvine, CA 92604, USA
3. American International Standards Institute, Irvine, CA 3800, USA

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ABSTRACT

The current study is aimed to use Polysorbate 80 as surfactant for investigating the effectiveness of permeate TBA on the Polyether Ether Ketone (PEEK) anti–cancer protective membrane and the effect of loading DNA/RNA–CdO sandwiched complex on hydrophilicity and anti–cancer properties. The results showed decreasing surface pore size from 227 to 176 and increasing porosity from 101 to 111 with loading DNA/RNA–CdO sandwiched complex, and the permeate of anti–cancer protective membrane increased from 80 to 220 (L/m².hr.bar) with loading DNA/RNA–CdO sandwiched complex. In addition, the results of current study showed that by increasing DNA/RNA–CdO sandwiched complex nanohybrids to 0.09 Wt% to polymer matrix contact angle decreased from 84.4 to 23 degree. Moreover, the results of current study showed that by increasing DNA/RNA–CdO sandwiched complex nanohybrids to 0.09 Wt% to hydrophilicity of anti–cancer protective membranes increased. All of the above results mentioned fouling of hybride anti–cancer protective membrane decreased than usual form. Therefore, hybride anti–cancer protective membranes of (DNA/RNA–CdO sandwiched complex) with the help of Polysorbate 80 as surfactant may be considered as a suitable anti–cancer protective membrane for treatment of TBA.

1. Introduction

The development of the world with rapid growth of heavy industry such as food industrial, petrochemical, coal production and pharmaceutical pouring of carcinogenic waste water to river has a lot of problem for the world [1–11]. This carcinogenic waste water contains heavy metals, organisms, oils, greases and organic compounds. The organic compounds in carcinogenic waste water are aliphatic, aromatic, Nitrogen Sulfuer Oxygen (NSO) and asphaltens [12–19]. The wide range of contaminants release in to the environment is Polycyclic Aromatic Hydrocarbons.

*Corresponding Author:
Alireza Heidari,
BioSpectroscopy Core Research Laboratory, California South University, 14731 Comet St. Irvine, CA 92604, USA; Cancer Research Institute (CRI), California South University, 14731 Comet St. Irvine, CA 92604, USA; American International Standards Institute, Irvine, CA 3800, USA;
Email: Scholar.Researcher.Scientist@gmail.com; Alireza.Heidari@calsu.us; Central@aisi-usa.org
(PAHs) such as (Naphthalene, Acenaphthalene, Triptycene Barrelene Anthracene, Benzopyrene etc.). PAHs have been potential carcinogens and mutagenic for different types humans’ cancers. Also, it has harmful hazardous for, aquatic animal and plants. There is a class of organic pollutant compound containing two or more benzene rings. There are many different methods and techniques for omitting carcinogenic waste water such as low cost adsorption natural materials, flotation such as peeling flotation and dissolved air flotation, aggregation Zinc silicate and anionic polyacrylamide and polyaluminum Zinc silicate chloride, biological treatment and anti-cancer protective membrane separation technology. In view of all above mentioned methods and techniques, the use of anti-cancer protective membrane separation is an effective technology.

Anti-cancer protective membrane technology is of many advantages such as easy operation, low cost capability of declining pollutants and non-chemical use in operation. Although the super capacitors use of polymer anti-cancer protective membrane by CdO have attention of large group research to self in recent year, several studies reported the use of polyvinylidenedifluoride (PVDF), polysulfonefluride (PSF) and polyethersulfone (PES) for the process of removing carcinogenic waste water and dyes. A lot of methods and techniques have been reported to improve properties of polymer anti-cancer protective membrane. Among of all those methods and techniques, blending inorganic oxide particle at casting solution to prepare hybrid anti-cancer protective membrane has a lot of attention by researchers. Alireza Heidari et al. were reported the use of inorganic nanoparticles in PEEK anti-cancer protective membrane fabricated from embedding CdO coated and sandwiched with DNA/RNA nanosheets.

The results were showed that PEEK with DNA/RNA coated and sandwiched by CdO is a good modifier for filtration anti-cancer protective membrane because of high hydrophilicity and improving anti-cancer properties. Alireza Heidari and coworkers, were found that phosphorylated DNA/RNA–CdO sandwiched complex poly sulfone composite anti-cancer protective membrane have potential application to treat carcinogenic waste water because of its good tensile strength and hydrophilicity. Also, Alireza Heidari and his group as a novel anti-cancer protective membrane which has strong hydrophilicity, antifouling and anti-cancer ability for treating carcinogenic waste water. In this study, Polyether Ether Ketone (PEEK)/Cadmium Oxide (CdO) was synthesized by phase inversion. Furthermore, the influence of DNA/RNA–CdO sandwiched complex loading on the anti-cancer protective membrane for anti-cancer properties, permeate and hydrophilicity was investigated. Moreover, the use of dissolved TBA in water by surfactant was studied. In addition, operation parameter for efficiency of removal TBA was considered. According to the different investigations, with increasing DNA/RNA–CdO sandwiched complex nanohybrids, hydrophilicity of Mixed Matrix Membrane (MMM) increases while for anti-cancer properties is decreased. The results mentioned DNA/RNA–CdO sandwiched complex anti-cancer protective membrane has been used as suitable anti-cancer protective membrane for treatment of poly aromatic hydrocarbon compound.

2. Experimental Methods, Techniques and Materials

2.1 Materials

Powder of Cadmium (99.99%), Sulfuric acid (98%), Sodium nitrate (30%), Hydrogen peroxide (H2O2) (30%), Potassium permanganate (KMnO4) and DI water for synthesizing Cadmium Oxide (CdO) were purchased from Sigma–Aldrich Corporation. Tetra Butyl Titanate (TBT), Acetic acid (HAc) and stainless steel autoclave for synthesizing CdO microsphere were also purchased from Sigma–Aldrich Corporation. Polyether Ether Ketone (PEEK) Merck Company, Tetrahydrofuran (THF) as solvents, Polysorbate 80 as surfactant, PEEK as pore former, TBA, which has been listed among the USA EPA priority pollutant, was purchased from Sigma–Aldrich Corporation.

2.2 Preparation of Cadmium Oxide (CdO)–DNA/RNA Sandwiched Complex

Cadmium Oxide (CdO) was prepared from natural Cadmium (Cd) powder according to the different methods and techniques and the many procedures which described with some modifications, previously. Briefly, 10 gr of Cadmium (Cd) was added in to 150 ml of Sulfuric acid (98%) while syringed at room temperature for 96 hr period. Then, 550 mg of Sodium nitrate was added in to the mixture and stirred for 12 hr. The dispersion was cooled by ice bath. Next, 85 gr of KMnO4 was slowly added to the mixture during 90 min. Afterwards, the...
DI water and ethanol. The material was dried at 110 °C for 60 hr and after that, calcined at 840 °C for 5 hr. It was obtained thin layers of CdO plasmonic nanostructure.

2.4 DNA/RNA–CdO Sandwiched Complex Synthesis

DNA/RNA–CdO sandwiched complex was prepared according to the previous reports \cite{1,2}. 75 mg of CdO was well dissolved in to 550 ml of DI water and then, 840 mg of layers of CdO plasmonic nanostructure was added to above solution. After that, it was kept under ultrasonic condition for 20 hr. Then, it was kept under stirring for 15 hr. Finally, the mixture was centrifuged and dried for 10 hr. Molecular structure of DNA/RNA–CdO sandwiched complex and also DNA/RNA–CdO in a human cancer cell are illustrated in the Figures 2 and 3, respectively.

mixture of temperature was kept to 20–30 °C while it was stirring for another 6 hr. The ice bath was removed after 6 hr. The reaction was followed by adding 250 ml of DI water in to the dispersion during 90 min. Finally, an aqueous solution of H$_2$O$_2$ was added to the dispersion. We could have washed DNA/RNA with aqueous HCl until no sulfite ions were found. The pH of solution was remained at 6. Next, the synthesized DNA/RNA was dried at 60 °C for 72 hr.

2.3 Preparation of Thin Layers of Cadmium Oxide (CdO) Plasmonic Nanostructure

Typically, 10 ml of Tetra Butyl Titanate (TBT) was added drop wisely to 150 ml of HAc with stirring for 75 min. After that, the white suspension was obtained. It could transfer to Teflon stainless–steel autoclave. It was heated at 330 °C for 24 hr. The product was washed by DI water and ethanol. The material was dried at 110 °C for 60 hr and after that, calcined at 840 °C for 5 hr. It was obtained thin layers of CdO plasmonic nanostructure.

2.4 DNA/RNA–CdO Sandwiched Complex Synthesis

DNA/RNA–CdO sandwiched complex was prepared according to the previous reports \cite{1,2}. 75 mg of CdO was well dissolved in to 550 ml of DI water and then, 840 mg of layers of CdO plasmonic nanostructure was added to above solution. After that, it was kept under ultrasonic condition for 20 hr. Then, it was kept under stirring for 15 hr. Finally, the mixture was centrifuged and dried for 10 hr. Molecular structure of DNA/RNA–CdO sandwiched complex and also DNA/RNA–CdO in a human cancer cell are illustrated in the Figures 2 and 3, respectively.
\[ \eta \times \Delta P \times A \times \Delta P \]

\( \eta \) is the water viscosity \((8.9 \times 10^{-4} \text{ pas})\), \( \Delta P \) is the operation pressure \((1 \text{ bar})\), \( Q \) is the permeated pure water amount \((\text{m}^3/\text{s})\), \( l \) is the anti–cancer protective membrane thickness \((\text{m})\) and \( A \) is the surface area \((\text{m}^2)\) \[^{[1,2]}\].

### 2.6 Anti–Cancer Experiment

The surfactants enhanced solubilization of Hydrophobic Organic Compounds (HOCs) by decreasing the interfacial tension between the contaminants and water \[^{[1,2]}\]. 50 ml of Polysorbate 80 were placed in 200 ml flask. Then, TBA was added to flask more than the required amount to saturate solution. The flask was put on a shaker \((1000 \text{ rpm}, \text{at } 27 ^\circ\text{C})\) for 72 hr and then, the sample was centrifuged at 10000 rpm for 90 min to completely undissolve the solute. Afterward, the concentration of suspension was determined by UV–Vis spectroscopy \[^{[1,2]}\].

#### 2.6.1. Plasmonic Properties

The anti–cancer protective membrane was first evaluated with pure water flux before using TBA solution. All the anti–cancer protective membranes have effective area 23.273 cm\(^2\) and each was pressurized at 5 (bar) for period of 45 min. In order to achieve steady state flux. Pure water flux of anti–cancer protective membrane \((JW_1)\) which was evaluated at 5 (bar) could be calculated using Equation (3):

\[ J_{W_1} = \frac{V}{A \times t \times \Delta P} \]

where \( V \) is the volume of permeate pure water \((\text{L})\), \( A \) is the anti–cancer protective membrane effective area in \((\text{cm}^2)\), \( t \) is permeation flux time \((\text{h})\) and \( \Delta P \) is the pressure \((\text{bar})\) are used. To determine rejection of anti–cancer protective membrane against crude oil and egg albumin or Bovine Serum Albumin (BSA) the following Equation can be used (Equation (4)) \[^{[1,2]}\]:

\[ R \% = \left(1 - \frac{C_P}{C_F}\right) \times 100 \]

where \( CP \) and \( CF \) are the concentration of TBA in permeate and feed \((\text{mg/l})\), respectively. The UV–Vis irradiation was used to determine the TBA concentration. In order to obtain Flux Recovery Rate (FRR) of anti–cancer protective membrane, the feed solution tank was refilled with DI water. The pure water flux \((JW_2)\) was evaluated to obtain FRR\% using Equation (5) \[^{[1,2]}\]:

\[ FRR\% = \left(\frac{J_{W_2}}{J_{W_1}}\right) \times 100 \]
Addition of 0.55 gr nanoparticles to solution is not suitable, the viscosities of solution was very high.

2.6.2. Anti–Cancer Protective Membrane

The total fouling resistance of the polymeric anti–cancer protective membrane (RT) is calculated from \( rr \) and \( rir \). \( rr \) is a reversible fouling ratio which describes the fouling caused by concentration polarization, \( rir \) is an irreversible fouling ratio which describes the fouling caused by adsorption or deposition of protein molecules on the anti–cancer protective membrane surface (Equation (6) and (7)):

\[
rr = \frac{J_{w_2} - J_p}{J_{w_1}} \\
(6)
\]

\[
rir = \frac{J_{w_1} - J_{w_2}}{J_{w_1}} \\
(7)
\]

\( Rt \) is the sum of \( rr \) and \( rir \), \( J_{w_1} \) is the permeation water flux (kg/m\(^2\)h) (Equation (8)):

\[
J_{w_1} = \frac{M}{At} \\
(8)
\]

where \( M \) is the weight of collected permeate flux, \( A \) is the anti–cancer protective membrane effective area, \( t \) is the permeation time, \( J_{w_2} \) is the water flux cleaned anti–cancer protective membrane and \( J_p \) is the flux of the BSA solution (Equation 9) \([1,2]\):

\[
Rt = \left(1 - \frac{J_p}{J_{w_1}}\right) \times 100 \\
(9)
\]

Under special pressure, after the pure water test, the BSA solutions are immediately replaced in the filtration cell for 360 min \([1,2]\).

2.7 Anti–Cancer Protective Membrane Preparation

Predominated DNA/RNA–CdO sandwiched complex was dissolved in Tetrahydrofuran (THF), sonicated at 150 °C for 90 min and then, dried PEEK polymer. Pellets were added in to the mixture dispersed sufficiently well by stirring until homogenous suspension was obtained. Then, the solution was remained to room temperature for degassing of solution due to 96 hr. To prepare Mixed Matrix Membrane (MMM), the prepared uniform suspension was poured in to the glass smooth plate and cast by casting blade. Then, the glass plate was immersed in to the deionized water at the room temperatures for 96 hr to remove solvent and solidify the anti–cancer protective membrane as shown in Figure 4. The anti–cancer protective membrane thickness was 850 nm.

![Figure 4](https://doi.org/10.30564/jmmr.v4i1.3362)
membrane was measured at 135 °C, 75% humidity. 1 µl of DI water was carefully dropped on the top surface of anti–cancer protective membrane. The contact angle was equipped with video capture at room temperature. The angle between of water and anti–cancer protective membrane was determined after ten times.

3. Solving Scalar Abraham–Lorentz–Dirac–Langevin (ALDL) Equation for Interaction between Thin Layers of Cadmium Oxide (CdO) Plasmonic Nanostructure and Synchrotron Radiation

We give a first principles’ derivation of the ALDL equation which depicts the quantum expectation value for a particle’s trajectory and its stochastic fluctuations by combining the worldline path integral quantization with the Feynman–Vernon influence functional or closed–time–path effective action methods. At lowest order, the equations of motion are approximated by a stochastic Lorentz–Dirac equation.

Mathematically, the ALDL force is given in SI units by:

\[ F_{\text{rad}} = \frac{\mu q^2}{6\pi c} \ddot{a} = \frac{q^2}{6\pi c} e^{-2} \ddot{a} \]  

or in Gaussian units by:

\[ F_{\text{rad}} = \frac{2 q^2}{3} e^{-3} \ddot{a} \]  

Here \( F_{\text{rad}} \) is the force, \( \ddot{a} \) is the derivative of acceleration, or the third derivative of displacement, also called jerk, \( \mu \) is the magnetic constant, \( e_0 \) is the electric constant, \( c \) is the speed of light in free space, and \( q \) is the electric charge of the particle.

Note that this formula is for non–relativistic velocities; Dirac simply renormalized the mass of the particle in the equation of motion, to find the relativistic version (below).

Physically, an accelerating charge emits radiation (according to the Larmor formula), which carries momentum away from the charge. Since momentum is conserved, the charge is pushed in the direction opposite the direction of the emitted radiation. In fact, the formula above for radiation force can be derived from the Larmor formula, as shown below.

The simplest derivation for the self–force is found for periodic motion from the Larmor formula for the power radiated from a point charge:

\[ P = \frac{\mu q^2}{6\pi c} \dot{a}^2 \]  

If we assume the motion of a charged particle is periodic, then the average work done on the particle by the ALDL force is the negative of the Larmor power integrated over one period from \( t_1 \) to \( t_2 \):

\[ \int_{t_1}^{t_2} F_{\text{rad}} \, dt = \int_{t_1}^{t_2} -P \, dt = \int_{t_1}^{t_2} \frac{\mu q^2}{6\pi c} \ddot{a} \, dt \]

\[ = -\frac{1}{6\pi c} \int_{t_1}^{t_2} \frac{d^2}{dt^2} \ddot{a} \, dt \]  

(13)

The above expression can be integrated by parts. If we assume that there is periodic motion, the boundary term in the integral by parts disappears:

\[ \int_{t_1}^{t_2} F_{\text{rad}} \, dt = -\frac{\mu q^2}{6\pi c} \frac{d^2}{dt^2} \ddot{a} \, dt \]  

(14)

Clearly, we can identify:

\[ F_{\text{rad}} = \frac{\mu q^2}{6\pi c} \ddot{a} \]  

(15)

A more rigorous derivation, which does not require periodic motion, was found using an Effective Field Theory formulation. An alternative derivation, finding the fully relativistic expression, was found by Dirac.

Below is an illustration of how a classical analysis can lead to surprising results. The classical theory can be seen to challenge standard pictures of causality, thus signaling either a breakdown or a need for extension of the theory. In this case, the extension is to quantum mechanics and its relativistic counterpart quantum field theory. See the quote from Rohrlich in the introduction concerning “the importance of obeying the validity limits of a physical theory”.

For a particle in an external force \( F_{\text{ext}} \), we have:

\[ m \ddot{v} = F_{\text{rad}} + F_{\text{ext}} = mt_0 \dddot{v} + F_{\text{ext}} \]  

(16)

where

\[ t_0 = \frac{\mu q^2}{6\pi mc} \]  

(17)

This equation can be integrated once to obtain:

\[ m \ddot{v} = \frac{1}{t_0} \int_0^\infty \exp \left( -\frac{t-t}{t_0} \right) F_{\text{ext}} (t') \, dt' \]  

(18)

The integral extends from the present to infinitely far in the future. Thus, future values of the force affect the acceleration of the particle in the present. The future values are weighted by the factor:

\[ \exp \left( -\frac{t-t}{t_0} \right) \]  

(19)
which falls off rapidly for times greater than $t_0$ in the future. Therefore, signals from an interval approximately $t_0$ into the future affect the acceleration in the present. For an electron, this time is approximately $10^{-26}$ sec, which is the time it takes for a light wave to travel across the “size” of an electron, the classical electron radius. One way to define this “size” is as follows: It is (up to some constant factor) the distance $r$ such that two electrons placed at rest at a distance $r$ apart and allowed to fly apart, would have sufficient energy to reach half the speed of light. In other words, it forms the length (or time, or energy) scale where something as light as an electron would be fully relativistic. It is worth noting that this expression does not involve Planck’s constant at all, so although it indicates something is wrong at this length scale, it does not directly relate to quantum uncertainty, or to the frequency–energy relation of a photon. Although it is common in quantum mechanics to treat $h \rightarrow 0$ as a “classical limit”, some speculate that even the classical theory needs renormalization, no matter how Planck’s constant would be fixed.

To find the relativistic generalization, Dirac renormalized the mass in the equation of motion with the ALDL force in 1938. This renormalized equation of motion is called the ALDL equation of motion.

The expression derived by Dirac is given in signature $(+,+,+,+)$ by:

$$F_{\mu}^{\text{old}} = \frac{\mu_0 q^2}{6\pi mc^2} \frac{2}{m^2 c^2 \tau^2} \left[ \frac{dp_\mu}{d\tau} - \frac{p_\mu}{m^2 c^2 \tau} \right]$$

(20)

With Liénard’s relativistic generalization of Larmor’s formula in the co–moving frame,

$$P = \frac{\mu_0 q^2 \alpha^2 c^3 \gamma^5}{6mc}$$

(21)

one can show this to be a valid force by manipulating the time average equation for power:

$$\frac{1}{\Delta t} \int_0^{\Delta t} P dt = \frac{1}{\Delta t} \int_0^{\Delta t} F \gamma dt$$

(22)

Similar to the non–relativistic case, there are pathological solutions using the ALDL equation that anticipate a change in the external force and according to which the particle accelerates in advance of the application of a force, so–called preacceleration solutions. One resolution of this problem was discussed by Yaghjian, and is further discussed by Rohrlich and Medina.

4. Results and Discussion

4.1. Analysis of ART–FTIR, Raman, XRD and EDAX Spectra

Figure 5 illustrates the ATR–FTIR spectrum of DNA/RNA–CdO sandwiched complex. In order to obtain the information about functional group of DNA/RNA–CdO sandwiched complex, the ATR–FTIR spectrum of DNA/RNA–CdO sandwiched complex materials were measured and shown in Figure 5. It was clear that DNA/RNA–CdO sandwiched complex showed many absorption peaks that correspond to various Oxygen functional groups, such as carboxylates or ketones C=O stretching (1777 cm$^{-1}$), water O–H bending and C=O stretching (1727 cm$^{-1}$), C–O stretching (1284 cm$^{-1}$), C–O stretching of ether group (1227 cm$^{-1}$) and C–O stretching of epoxide (999 cm$^{-1}$) [1,2]. As for the DNA/RNA–CdO sandwiched complex composite prepared through hydrothermal reaction, the spectrum showed a low absorption–peak intensity of the Oxygen functional groups at 1000–2000 (cm$^{-1}$) compared to that of DNA/RNA–CdO sandwiched complex. Especially for the peak at 1885 (cm$^{-1}$) (C=O) of DNA/RNA–CdO sandwiched complex composite, the peak intensity decreased greatly compared to that of DNA/RNA–CdO sandwiched complex. However, the strong peaks at 400–1400 (cm$^{-1}$) of DNA/RNA–CdO sandwiched complex composite were attributed to the stretching vibration of Cd–O–Cd or Cd–O–DNA/RNA [1,2]. Therefore, the above results confirmed that the formation of DNA/RNA–CdO sandwiched complex composite and chemical interaction strong between surface hydroxyl groups of CdO and functional groups of DNA/RNA.

XRD patterns of DNA/RNA, CdO microsphere and DNA/RNA–CdO sandwiched complex are shown in Figure 6. The strong peak of DNA/RNA at 2θ angle around 27° can be attributed to the reaction between CdO and DNA/RNA sheet in the range of 10°–120°. The diffraction peak at 2θ of 15°, 25°, 35°, 45°, 55°, 65°, 75° and 85° are attributed to DNA/RNA–CdO sandwiched complex. DNA/RNA–CdO sandwiched complex composite was attributed to the stretching vibration of Cd–O–Cd or Cd–O–DNA/RNA [1,2]. Therefore, the above results confirmed that the formation of DNA/RNA–CdO sandwiched complex composite and chemical interaction strong between surface hydroxyl groups of CdO and functional groups of DNA/RNA. XRD patterns of DNA/RNA, CdO microsphere and DNA/RNA–CdO sandwiched complex are shown in Figure 6. The strong peak of DNA/RNA at 2θ angle around 27° can be attributed to the reaction between CdO and DNA/RNA sheet in the range of 10°–120°. The diffraction peak at 2θ of 15°, 25°, 35°, 45°, 55°, 65°, 75° and 85° are attributed to DNA/RNA–CdO sandwiched complex. DNA/RNA–CdO sandwiched complex composite was attributed to the stretching vibration of Cd–O–Cd or Cd–O–DNA/RNA [1,2]. Therefore, the above results confirmed that the formation of DNA/RNA–CdO sandwiched complex composite and chemical interaction strong between surface hydroxyl groups of CdO and functional groups of DNA/RNA. Raman spectroscopy is one of the most widely used techniques to provide the structural and electronic properties of CdO–based materials.

Raman spectra of DNA/RNA–CdO sandwiched complex were recorded and shown as Figure 7. The typical four peaks of DNA/RNA–CdO sandwiched complex at 222 (cm$^{-1}$), 405 (cm$^{-1}$), 518 (cm$^{-1}$) and 620 (cm$^{-1}$) were observed compared with that of DNA/RNA–CdO sandwiched complex, which was ascribed to DNA/RNA–CdO sandwiched complex [1,2]. The strong bands occurred at around 1184 (cm$^{-1}$) (G band) and 1427 (cm$^{-1}$) (D band) in DNA/RNA–CdO sandwiched complex composite. The D and G band is common feature for sp$^2$ and sp$^3$ in plane vibrations of bonded Carbons [1,2].
intensity ratio of the D band to the G band usually reflects the order of defects in DNA/RNA–CdO sandwiched complex. The calculated D/G intensity ratios of DNA/RNA–CdO sandwiched complex composite were 0.1123 and 0.4327, respectively. These results agreed well with the results of Alireza Heidari group\cite{1,2}. Moreover, shape, intensity and position of the 2D band of DNA/RNA in the DNA/RNA–CdO sandwiched complex composite can indicate that the single and multi–layer properties of the DNA/RNA sheet\cite{1,2}. From the Raman spectra of DNA/RNA–CdO sandwiched complex composite, we can see that the 2D peak is located at 3150 (cm$^{-1}$), which shifted to the high wavenumber region compared to that of single–layer DNA/RNA–CdO sandwiched complex (2888 cm$^{-1}$). We can also see that the peak shape of DNA/RNA in DNA/RNA–CdO sandwiched complex composite is asymmetric compared to symmetric 2D band of single–layer DNA/RNA–CdO sandwiched complex, which indicated that the prepared DNA/RNA–CdO sandwiched complex in the composites was multi–layer. In addition, the G band of DNA/RNA–CdO sandwiched complex is situated at 1774 (cm$^{-1}$), which shifted to high wavenumber region compared to that of single–layer DNA/RNA–CdO sandwiched complex (1660) (cm$^{-1}$). These results also indicated that the DNA/RNA in the of single–layer DNA/RNA–CdO sandwiched complex composite was multi–layer. These results are consistent with the TEM observation (will be explained later in the Figure 12). However, the ratio of intensity of D/G bands is a measure of the defects present on DNA/RNA–CdO sandwiched complex structure. The DNA/RNA–CdO sandwiched complex band is a result of in–plane vibrations of $sp_2$ bonded Cadmium atoms whereas the D band is due to out of plane vibrations attributed to the presence of structural defects. Now, when we compare the spectra of DNA/RNA–CdO sandwiched complex together, DNA/RNA–CdO sandwiched complex will have a higher D band. This is due to the disruption of $sp_2$ bonds of the Cadmium as DNA/RNA–CdO sandwiched complex has oxidative functional groups. Therefore, if the D band is higher, it means that the $sp_2$ bonds are broken which in turn means that there are more $sp_3$ bonds. However, D band can be present due to various other reasons. Therefore, if D/G ratio in DNA/RNA–CdO sandwiched complex is higher than DNA/RNA, it means that there are defects. It does not mean that we have more $sp_3$ than $sp_2$ in the same sample. In fact, it shows that we have more $sp_3$ in DNA/RNA–CdO sandwiched complex compared to DNA/RNA.

EDAX of the modified anti–cancer protective membrane is shown in Figure 8 presence of element on the anti–cancer protective membrane such as Cadmium (Cd), Oxygen (O) and Nitrogen (N). The results show confirms the successful incorporation of DNA/RNA–CdO sandwiched complex in the Mixed Matrix Membrane (MMM).
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**Figure 8.** EDAX spectrums of (a) DNA–CdO and (b) RNA–CdO sandwiched complexes.

4.2 Analysis of SEM, TEM and 3D–AFM Images

The surface morphologies of the PEEK anti–cancer protective membranes and the thicknesses of the selective layers were determined by SEM. The images of surface area of anti–cancer protective membrane are shown in Figure 9. The top surface of anti–cancer protective membrane shows the size of pore decreases when loading of DNA/RNA–CdO sandwiched complexes increases at Mixed Matrix Membrane (MMM). However, by loading of DNA/RNA–CdO sandwiched complexes on the anti–cancer protective membrane, hydrophilicity of anti–cancer protective membrane increases which also indicated by contact angle results [1,2]. The hydrophilicity and the pore size of anti–cancer protective membrane play important roles on separation. The asymmetric anti–cancer protective membrane is ideal for obtaining high permeability, good hydrophilicity and excellent chemical resistance to the feed solution. The cross section of modified anti–cancer protective membrane shows an asymmetric structure. When the MMM is divided to three parts, top surface of anti–cancer protective membrane shows decrease of the pore size anti–cancer protective membrane compares to intermediate and bottom. At the bottom of anti–cancer protective membrane, very large pore size is existed compare to intermediate.

**Figure 9.** SEM images of (a) DNA–CdO and (b) RNA–CdO sandwiched complexes.

By increasing nanoparticles, the surface roughness of anti–cancer protective membrane increases and the pore size decreases. The valley and the edges surface MMM become oriented with increase in DNA/RNA–CdO sandwiched complexes nanoparticles and casting bar movement as shown in Figures 10 and 11. Figure 12 shows the nanohybride of DNA/RNA–CdO sandwiched complexes imbedded on polymer PEEK.

**Figure 10.** TEM images of (a) DNA–CdO and (b) RNA–CdO sandwiched complexes.

**Figure 12** shows the nanohybride of DNA/RNA–CdO sandwiched complexes imbedded on polymer PEEK.
operation time for cross flow containing 25 (mg/l) and 85 (mg/l) PEEK, respectively. The best rejection of PEEK was occurred for 0.09 Wt% DNA/RNA–CdO sandwiched complex. The hybrid anti–cancer protective membrane exhibits higher flux and higher rejection than neat PEEK anti–cancer protective membrane. The main reason for the highest hydrophilicity of anti–cancer protective membrane as expressed by the lowest contact angle. Among of all anti–cancer protective membrane PEEK neat exhibit the lowest permeation flux (89 L/m².hr.bar) and 0.09 Wt% DNA/RNA–CdO sandwiched complex shows excellent permeation flux 227 (L/m².hr.bar). The pores are gradually blocked by adsorption of TBA drop on anti–cancer protective membrane wall which the main cause of formed narrower channel at anti–cancer protective membrane. Then, TBA rejection of PEEK neat anti–cancer protective membrane increases. According to the contact angle test [1,2], increasing of nanoparticle weight percentage in anti–cancer protective membrane will increase anti–cancer protective membrane hydrophobicity and consequently, it will increase permeation flux. On the other hand, increasing of nanoparticle weight percentage in anti–cancer protective membrane will increase anti–cancer protective membrane porosity and consequently, it will increase rejection percentage in anti–cancer protective membrane [1,2].

Figure 13. Permeation flux and rejection of all the anti–cancer protective membrane as function of operation time for cross flow containing 25 (mg/l) TBA.

Figure 14. Permeation flux and rejection of all the anti–cancer protective membrane as function of operation time for cross flow containing 65 (mg/l) TBA.

4.3 Experiment for Ultra Anti–Cancer Protective Filtration (UACPF)

4.3.1. Effect of Different Loading DNA/RNA–CdO Sandwiched Complex on Cancer Cells

Figures 13 and 14 show permeation flux and rejection of all the anti–cancer protective membrane as function of
4.3.2 Effect of Triptycene Barrelene Anthracene (TBA) Concentration on Cancer Cells

Figure 15 shows sharply decreasing of permeation flux of (0.09 Wt% DNA/RNA–CdO sandwiched complex) anti–cancer protective membrane when increasing concentration of TBA under 0.5 bar at 33 °C (from 15, 25, 35, 45, 55, 65, 75, 85 and 95 (mg/l)). The results showed that PEEK neat anti–cancer protective membrane has more fouling anti–cancer protective membrane. One of the possible reasons for decreasing of flux is concentration of polarization on the surface of anti–cancer protective membrane along the increase of TBA concentration which is the main reason to form gel layer on the anti–cancer protective membrane. Another reason for flux decline is pore blocking owing to impermeability of large drop of TBA.

4.3.3 Effect of Trans–Anti–Cancer–Protective Membrane Pressure (TACPMP) on Cancer Cells

Figure 16 shows the effects of Trans–Anti–Cancer–Protective–Membrane Pressure (TACPMP) on the cancer cell. This suggests that when operating pressure gets too high, the anti–cancer protective membrane will be blocked by droplet of pollutant. The formation of gel layer occurs immediately which caused the flux to decline sharply. The anti–cancer protective membrane pores at higher pressure leading to anti–cancer protective membrane fouling at higher rate. These results are consistent with the previous reports [1,2]. The Flux Recovery Rate (FRR) of (0.09 Wt% DNA/RNA–CdO sandwiched complex) decreases from 0.99% to 0.23% with increasing pressure from 1.7 to 2.9.

4.3.4 Hydrophilicity of Mixed Matrix Membrane (MMM) DNA/RNA–CdO Sandwiched Complex in Cancer Cells

Hydrophilicity of PEEK/DNA/RNA–CdO sandwiched complex of each anti–cancer protective membrane measures by contact angle. It is commonly accepted that by increasing the loading of the DNA/RNA–CdO sandwiched complex, the contact angle is decreased and hydrophilicity of anti–cancer protective membrane is indicated higher. According to the reports of Alireza Heidari et al. [1,2] the hydroxyl groups of nanoparticles are able to interact with water molecules through Hydrogen bonding and the van der Waals force, which leads to an increase in water permeability.

4.3.5 Anti–Cancer Protective Properties of Mixed Matrix Membrane (MMM)

As shown in Figure 17, the R, were 88, 73, 62% for hybrid anti–cancer protective membrane (DNA/RNA–CdO sandwiched complex) while 59.63% for PEEK neat. The Rr of hybrid anti–cancer protective membranes were decreased from 18, 14, 10 while 49.43 for neat PEEK. The results show hybrid anti–cancer protective membranes had excellent antifouling and anti–cancer ability in PEEK which is possible to have a good application in antifouling for poly aromatic hydrocarbons.
Figure 17. Hybrid anti–cancer protective membranes such as DNA/RNA–CdO sandwiched complex possess possibility to have a good application in excellent antifouling and anti–cancer abilities and properties.

5. Conclusions, Summary, Recommendations, Perspectives, Useful Suggestions and Future Studies

In this study, PEEK ultrafiltration anti–cancer protective membranes were prepared by phase inversion with adding different rate nanoparticles DNA/RNA–CdO sandwiched complex. It was used from surfactant Polysorbate 80 for increasing solubility of TBA in water. The current study investigated effects of nanoparticles on permeate, hydrophilicity and antifouling of PEEK on the anti–cancer protective membrane. Many reasons that make of DNA/RNA a suitable material to combine with CdO and used to make polymer anti–cancer protective membrane. By increasing of DNA/RNA–CdO sandwiched complex nanohybrids increasing of hydrophilicity of MMM. The permeation flux of 100 (mg/ l) PEEK was increased by increasing of the nanoparticles which show in anti–cancer protective membrane contact angle test. Also, by increasing of the nanoparticles in anti–cancer protective membrane increasing of roughness and decreasing of pore size of MMM. Therefore, the MMM (0.09 Wt%) with good rejection and low antifouling will be potentially useful for treatment of the water pollutant with PAHs.

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Abbreviations

CdO: Cadmium Oxide
TBA: Triptycene Barrelene Anthracene
PEEK: Polyether Ether Ketone
ATR–FTIR: Attenuated Total Reflection–Fourier Transform–Infrared
XRD: X–Ray Diffraction
SEM: Scanning Electron Microscope
EDAX: Energy–Dispersive X–Ray
3D–AFM: 3D–Atomic–Force Microscopy
TEM: Transmission Electron Microscopy
NSO: Nitrogen Sulfuer Oxygen
PAHs: Polycyclic Aromatic Hydrocarbons
SSA: Specific Surface Area
PVDF: Polyvinylidenedifluride
PSF: Polysulfonefluride
PES: Polyethersulfone
HMO: Hydrous Manganese Dioxide
MMM: Mixed Matrix Membrane
HAc: Acetic Acid
TBT: Tetra Butyl Titanate
THF: Tetrahydrofuran
HOCs: Hydrophobic Organic Compounds
FRR: Flux Recovery Rate
BSA: Bovine Serum Albumin
CPPs: Cell Penetrating Peptides
UACPF: Ultra Anti–Cancer Protective Filtration
CAP: Cold Atmospheric Plasmas
TACPMP: Trans–Anti–Cancer–Protective Membrane Pressure
CBLs: Concentration Boundary Layers
ALDL: Abraham–Lorentz–Dirac–Langevin

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