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The Importance of Attenuated Total Reflectance Fourier Transform Infrared (ATR–FTIR) and Raman Biospectroscopy of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) in Interpreting Infrared and Raman Spectra of Human Cancer Cells, Tissues and Tumors

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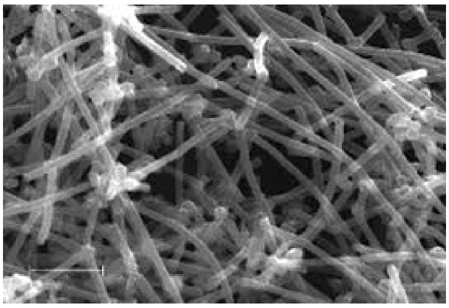
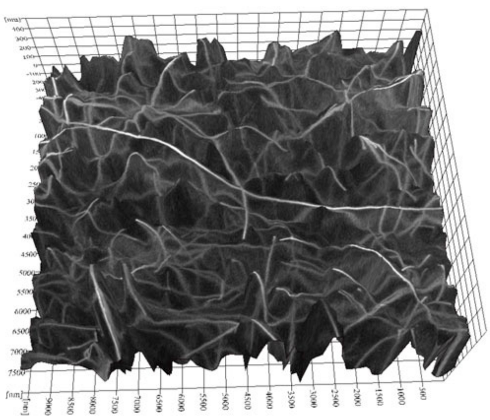


Scanning Electron Microscope (SEM) image of Single–Walled Carbon Nanotubes (SWCNT) with 90000x zoom.



3D simulation of Multi–Walled Carbon Nanotubes (MWCNT).

Graphical Abstract

In the current research, structure of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) was investigated by Attenuated Total Reflectance Fourier Transform Infrared (ATR–FTIR) and Raman spectroscopies and it was combined with Carbon nanotubes to evaluate its ability in act as radar absorber for interpreting infrared and Raman spectra of human cancer cells, tissues and tumors. In order to structurally characterize the sample and to determine characteristics related to degree of wave absorption by the sample, some analyses such as Back Scattering Raman, Attenuated Total Reflectance Fourier Transform Infrared Biospectroscopy (ATR–FTIR), X–Ray Diffraction (XRD) and Network Analyzer (NA) were used. The structure of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) was clearly observable through active modes of Raman spectra and results of X–Ray Diffraction (XRD). According to Network Analyzer (NA) spectrum analysis, the effect of nanotubes on wave absorption characteristics of sample was determined for interpreting infrared and Raman spectra of human cancer cells, tissues and tumors.

Keywords: Single–Walled Carbon Nanotubes (SWCNT), Multi–Walled Carbon Nanotubes (MWCNT), X–Ray Diffraction (XRD), Back Scattering Raman, Attenuated Total Reflectance Fourier Transform Infrared Biospectroscopy (ATR–FTIR), Raman Biospectroscopy, Network Analyzer (NA), Scanning Electron Microscope (SEM), Interpreting, Infrared Spectra, Raman Spectra, Human Cancer Cells, Tissues and Tumors

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Introduction

Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) are magnetics that are very useful due to their various applications and high electromagnetic efficiency in a wide range of frequency [1–12]. In recent years, due to extraordinary use of electronic tools such as cellphone, private computers and radar systems, interference of electromagnetic waves and its harmful effects have been widely interested. As a result, investigation about electromagnetic wave absorbers are increasingly developed [12–15].

Among wave absorbers, soft magnetic Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) can be an appropriate option in investigation about wave absorbers because of having characteristics such as high magnetic saturation, considerable Snoek's limit, high magnetic coercivity, high chemical stability and resistance against corrosion [16, 17].

Regarding the fact that Raman spectra can be considered as finger print of each chemicals, the aim of the current study is to structurally investigate one of these chemicals called Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT). Moreover, due to special physic–chemical characteristics of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) such as low weight, resistance against corrosion, high mechanical strength, high flexibility and unique electrical performance [18–223], the effect of these nanotubes on radar absorption ability of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) was studied by analyzing network analyzer (NA) spectrum for interpreting infrared and Raman spectra of human cancer cells, tissues and tumors such as Carcinomas, Sarcomas, Myelomas, Leukemias, Lymphomas, Mixed types (including blastomas), Adenocarcinomas: Adenocarcinomas begin in glandular cells that manufacture fluids, such as breast milk, Squamous cell carcinomas: Examples of squamous cells include those in the top layer of the skin, the upper portion of the esophagus and airways, and the lower portion of the cervix and vagina, Basal cell carcinomas: Basal cells are only present in the skin and are the deepest layer of skin cells, Transitional cell carcinomas: Transitional cells are epithelial cells that are "stretchy" and are present in the bladder and parts of the kidney, Osteosarcoma (bone cancers): Osteocytes are bone cells, Chondrosarcoma (cartilage cancers): Cartilage cells are called chondroblasts, Liposarcoma (fatty tissue cancers), Rhabdomyosarcoma (skeletal muscle cancers), Leiomyosarcoma (smooth muscle cancers), Angiosarcoma (blood vessel cancers), Mesothelioma (cancers of the mesothelium, the tissues that line the chest and abdominal cavities), Fibrosarcoma (cancers of fibrous tissues), Glioma and astrocytoma (cells of the connective tissue in the brain), Acute lymphocytic leukemias (ALL): These are cancers of white blood cells known as lymphocytes, Chronic lymphocytic leukemia (CLL), Acute myelocytic leukemias (AML): These are cancers of mature or immature cells known as myelocytes, such as neutrophils, Chronic myelocytic leukemia (CML), Hodgkin lymphoma, Non–Hodgkin lymphoma, Oral cancer: Roughly 85 percent of head and neck cancers are oral cancers. These cancers may involve the mouth, the tongue, the tonsils, the throat (the pharynx), and the nasal passageways, Laryngeal cancer: (cancer of the vocal cords), Ductal carcinoma in situ of the breast and lobular carcinoma in situ, Invasive (infiltrating) breast cancer (both ductal and lobular), Inflammatory breast cancer, Male breast cancer, Non–small cell lung cancer, Small cell lung cancer, Mesothelioma, Esophageal cancer, Stomach cancer, Pancreatic cancer, Liver cancer, Colon cancer, Anal cancer, Kidney cancer, Bladder cancer, Prostate cancer, Testicular cancer, Ovarian cancer (including germ cell tumors), Uterine cancer (endometrial cancer), Fallopian tube cancer, Cervical cancer, Thyroid cancer, Osteosarcoma (bone cancers), Kaposi's sarcoma: Kaposi's sarcoma is a soft tissue cancer often seen in people with HIV/AIDS, Ewing's sarcoma: Ewing's sarcoma is a bone cancer that primarily affects children, Hodgkin's lymphoma, Non–Hodgkin's lymphoma, Acute lymphocytic leukemia (ALL), Chronic lymphocytic leukemia (CLL), Acute myelogenous leukemia (AML), Chronic myelogenous leukemia (CML), Myeloma, Melanoma, Squamous cell carcinoma of the skin, Basal cell carcinoma, By the grade of the tumor, By the stage of the tumor, Non–hereditary cancer vs hereditary cancer, DNA/RNA molecular profiles.

Methodology

An analogy to describe cancer cells has been that of a car. The growth of the cells can be pictured as a car that has the accelerator stuck down. At the same time, the brakes don't work (the cells doesn't respond to tumor suppressor proteins.)

We can take this analogy a step further. The invasion of cancer cells can be viewed as a car breaking through a gate into a gated community. Normal cells respond to signals from neighboring cells that say "this is my boundary, stay out." Cancer cells are antisocial in other ways as well. As they "gang" up with other cancer cells, all of which are becoming more immature

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in their actions over time (due to rapid division), they spread out and invade other communities as well.

But just as crime hasn't overridden the United States, there are many police officers (checkpoints) that keep the majority of cells in the body in line.

It is actually very difficult for a normal cell to become a cancer cell. It has to be abnormal in ways that facilitate growth, inhibit repair and death, ignore signals from neighbors, and achieve a form of immortality. This is why cancer isn't caused by a single mutation, but rather by a series of mutations. But considering that a billion cells in our bodies divide every day, something is bound to go wrong and mutations occur once in a while. And they do, for an estimated 1.6 million people in the United States each year.

Results and Discussion

As we know, each crystalline structure has different labels for its Raman active modes in Raman spectrum and this unique combination of modes is the characteristic of each structure and called as finger print of structure. In this regard, to investigate the formation of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) structure and to identify its modes, Raman dispersion spectrum of both produced samples at two different temperatures are shown in Figure (1).

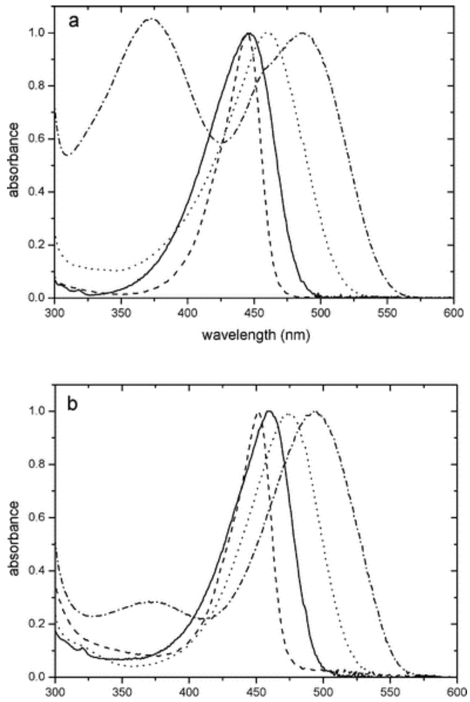

Figure 1: Raman dispersion spectrum of (a) Single–Walled Carbon Nanotubes (SWCNT), (b) Multi–Walled Carbon Nanotubes (MWCNT)

As spinel oxides of metallic conductors are divided into normal and reverse groups, Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) have a reverse spinel structure and its initial symmetry and spatial group are O_h^7 and $FD\overline{3}m$, respectively.

The difference between these two spectrums is that the related modes are of lower intensity in lower temperature and at the other hand, additional modes are observed that can be attributed to incomplete structure and presence of impurities such as Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT). Adjacent to each of these modes, observing a small peak (like a brush) is possible which attributed of reverse spinel structure of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) that emerge as E_g and A_{1g} modes.

To investigate functional groups presented in the compound, Attenuated Total Reflectance Fourier Transform Infrared (ATR–FTIR) analysis was used for interpreting infrared and Raman spectra of human cancer cells, tissues and tumors such as Carcinomas, Sarcomas, Myelomas, Leukemias, Lymphomas, Mixed types (including blastomas), Adenocarcinomas: Adenocarcinomas begin in glandular cells that manufacture fluids, such as breast milk, Squamous cell carcinomas: Examples of squamous cells include those in the top layer of the skin, the upper portion of the esophagus and airways, and the lower portion of the cervix and vagina, Basal cell carcinomas: Basal cells are only present in the skin and are the deepest layer of skin cells, Transitional cell carcinomas: Transitional cells are epithelial cells that are "stretchy" and are present in the bladder and parts of the kidney, Osteosarcoma (bone cancers): Osteocytes are bone cells, Chondrosarcoma (cartilage cancers): Cartilage cells are called chondroblasts, Liposarcoma (fatty tissue cancers), Rhabdomyosarcoma (skeletal muscle cancers), Leiomyosarcoma (smooth muscle cancers), Angiosarcoma (blood vessel cancers), Mesothelioma (cancers of the mesothelium, the tissues that line the chest and abdominal cavities), Fibrosarcoma (cancers of fibrous tissues), Glioma and astrocytoma (cells of the connective tissue in the brain), Acute lymphocytic leukemias (ALL): These are cancers of white blood cells known as lymphocytes, Chronic lymphocytic leukemia (CLL), Acute myelocytic leukemias (AML): These are cancers of mature or immature cells known as myelocytes, such as neutrophils, Chronic myelocytic leukemia (CML), Hodgkin lymphoma, Non–Hodgkin lymphoma, Oral cancer: Roughly 85 percent of head and neck cancers are oral cancers. These cancers may involve the mouth, the tongue, the tonsils, the

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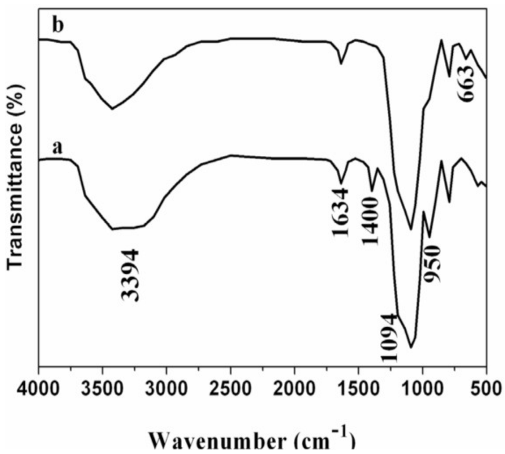

Figure 2: Attenuated Total Reflectance Fourier Transform Infrared (ATR–FTIR) spectrum of (a) Single–Walled Carbon Nanotubes (SWCNT), (b) Multi–Walled Carbon Nanotubes (MWCNT).

There are four active IR for this structure that are emerged in v_1 (613–890 cm^{-1}), v_2 (1044–1390 cm^{-1}), v_3 (1400–1590 cm^{-1}) and v_4 (1590–3420cm^{-1}). Two bands are in far–infrared zone (Far–IR) and are not observable. Comparing two spectrums show that characteristic modes are of higher intensity and there are not additional modes. This can be attributed to complete formation of crystalline structure of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT).

The spectrum of network analyzer (NA) which is shown in Figure (3) indicates the amount of wave absorption in frequency range of 14–44 (GHz) related to Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) samples. According to comparison with the single samples of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT), a considerable change was observed in the amount of compound absorption in relation with single sample and it can be concluded that the considered compound is of important and favorable abilities for applying as radar absorption covers for interpreting infrared and Raman spectra of human cancer cells, tissues and tumors such as Carcinomas, Sarcomas, Myelomas, Leukemias, Lymphomas, Mixed types (including blastomas), Adenocarcinomas: Adenocarcinomas begin in glandular cells that manufacture fluids, such as breast milk, Squamous cell carcinomas: Examples of squamous cells include those in the top layer of the skin, the upper portion of the esophagus and airways, and the lower portion of the cervix and vagina, Basal cell carcinomas: Basal cells are only present in the skin and are the deepest layer of skin cells, Transitional cell carcinomas: Transitional cells are epithelial cells that are "stretchy" and are present in the bladder and parts of the kidney, Osteosarcoma (bone cancers): Osteocytes are bone cells, Chondrosarcoma (cartilage cancers): Cartilage cells are called chondroblasts, Liposarcoma (fatty tissue cancers), Rhabdomyosarcoma (skeletal muscle cancers), Leiomyosarcoma (smooth muscle cancers), Angiosarcoma (blood vessel cancers), Mesothelioma (cancers of the mesothelium, the tissues that line the chest and abdominal cavities), Fibrosarcoma (cancers of fibrous tissues), Glioma and astrocytoma (cells of the connective tissue in the brain), Acute lymphocytic leukemias (ALL): These are cancers of white blood cells known as lymphocytes, Chronic lymphocytic leukemia (CLL), Acute myelocytic leukemias (AML): These are cancers of mature or immature cells known as myelocytes, such as neutrophils, Chronic myelocytic leukemia (CML), Hodgkin lymphoma, Non–Hodgkin lymphoma, Oral cancer: Roughly 85 percent of head and neck cancers are oral cancers. These cancers may involve the mouth, the tongue, the tonsils, the throat (the pharynx), and the nasal passageways, Laryngeal cancer: (cancer of the vocal cords), Ductal carcinoma in situ of

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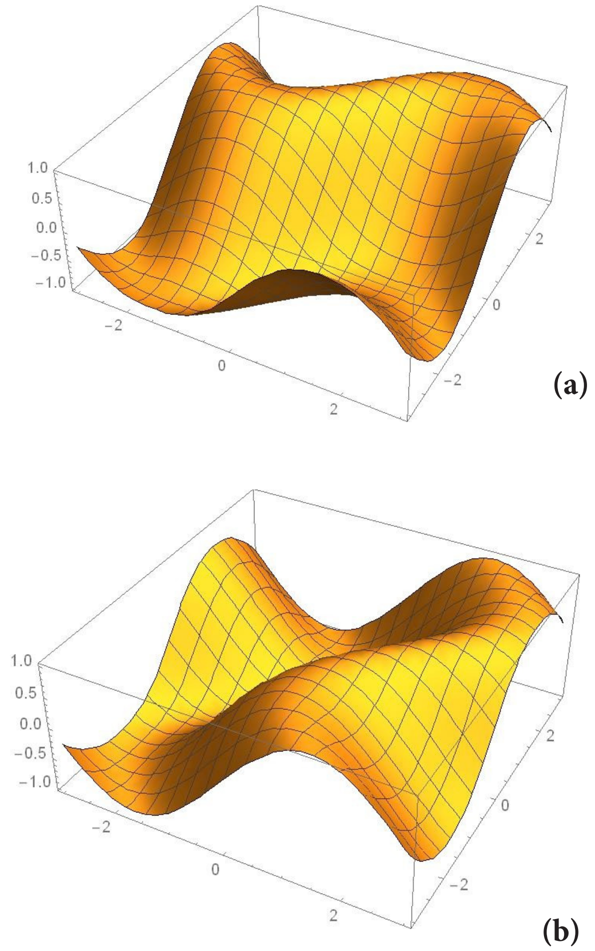

Figure 3: Dissipation of sample reflection of (a) Single–Walled Carbon Nanotubes (SWCNT), (b) Multi–Walled Carbon Nanotubes (MWCNT).

Finally, in order to identify crystalline phase and formed structure, X–Ray Diffraction (XRD) pattern of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) is shown in Figure (4).

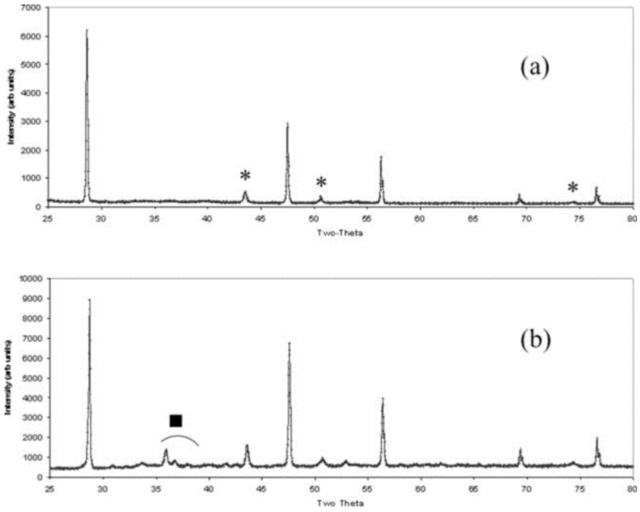

Figure 4: X–Ray Diffraction (XRD) pattern of (a) Single–Walled Carbon Nanotubes (SWCNT), (b) Multi–Walled Carbon Nanotubes (MWCNT).

This pattern is in accordance with X–Ray Diffraction (XRD) pattern of crystalline structure of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) and the crystalline lattice structure is face centered cubic (fcc) and the mean crystalline size is smaller than 100 (nm).

Conclusion and Summary

In the current research, in order to determine the structure of sample and characterize the vibration modes related to the sample, back scattering Raman biospectroscopy and Attenuated Total Reflectance Fourier Transform Infrared biospectroscopy (ATR–FTIR) were performed and the related modes of sample were completely identified in these spectra. Regarding the importance of electromagnetic wave absorbers in various industries, reflection dissipation spectrum of sample and effect of nanotubes on Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) were investigated. It was observed that the presence of nanotubes is of considerable effect on wave absorption of Single–Walled Carbon Nanotubes (SWCNT) and Multi–Walled Carbon Nanotubes (MWCNT) and the saved spectrum data confirm this claim for interpreting infrared and Raman spectra of human cancer cells, tissues and tumors such as Carcinomas, Sarcomas, Myelomas, Leukemias, Lymphomas, Mixed types (including blastomas), Adenocarcinomas: Adenocarcinomas begin in glandular cells that manufacture fluids,

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