



# **SEMINAR BOOK**

***SEMINAR***  
***“MULTI-SCALE SELF-HEALING NANOCOMPOSITE***  
***SHIELDING MATERIAL”***  
***TUBITAK 1001 PROJECT - Project No:115R017***

***SEMİNER***  
***“KENDİNİ ÇOK YÖNLÜ ONARABİLEN***  
***NANOKOMPOZİT GELİŞTİRİLMESİ VE***  
***ZİRH MALZEMESİ OLARAK***  
***MEKANİK DAVRANIŞLARININ İNCELENMESİ”***  
***TÜBİTAK 1001 PROJESİ-Proje No: 115R017***





**MULTI-SCALE SELF-HEALING NANOCOMPOSITE  
SHIELDING MATERIAL,  
TÜBİTAK 1001 PROJECT - Project No:115R017**

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**Istanbul Technical University ( ITU )  
ARI 6 Seminar Hall &**

**Ayazaga Campus, Istanbul, TURKEY**



## **Foreword**

I had the honour of presiding the seminar on “**Multi-Scale Self-Healing Polymer Nanocomposite Shielding Material - Kendini Çok Yönlü Onarabilen Nanokompozit Geliştirilmesi ve Zırh Malzemesi Olarak Mekanik Davranışlarının İncelenmesi with Project No:115R017**” held in Istanbul Technical University, Istanbul Technical University ( ITU ) ARI 6 Seminar Hall, 21 February 2018. This seminar aims to bring together academicians, researchers and industry. This high profile delegates try to exchange and discuss this project results as an original research results, practical development experiences and technological advancements of future applications.

The main objective of this seminar was to provide a common platform to improve theory and practice of various disciplines and sectors. This seminar has performed a perfect opportunity for Academicians, Researchers and investors to express their innovative and unique ideas and experiences. Moreover, it has provided to participants to meet and interact with each other.

This seminar has provided a privilege to participants to discuss the advantages, disadvantages and opportunities involved in sustainability of innovation in multi-scale self-healing polymer nanocomposite shielding material with respect to current industrial and academically researches.

**Thank you for your participations.**

Project Manager of TUBITAK 1001 Project with No:115R017

Prof. Dr. Nilgün BAYDOĞAN



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## **SUMMARY**

PMMA (poly methyl methacrylate) is a thermoplastic polymer in high transparency and is made of polymerization of methylmethacrylate monomer. By its aesthetic appearance, transparency and scratch resistance, it is highly preferred polymer for industrial usage during last decades.

Poly (methyl methacrylate) (PMMA) is a clear, transparent thermoplastic material with good mechanical properties, high resistance to weathering and excellent heat resistance. Mechanical, thermal, electrical and radiation shielding properties of PMMA can be improved by adding several nanomaterials with excellent properties. The enhanced PMMA materials are the ideal candidates for several application areas such as medical, sensor, solar cell, electronic and aerospace areas.

PMMA has better impact resistance comparing to glass and polystyrene and it has wider scope for area of usage, by dint of its aesthetic, economic and simplicity to produce and to repair. To increase its resistance level against fatigue and impact, there have been improved sort of methods. Those methods aimed to produce an alternative matter for PMMA, to modify the chemistry of PMMA, to support PMMA with some strengthening matters.

## 1) INTRODUCTION

Glass-transition temperature of PMMA is about 105 °C. It has perfect optical transparency and is possible to use this specification on the applications that are based on light transmittance. It has excellent UV and weathering resistance. PMMA can be produced till 35 cm without losing its transparency. The tensile strength of PMMA can reach 70 MPa measure. Temperature of deflection under load of thermotropic PMMA can reach over 90 °C and it is generally easy moulding plastic.

PMMA is generally polymerized by heat. The polymerization method with Gamma Rays is commonly used on the polymer industry. PMMA has been seen in synthetic fiber and paints. These materials are pretty strong, tough and more transparent comparing with glass. PMMA is called 'plexiglass' as its market name and it's been used in many industries as glass. After world war 2, following the technological developments on space and automotive industries, it also came into use in those industries. In today's world, composite materials are preferred in many industries such as electronic, rail systems and sports equipments.

In the past two decades, the attention of researchers shifted from intellectual to experimental studies that are appliance-directed (Portale, Hermida-Merino, & Bras, 2016). The area of polymeric radiation shielding materials is highly underrated as it has great application potential. Polymer shielding materials offer advantages such as enhanced homogenous shielding, flexibility, and lower weight relative to metallic shielding materials (Håkansson, Amiet, Nahavandi, & Kaynak, 2007). Such improvement is essential for the protection of astronauts, spacecraft, and payloads

from radiation damage in long-term space missions (Emmanuel & Raghavan, 2016; Pohl & Britt; Slaba et al., 2017).

Poly(methyl) methacrylate (PMMA) is a thermoplastic polymer with exceptional mechanical properties. (PMMA)  $(C_5O_2H_8)_n$  is widely used in the automotive and aerospace industry. PMMA is used in aircraft windshields, radar screens, and telescope production (Hu et al., 2016). Polymer's functionality such as magnetic, optical, and mechanical properties can be enhanced through the incorporation of inorganic nanomaterials into the polymer matrix. Changes in properties of the polymer depend on filler type and preparation method of the nanocomposite (Chang et al., 2008).

One of the main reasons for polymer degradation is chain scission under radiation energy (I. H. Kim, Cho, Bae, Park, & Chung, 2003). This deterioration creates both new radicals and the macromolecules. The living polymer produced with the ATRP method has a potential advantage as the living matrix might allow self-healing from the damage induced by ionizing, ultraviolet, and electromagnetic radiation. The living polymer can induce recombination between new radicals and the macromolecular on the end of the matrix chain (Ming Qiu Zhang & Rong, 2011b; Zhu, Rong, & Zhang, 2015). For this reason, PMMA living polymer synthesized by ATRP was chosen as the matrix material of reinforced nanocomposites.

## **2) INVESTIGATION OF EMITTED GAS EFFECT ON POLYMER STRUCTURE BY USING GAMA TRANSMISSION TECHNIQUE IN PRODUCTION PROCESS OF POLY (METHYL METHACRYLATE)**

In this study, the characteristic features of PMMA which is produced by ATRP (Atom Transfer Radical Polymerization) method, are examined. During the process of being exposed to gamma rays, both structural characteristics which are applied and non-applied dissolved gas in solution free from the structure application of polymer PMMA are examined. The changes in structural characteristics influenced the optical properties, too. Therefore, the changes of optical properties of applied and non-applied dissolved gas in solution free from structure application polymer PMMA materials are indicated with PG Instruments T80 UV-VIS-NIR spectrophotometer in 190–1100 nm wavelength range.

The structure of PMMA produced by non-applied dissolved gas in solution free was not homogeneous. By dint of dissolved gas in solution free from the structure method, obtaining compactness in the structure, it is seen that the structure is more homogeneous in the photomicrographs.

The changes in curves of transmittance and reflectance of PMMA polymer structure are analyzed in detail. After, the measures of PMMA samples in different thickness that are put into XRF analysis machine are collected. The elements of samples in different forms that are in sodium-uranium gap are analyzed in ppm % concentration

level with XRF system, according as sample's matrix. FTIR analyses are done in 650–4000  $\text{cm}^{-1}$  gap for PMMA polymer materials that have been produced by ATRP method. The results of FTIR analyses are analyzed comparing the technical literature.

In this study, Co-60 and Cs-137 isotopes were used for gamma transmission technique. PMMA samples in different thicknesses were worked on. For each thickness, using the Co-60 ve Cs-137 radioisotopes, countings were collected by gamma transmission mechanism. Gamma transition method is based on interaction between atoms of matter and gamma rays while they are passing-through the matter. As a result of these interactions, gamma rays loose a part or all of energy. Putting the gamma radioisotope source and detector materials in the same line, intensity of gamma rays that are emanating from the source and passing-through the material are measured.

In this study, with gamma transition method, an experimental research, related to the definition of radiation attenuation coefficient of PMMA polimer samples that are produced in different qualifications, using Cs-137 and Co-60 gamma radioisotopes sources, is done. The researches are done in stationary test conditions. After the system is build, first of all, the background radiation of system is measured. Afterwards, without putting the material, inception gamma radiation ( $I_0$ ) that is emanating from the source, passing-through collimator and reaching the detector is measured. After that work, putting the samples in different thicknesses for each matter in front of the collimator, gamma radiation ( $I$ ) for each thickness is measured.

The relative counting values are obtained dividing the measured clear counting values by inception counting values ( $I/I_0$ ) for every different thicknesses of each material.

Creating relative counting–thickness graphs, gamma attenuation curves are obtained. The matters are examined with comparing each others. Based on these countings, standard deviations and relative countings of samples were determined. Linear attenuation coefficients were reached by analyses of acquired relative countings. As a result of acquired conclusion, the increment in reflectance and decrease in transmittance of PMMA polymer sample, when the thicknesses of PMMA polymer sample are increased, are determined.

### **3) PHYSICAL PROPERTIES OF POLY(METHYL METHACRYLATE)/GRAPHENE NANOPATELETS NANOCOMPOSITE**

In this study, Graphene Nanoplatelets (GNPs) was selected as nanofiller to enhance the mechanical, thermal, electrical and radiation shielding properties of PMMA. PMMA was produced via ATRP technique. GNPs nanofiller was dispersed by in situ polymerization method because it was the most efficient method to disperse the layered GNPs nanomaterial.

SEM, XRD, FTIR, TGA, hardness and compression test, ultrasonic test and gamma transmission techniques are performed to examine the changes in the characteristic properties of PMMA.

SEM characterization combined with elemental mapping technique showed that GNPs nanofiller homogeneously dispersed in the PMMA polymer matrix via in situ polymerization method. Besides, the results of the ultrasound tests were supported a homogeneous structure of PMMA/GNPs nanocomposites.

XRD pattern of PMMA/GNPs nanocomposites presented a pick at  $\sim 26.5^\circ$ , which is corresponding to the stacking of the graphene layers at a distance of 0.34 nm. The intensity of the pick increased with the rise of the GNPs concentration. The FITR spectra of PMMA/ nanocomposite presented similar spectra with pure PMMA, indicating that interaction occurred between GNPs nanofiller and PMMA polymer matrix.

TGA results showed that with the addition of 2% GNPs, the 5% weight loss temperatures shifted from  $196.73^\circ\text{C}$  to  $243.00^\circ\text{C}$ , improved by  $46.27^\circ\text{C}$ . The thermal stability of PMMA enhanced significantly. With the addition the electric conductivity of PMMA improved dramatically from  $\sim 10^{-14}$  S/m to 0.72 S/m.

In the ultrasonic test, the Shear modulus, Young's modulus and Microhardness values of pure PMMA were increased by 19.5%, 16.8 %, and 14.2% respectively with the addition of 2 wt.% GNPs. Compare to the pure PMMA, with the addition of 2 wt.% GNPs the Rockwell hardness and compressive strength increased by 19.9% and 42.7% respectively.

The linear attenuation coefficients increased slightly with the rise of GNPs concentration, for Cs-137 and Co-60 radioisotopes. However the mass attenuation coefficients decreased slowly.

#### **4) THE INVESTIGATION OF THE IRRADIATION EFFECT ON PMMA/MWCNTs POLYMER NANOCOMPOSITES**

Poly (methyl methacrylate) (PMMA) is a transparent thermoplastic material that shows good mechanical properties, high resistance to abrasion and superior heat resistance. Mechanical, thermal and radiation shielding properties of PMMA can be enhanced by addition of multiwall carbon nanotubes (MWCNTs). PMMA is an ideal candidate for some applications such as sensor, solar cell, electronic and aerospace fields due to suitable structural properties of MWCNTs.

Carbon nanotubes separate two parts which are single-wall carbon nanotubes and multi-wall carbon nanotubes. Single-wall carbon nanotubes (SWCNTs) have scale from 0.5 nm to 1.5 nm. On the other hand, multi-wall carbon nanotubes (MWCNTs) are bigger than 100 nm scale. The use of MWCNT in polymer results with higher mechanical properties than SWCNT in polymer. Besides, MWCNT in polymer gives more chemical resistance than SWCNT.

Polymer nanocomposites containing MWCNT can be utilized in a several industrial application areas such as automotive and aerospace due to their outstanding advantages such as high durability, high strength and light weight. PMMA is one of the thermoplastic polymers coming from the acrylate family. PMMA reinforced by carbon nanotubes has significant importance in many applications ranging from large scales to nanometer scales. It is considered as a candidate for the applications in new technologies depending on the improved mechanical, electrical, optical properties of polymer.

There are three methods to produce PMMA reinforced by MWCNTs which are solution-mixing, melt compounding, in-situ polymerization. In this study, it was preferred to use Atom Transfer Radical Polymerization (ATRP) method to disperse MWCNTs in PMMA effectively. MWCNTs were selected as nanofiller to improve the mechanical and thermal properties of PMMA with the investigation of the changes in radiation shielding performance.

Several analysis and tests were performed to examine the main characteristic properties of the PMMA/MWCNTs nanocomposites such as SEM, XRD, FTIR, TGA, hardness, ultrasonic test, gamma transmission technique and the behaviors of the PMMA/MWCNTs nanocomposite against neutrons.

PMMA/MWCNTs nanocomposite samples were irradiated at 50 kGy using Co-60 radioisotope. The irradiated polymer nanocomposite samples were characterized to examine the structural changes after irradiation treatment. The surface morphology of the PMMA/MWCNTs nanocomposite in SEM images indicated that ATRP method was efficient to get homogeneous dispersion of MWCNTs in the PMMA matrix. The results of the ultrasonic test supported the homogeneous structure of PMMA/MWCNTs nanocomposites at 2 wt.%MWCNTs.

PMMA/MWCNTs nanocomposite presented three characteristic diffraction peaks in XRD analysis. The FTIR spectra of PMMA/MWCNT nanocomposites revealed the similar spectrum with pure PMMA, showing that interaction occurred between MWCNTs nanocomposites and PMMA polymer matrix.

TGA results of unirradiated nanocomposite at the addition of 2 wt. % MWCNTs exhibited that the 5% weight loss temperatures shifted from ~191 °C to 243 °C with the improvement in the temperature (as ~52 °C). The thermal stability of PMMA was enhanced with the rise of the amount of the MWCNTs from (0.25 to 2 wt. %) in PMMA/MWCNTs nanocomposite. The 5 % weight loss temperatures increased after irradiation process.

In the ultrasonic test, the Shear modulus, Young's modulus and Microhardness values of pure PMMA were increased with the addition of 2 wt. % MWCNTs. The improvement in Rockwell hardness values between the pure PMMA and PMMA/MWCNTs at 2 wt. % MWCNTs is ~ 11 %. The difference in Rockwell hardness values is almost ~3 % for unirradiated and irradiated states of PMMA/MWCNTs at 2 wt. % MWCNTs. The linear attenuation coefficient values for Cs-137, Co-60 radioisotopes changed slightly with the rise of the MWCNTs amount and macroscopic cross sections for neutrons Pu-Be neutron source increased slightly.

## **5) MULTI-SCALE SELF-HEALING NANOCOMPOSITE SHIELDING MATERIAL FOR AEROSPACE**

In this study, the content of GMA loaded microspheres (MK) and Halloysite clay nanotubes (HNTs), as well as Montmorillonite clay nanoplates (MMT) and Colemanite (CMT), were optimized in a living PMMA matrix to achieve maximum radiation-shielding capacity while keeping the mechanical properties and the self-healing capacity.

A multiphase autonomous self-healing approach was followed for maximum efficiency. The most promising nanocomposite compositions have been determined by applying the hardness, impact, flexural, and compression tests for mechanical shielding applications.

Samples are tested for shielding gamma and neutron radiation for radiation shielding properties. Thus, it is determined how to produce a multiphase self-healing nanocomposite shielding material for aerospace.

## **6) GENERAL RESULTS**

This research was performed to enhance the properties of PMMA polymer by adding GNPS nanofiller with different concentration. PMMA was produced via ATRP technique. GNPs nanofiller was dispersed by in situ polymerization method because it was the most efficient method to disperse the layered GNPs nanomaterial.

The surface morphology of the PMMA/GNPs nanocomposites were examined with SEM techniques. SEM characterization combined with elemental mapping technique showed that GNPs nanofiller homogeneously dispersed in the PMMA polymer matrix via in situ polymerization method.

The structural characterization of PMMA/GNPs nanocomposite structure was carried out to examine the effect of GNPs nanofiller on PMMA using XRD analysis. XRD diffraction patterns of PMMA/GNPs nanocomposites presented a pick at  $\sim 26.5^\circ$ ,

which was corresponding to the stacking of the graphene layers at a distance of 0.34 nm. The intensity of the pick increased with the rise of the GNPs concentration.

The chemical structure was investigated with FTIR spectroscopy. The FTIR spectra of PMMA/GNPs nanocomposite presented similar spectra with pure PMMA, indicating that interaction occurred between GNPs nanofiller and PMMA polymer matrix.

Thermal stability was evaluated with the Thermogravimetric Analysis (TGA). TGA analysis results showed that the addition of GNPs nanofiller into the PMMA, the thermal stability of PMMA enhanced significantly.

Electrical conductivity was measured with four-point probe method. The conductivity of PMMA was improved dramatically from  $\sim 10^{-14}$  S/m to 0.72 S/m with the addition of 2.0 Wt.% GNPs nanofiller into PMMA polymer.

The dispersion quality of GNPs nanofiller, the volumetric changes or discontinuous in the PMMA/GNPs nanocomposite structure were examined by using ultrasonic tests. Test results showed that GNPs nanofiller homogeneously dispersed in PMMA polymer matrix. There was not considerable discontinuous observed at the ultrasonic inspection. Besides, the ultrasonic nondestructive test was used to obtain more detailed information on mechanical properties of PMMA/GNPs nanocomposite. Shear modulus, Young's modulus and microhardness values of pure PMMA were reached to maximum level at 2 wt.% GNPs concentration. These values were increased by 19.5%, 16.8 %, and 14.2% respectively depending on the GNPs addition at 2 wt.% GNPs concentration.

Hardness and compressive strength were tested to study the mechanical performance of the nanocomposites. Compare to the pure PMMA, with the addition of 2 wt.% GNPs the Rockwell hardness and compressive strength increased by 19.9% and 42.7% respectively.

Gamma transmission technique was carried out to investigate the gamma ray shielding performance of the nanocomposites using Cs-137 and Co-60 radioisotopes.

Dispersion of the MWCNTs in the matrix is one of the key parameter in polymer nanocomposite. It was determined that “in-situ polymerization method” was an efficient method to get homogeneous dispersion at PMMA/MWCNTs nanocomposite in this study.

SEM image of the PMMA/MWCNTs nanocomposite at 2 wt. % PMMA/MWCNTs indicated that MWCNTs nanofillers dispersed homogeneously in the PMMA polymer matrix. XRD patterns of PMMA, MWCNTs and PMMA/MWCNTs nanocomposites explained that there were three characteristic diffraction peaks. One of them centered at  $\sim 13^\circ$ , and two small peaks placed at  $\sim 28^\circ$  and  $\sim 42^\circ$ .

The changes in the Rockwell hardness values of the nanocomposite were examined before and after the irradiation treatment at 50 kGy. The Rockwell hardness values of the pure PMMA increased with the addition of MWCNTs nanofiller. The addition of MWCNTs at 2 wt. % amount supported to improve the Rockwell hardness value of the PMMA/MWCNTs nanocomposite. The difference of the Rockwell hardness value

was ~11 % between pure PMMA and PMMA/MWCNTs nanocomposite with 2 wt. % PMMA/MWCNTs amount. Besides, the irradiation process improved the hardness value of the PMMA/MWCNTs nanocomposite. The difference in the Rockwell hardness values between the unirradiated and the irradiated states was ~ 3 % for PMMA/MWCNTs.

The ultrasonic inspection as a nondestructive testing was used to examine the detailed information on the structural changes and the elastic properties of pure PMMA and PMMA/MWCNTs nanocomposite. The ultrasonic test results of the PMMA/MWCNTs nanocomposite at 2wt. % PMMA/MWCNTs amount indicated that MWCNTs nanofiller has dispersed homogeneously in PMMA polymer matrix. The ultrasonic test results of the PMMA/MWCNTs nanocomposite asserted that the addition of MWCNTs at 2 wt. % amount into the PMMA improved the elastic properties of its structure.

The irradiation process at 50 kGy addressed to decrease in the elastic modulus of the PMMA/MWCNTs nanocomposite and this change supported to the enhancement in the flexible property of the polymer nanocomposite with the same geometry but with lower elastic modulus. After the irradiation of the PMMA/MWCNTs nanocomposite, the decrease in elastic properties (such as Shear modulus and Young's modulus) of the nanocomposite with the rise of Rockwell Hardness (M scale) value addressed to lead the enhancement of the resulting forward speed at high speed applications of the vehicles containing PMMA/MWCNTs nanocomposite.

The decrease in the Shear modulus and Young's modulus values and the enhancement in Rockwell Hardness value of the irradiated nanocomposite addressed to use this nanocomposite at the high-speed applications.

In this study, surface-modified Montmorillonite (MMT) nanoplates and Halloysite (HNTs) clay nanotubes with a thickness of 15 nm in the polymer melt could be dispersed in a manner compatible with the polymer structure without agglomerating. Due to the presence of canals in the clay HNTs nanotubes, better integration of HNTs with the monomer present in the polymer melt can be achieved.

It has been determined that HNTs are more readily dispersed in the polymer structure when the dispersion time (~ 1 hour) of the HNTs in the polymer structure and the dispersion time (~ 2-3 hours) of the MMT in the polymer structure are compared. The SEM studies have shown that HNTs and MMT are distributed more homogeneously in the matrix structure than in CMT. The surface images obtained show that the HNTs reinforcements have improved the processability of the material.

High flexural strengths in nanocyl-reinforced composites, MK 1% wt., HNTs 0,5% wt. PMMA / MK / HNTs and MK 1% wt., MMT 1% wt. PMMA/ MK/MMT. It has been found that, after self-repair, the rate of decrease in flexural strength remains at the same level in MMT-reinforced specimens; whereas in HNTs' reinforced specimens, the self-repair capacity decreases with an increasing reinforcement ratio.

The MK was 1% wt., MMT 1% wt when it is considered the increase in impact strength by ~4 times and the change in bending strength test after self-repairing,. The PMMA/MK /MMT nano-composite was chosen as the best self-repairing material.

The changes in gamma attenuation properties of MK at 1% wt., MMT 5 % wt., PMMA/MK/MMT, and 1wt.% MK, 5wt.% CMT, and PMMA/MK/CMT for Cs-137 radioisotope were compared theoretically (WinXCOM) and experimentally studied. Neutron shielding capacity was experimentally studied with a neutron howitzer ( $^{239}\text{Pu}$  - Be).

The incorporation of 1wt.% MK, 5wt.% CMT, PMMA/MK/CMT had increased the  $^{239}\text{Pu}$ -Be neutron attenuation capacity by % 4,83. CMT includes both boron and hydrate; thus, it is effective against shielding both fast and thermal neutrons.

MK 1% wt., MMT 5 % wt. PMMA/MK/MMT and MK 1% wt., CMT 5 % wt. PMMA/MK/CMT has improved Cs-137 attenuation capacity by ~4%. Thus, both MMT and CMT increased the radiation-shielding capacity of the PMMA. Further studies are suggested for the purification and nano-sized production of CMT. Nano-sized CMT can be used for PMMA/MK/CMT nanocomposites.

Hence, it was possible to produce MK 1% wt. and MMT 1% wt. The PMMA/MK/MMT nano-composite was a multi-scale self-healing nanocomposite shielding material for aerospace applications.

## **7) Conclusions**

The gamma attenuation coefficient of PMMA/GNPs nanocomposite was improved slightly by the addition of GNPs nanofiller into PMMA polymer. Experimental attenuation coefficient results were compared with the theoretical attenuation coefficient results. Their results indicated that there was a similarity between the experimental and theoretical attenuation coefficient results.

The application of the gamma transmission technique performed to examine the variations in the radiation shielding performance of the PMMA/MWCNTs nanocomposite against to gamma radiation by using two different gamma sources (such as Cs-137 and Co-60 radioisotopes). The linear attenuation coefficient of PMMA/MWCNTs nanocomposite changed slightly with the rise of the amount of the MWCNTs nanofiller. The experimental attenuation coefficient values were compared with the theoretical attenuation coefficient values. The comparison of their results addressed to a similarity between the experimental and theoretical attenuation coefficient values.

The use of Pu-Be Neutron Howitzer supported to examine the details on the structural characteristics of PMMA/MWCNTs nanocomposites and to evaluate the effect of MWCNTs on PMMA/MWCNTs nanocomposite. These results indicated that PMMA/MWCNTs nanocomposite produced by ATRP method was a suitable lightweight material to use several industrial areas such as the aviation and aerospace industries.

MK 1% wt., MMT 1% wt. The PMMA/MK/MMT increases the impact strength by ~4 times. The loss in the bending strength test after self-repairing is the lowest for the MK 1% wt. and MMT 1% wt. The PMMA/MK/MMT. The possible applications for the novel PMMA/MK/MMT shielding material include facilities such as the biological shielding of nuclear submarines, high-altitude planes, satellites, space shuttles, medical cyclotrons, nuclear investigation centers, and linear accelerators.