Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi

Pamukkale University Journal of Engineering Sciences

Kabul Edilmiş Araştırma Makalesi (Düzenlenmemiş Sürüm)

Accepted Research Article (Uncorrected Version)

Makale Başlığı / Title	Grafen oksit (GO) ve indirgenmiş grafen oksit (RGO) dolgulu PVC kompozitlerin mekanik özelliklerinin karşılaştırılması A comparison study on mechanical properties of PVC composites filled by graphene oxide (GO) and reduced graphene oxide (RGO)
Yazarlar / Authors	Ferda MİNDİVAN[1]
Referans No / Reference No	PAJES-39114
DOI	10.5505/pajes.2018.39114

Bu PDF dosyası yukarıda bilgileri verilen kabul edilmiş araştırma makalesini içermektedir. Sayfa düzeni, dizgileme ve son inceleme işlemleri henüz tamamlanmamış olduğundan, bu düzenlenmemiş sürüm bazı üretim ve dizgi hataları içerebilir.

This PDF file contains the accepted research article whose information given above. Since copyediting, typesetting and final review processes are not completed yet, this uncorrected version may include some production and typesetting errors.

0 Á í õ ë ë Á ì Å - î é ö Å ò ó é ô Å ó é -
Pamukkale University Journal of Engineering Sciences

' Ò Á Æ Å î ï ë ó é ô ¡ ' / Q ö Å é î ä é ò ç Å î í é ĥ ë ï í Đ ï ú é ô ì Å ò é î í Å ë Á î é ë ¡ Á ĥ ô Å ì ì Á ó Ģ

! Ã ï í Đ Á ò é ó ï î ó ô õ ä ù ï î í Å Ã è Á î é Ã Á ì Đ ò ï Đ Å ò ô é Å ó ç ò Á Đ è Å î Å ï ø é ä Å ¡ ' / Q Á î ä ò Å ä õ Ã Å ä

& Å ò ä Á - é î ä é ö Á î

¹ " é ù ï ô Å ë î ï ì ï ê é ! ò Á ĥ ô ą ò í Á ö Å 5 ù ç õ ì Á í Á - Å ò ë Å ú é ¢ é ì Å Ã é ë
ferda.mindivan@bilecik.edu.tr

Geliĥ Tarihi/ Received 15.01.2018, Kabul Tarihi/ Accepted 25.06.2018 doi: 10.5505/pajes.2018.39114
ɕ 9 Á ú ą ĥ ą / Corresponding Author ! ò Á ĥ ô ą ò í Á - Á ë Á ì Å ó é / Research Article

v ú

' Ò Á Æ Å î ô ì Å ò ö Å ì Å ò é ¡ ç ò Á Æ Å î ï ë ó é ô ¡ ' / Q ĥ ... Kompozitler, dolgu maddeleri olarak GO ve RGO, matriks olarak ... dolgu-matris ... ' / ö Å 2 ' / ... zellikleri ...

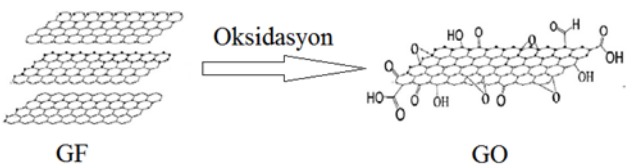
Abstract

Graphene derivatives (graphene oxide-GO, reduced graphene oxide-RGO, multi-layer graphene-MLG, etc.) generally are considered to be extremely significant fillers to improve properties of polymer materials. In this work, the mechanical properties of the composites according to filler type and filler loading were investigated. The composites were prepared using GO, RGO as the fillers and polyvinyl chloride (PVC) as a matrix. The X-ray diffraction (XRD) studies on the composites showed that the GO and RGO layers well-dispersed in polymer matrix. The scanning electron microscopy (SEM) showed that the composite with RGO exhibited smooth and clean surfaces, but the surface images of the composite with GO showed highly porous morphology because of good filler-matrix interaction. The composites at a high GO loading (1% wt.) and a low RGO loading (0.1% wt.) indicated a prominent improvement in the mechanical properties. When compared the unfilled PVC, the tensile strength of the composite with 1 wt.% loading of the GO and 0.1 wt.% loading of the RGO increased by 84% and 4...% respectively. The composite with RGO showed a higher microhardness value compared to that of the composite with GO, but the elongation at break of the composite with RGO decreased because RGO loading increased the brittleness of composite structure.

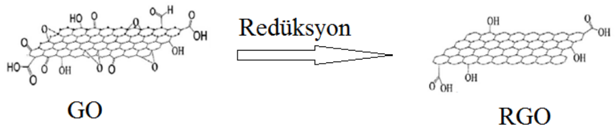
Anahtar kelimeler: Grafen oksit (GO), ¡ ' / Q ĥ grafen oksit (RGO), PVC kompozit, Mekanik özellikler

Keywords: Graphene oxide (GO), Reduced graphene oxide (RGO), PVC composite, Mechanical properties

1 ' é ò é ĥ

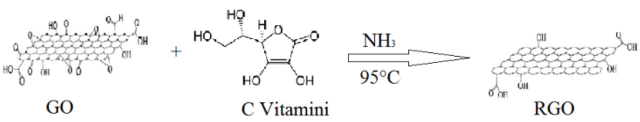


0 ï ì é 6 é î é ì ¡ ð 6 # ò é ... termoplastiklerden biridir ... dolgu maddeleri polimer kompozit ve nanokompozitlerin ... GO sentezi [10]. ... (-COOH) ve ... gibi grafen temelli ...



¤ÅËÉÌ 1. GO'dan RGO sentezi [10].

dÎÄÉÒÇÅÍÅ ÉñÌÅÍÉÎÄÅ ëÏÌÌÁÎÉÌÁÎ ÉÎÄÉÒÇÅÍÅ ïÌÁÎ ÈÉÄÒÁÚÉÎ (N_2H_4) / ÈÉÄÒÁÚÉÎ ÈÉÄÒÁÔ (N_2H_4·H_2O) ... indirgeyicidir [13]. Son zamanlarda bahsedilen kimyasallar yerine, sodyum bikarbonat ($NaCO_3$) [9], etilen glikol [13], ... [11] ...



¤ÅËÉÌ 2. C vitamini ile GO'nun RGO'ya indirgenmesi.

06# ËÏÍÐÏÚÉÔÌÅÒÉÎ ... inÄÉÒÇÅÍÅ ... reaksiyonu ile sentezlenen RGO, PVC ... 3%- ...

2 Deneysel çalışma

"Õ ... '&õ ... 69 mL H_2SO_4 ile 30 dk. buz banyosunda ... H_2O_2 ... 12 sa kurutuldu [17].

Hummers metodu ile ... (NH_3) ... C vitamini ekleneme ... 65 °C'de kurutuldu.

06#/'/ ÖÅ 06#/2'/ ËÏÍÐÏÚÉÔÌÅÒ ... kadar bekletildi. ... 4 (& ... 60 °C ...

Tablo 1. ...

PVC	-
PVC/GO-0.1	0.1
PVC/GO-0.3	0.3
PVC/GO-0.5	0.5
PVC/GO-1	1
PVC/RGO-0.1	0.1
PVC/RGO-0.3	0.3
PVC/RGO-0.5	0.5
PVC/RGO-1	1

... PVC/GO ve PVC/RGO kompozitlerin XRD ... PANalytical, Empyrean marka cihaz ile ... DuraScan 20 (EmcoTest, Germany) model mikrosertlik ... HV0.01 ... kompozit ...

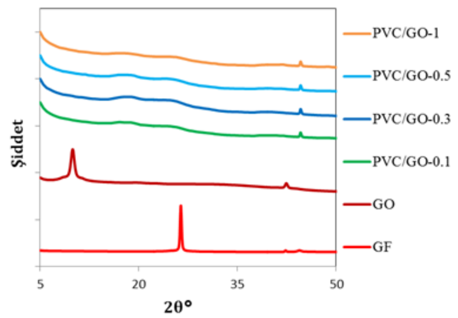
... PVC/RGO-1 ...

3 [illegible]

3.1 XRD analiz [illegible]

[illegible]

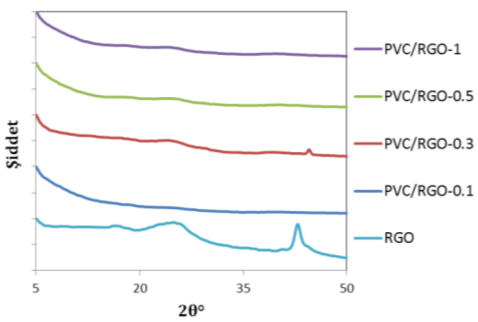
gibi birbirine benzemektedir [illegible]



[illegible] kompozitlere ait XRD paternleri.

[illegible] XRD difraksiyon [illegible] vitamini ile [illegible]

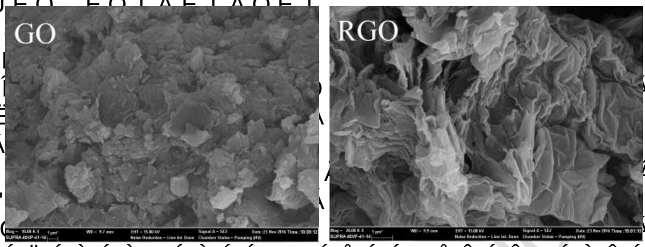
dolgu maddesinin polimer matrikste her oranda [illegible]



[illegible] kompozitlerine ait XRD [illegible] paternleri.

3.2 FE-SEM

[illegible]

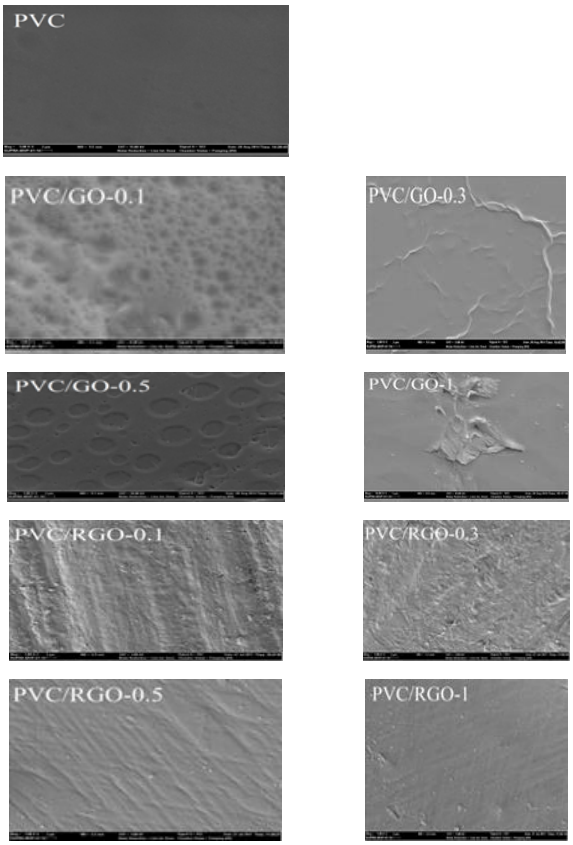


[illegible]

[illegible]	[illegible] (% atom)
GO	46.78
RGO	24.03

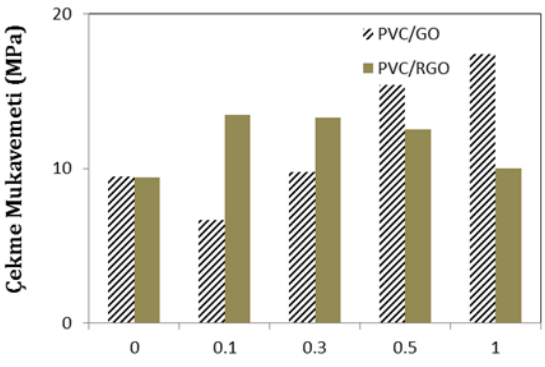
[illegible] PVC [illegible] bu [illegible] dolgu [illegible] kompozitlere [illegible] bilinmektedir [24].

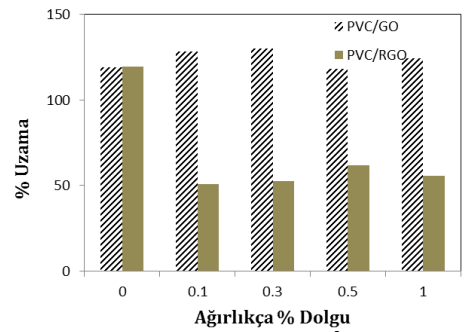
Düzeltilmemiş Sürüm - Uncorrected Version



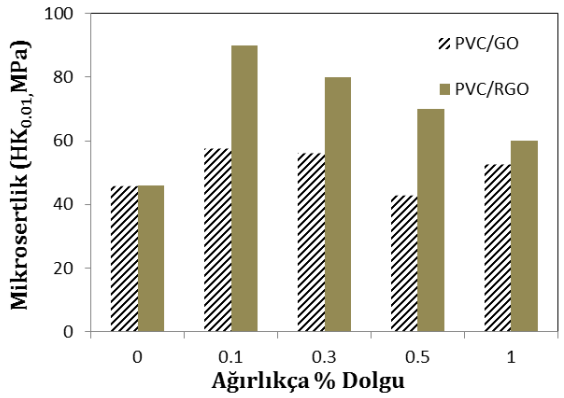
¤ÅËÉÌ ψd 06#7'/ ÖÅ 06#72'/ ËÌÐÏÚÉÔÌÅÒÉ ÇÝÒÌÎÔÌÅÒ ÍÅÔÏ

3.3 Mekanik karakterizasyon





Uncorrected version



¤ ÅËÉÌ ρρq ' / ÖÅ 2 ' / ÉëÅÒÉøÉÎÅ ÄÅÉôÎ É Í É 8

4 3 Ï Î Õë

4 Ì Í ÁÎÁÌÉÚ ÓÏÎÕëÌÁÒą ÄÌÇÕ ÍÁÄÄÅÄÅ ËÏÌÐÏÚÉÔÌÅÒÏÂÁÓÅÄ ÂÁħÁÓą Ì ą ÂÉÒ ħÅËÅÌÁÅ ÚÁÓą ÓÏÌÕÔÉÏÎ ÏÆ ÇÒáÐÈÉÔÅ ÏØÉDE (ÅÒ ÉËËÉ ÄÌÇÕ ÍÁÄÄÅÄÓÉ ÉÌÅ ÈÁÚą ÓÏÌÕÔÉÏÎ ÏÆ ÇÒáÐÈÉÔÅ ÏØÉDE ÓÏÎÕëÌÁÒą ÂÅÎÚÒÌÉË ÇĘÓÔÒÌÅÌÅÒ ÔÁÂÁËÁÌÁÒÍą ÁÎą ÔÉËËÉ ÓÏÌÕÔÉÏÎ ÏÆ ÔÈÅ ÍÉØÅÄ ÓÏÌÕÔÉÏÎ ÉÓ ÁËËÏ ÇĘÌÌÍÌÎÇÔÏÎ8 ' / ÉëÅÒÅÎ ËÏÌÐÒÕÐÏÌÅÒ ÇĘÌÌÍÌÎÇÔÏÎ ÄÁøą ÌÍÁÍą ħ ËÌëÌË ÇĘÚÅÎÅ ' / ÉÌÅ 06# õÎÉÎ 2 ' / õr matriksdeğu ÇĘÕÅ ÄÉÅÁ ÇÌÅ ÅÔËËÌÅħÉÍÉÎÅ ÓÁÈÉÐ ÌÌÄÕËÌÁÒą Î ą 2 ' / ÉëÅÒÅÎ ËÌÍÐÒÚÉÔÌÅÒÉ ÄÌÇÕÕÚ (h 06# ÕÚÅ ÇĘÕÅ ħ ÓÁÅÚÁ ÖÅ Þτς ÌÒÁÎÌÁÒą ÎÄÁ ëÅËÍÅ ÍÕËÁÒÁÌÁÒÌÁÒÉÌÉÌÁÒÕÇą ÂÅÌÉÒÌÅÎÉħÔÉÒ8 ' / ÉëÅÒÅÎ ËÌÍÐÒÚÉÔÌÅÒÉ ÄÌÇÕÕÚ ÂÉÒ ÍÁÄÄÅÄÇÅÚÌÅÎÍÅÚ ÉËÅÎħ 2 ' / ÉëÅÒÅÎ ÁÚÁÌÍÁ ÇĘÚÌÅÎÍÉħÔÉÒ8 3ÅÒÔÌËË ÓÌÐ ËÌÍÐÒÚÉÔÌÅÒ ÄÌÇÕÓÕÚ ÐÌÌÉÍÅÒÅ ÇĘÇÁÐÁÚÌÅÒÉ ËÌÍÐÒÚÉÔÌÅÒ ÉÓÅ Þωψ ÄÁÈÁ ÓÁÒÒÔ ÓÁÒÒÔÌÉË ÈÅÍ ÄÅ Þ ÕÚÁÇÇÁÓÕÕÚ ÕÕÚ ÕÕÚ ËÌÍÐÒÚÉÔÌÅÒÉ ÄÌÇÕÕÚ ÇÒÁÆÅÎ ÂÁÓÅÄ ÇÒÁÆÅÎ ÓÕÒÆÁÇÅ ÍÏÄÉÆÉÅÄ ÇÒÁÆÅÎ ÏØÉDE/ÔÉÔÁÎ ÄÉØÉDE ÎÁÎÏÃÏÍÐÏÓÉÔÅ ÆÏÒ ÈÉÇÈ ÐÅÒÆÏÒÍÁÎÃÅ ÓÕÐÅÒÃÁPACITORS8

5 Kaynaklar

[1] - ÁÒÁÔÈÅ $3ħ * ÏÓÈÉ 038 Ð#ÈÁÒÁÇÁÓÏÇLU ÆÉÌÌÁÒÁ ÓÕÕÕÄÅÅÅ wood flour-PVC composites: Morphological and thermal properties. *Journal of Applied Polymer Science*, 111(1), 90-96, 2009.

[2] Janajreha I, Alsh ÒÁÈÁ - ħ : ÁÍÚÁÍ 38 Ð-ÅÅÈÁÌÉÁÌÉÁÓÏÇLU of PVC plastic waste streams from cable industry: A case study. *Sustainable Cities and Society*, 18, 13-20, 2015.

[3] 7ÁÎÇ (ħ 8ÉÅ 'ħ &ÁÎÇ -ħ 9ÉÎÇ :ħ 4ÉÎÇ 9ħ ÅÎÇ 98 Ó%ÌÅÂÒÉÃÁÌ and mechanical properties of antistatic PVC films containing multi-ÌÁÙÅÒ ÇÒÁÐÈÅÎÅ. *Composites Part B*, 79, 444-450, 2015.

[4] Hu J, Jia X, Li C, Ma Z, Zhang G, Sheng W, Zhang X, Wei Z. Ó%ÆÆÅÃÔ ÏÆ ÉÎÔÅÒÆÁÃÉÁÌ ÉÎÔÅÒÁÃÔÉÏÎ ÏÆ ÇÒáÐÈÅÎÅ derivatives and poly(vinyl chloride) upon the mechanical properties of ÇÒáÐÈÅÎÅ/ÐÏÌÙ(ÖÉÎÙÌ ÃÈÌÏÒÉÄÅ) ÃÏÍÐÏÓÉÔÅÓ. *Journal of Materials Science*, 49( ), 2943-2951, 2014.

[5] $ÁÓÈÉÎÕËÅ + ħ * Ï-mechanical properties of ÇÒáÐÈÅÎÅ/ poly (vinyl chloride)/graphene oxide as high performance ÎÁÎÏÃÏÍÐÏÓÉÔÅÓ. *Polymer Testing*, 34, 211-219, 2014.

[6] Zhu Y, Murali S, Cai W, Li X, Suk JW, Potts JR, Ruoff RS. Ó'ÒÁÐÈÅÎÅ ÁÎÄ 'ÒÁÐÈÅÎÅ /ØÉÄÅą ÁÎÄ !ÐÐÌÉÃÁÔÉÏÎÓ. *Advanced Materials*, 22, 3906-3924, 2010.

[7] +ÉÍ &ħ #ÏÎÅ ,*ħ (ÕÁÎÇ *8 Ó'ÒÁ and Two-Dimensional !ÓÓÅÍÂÌÉÅÓ. *Advanced Materials*, 22, 1954-1958, 2010.

[8] *ÏÓÈÉ '-ħ $ÅÓÈÍÕËÈ +8 Ó/ÐÉÍ Graphene Oxide2 ÉÎÆÏÒÍÅÄ 06# *Journal of Electronic Materials*, 43(4), 1161-1165, 2014.

[9] *ÉÎ 9ħ (ÕÁÎÇ 3ħ :ÈÁÎÇ Efficient Method to Produce Graphene for Electrochemical Capacitors From Graphene Oxide Using Sodium Carbonate !Ó ! 2ÅÄÕÃÉÎÇ. *Applied Surface Science*, 268, 541-546, 2013.

[10] Wang H, Yuan X, Wu Y, Huang H, Peng X, Zeng G, Zhong H, ,ÉÁÎÇ *ħ Graphene-Based Materials: fabrication, characterization and application for the decontamination of wastewater and wastegas and hydrogen storage. *Advances in Colloid and Interface Science*, 195-196, 19-40, 2013.

[11] Singh V, Joung D, Zhai L, Das S, Khondaker SI, Seal S. Ó'ÒÁÐÈÅÎÅ "ÁÓÅÄ -ÁÔÅÒÉÁÌÓ. *Progress In Materials Science*, 56, 1178-1271, 2011.

[12] $ÁØÁÇ, ÁÎÄ ÔÈÅ ÉÎÆÌÕÅÎÃÅ ÏÆ ÇÒáÐÈÅÎÅ ÏØÉDE ÏÎ ÔÈÅ ÍÅÃÈÁÎÉÃÁÌ ÐÒÏÐÅÒÔÉÅÓ ÏÆ ÐÏÌÙ(ÖÉÎÙÌ ÃÈÌÏÒÉÄÅ)/ÇÒáÐÈÅÎÅ ÏØÉDE ÃÏÍÐÏÓÉÔÅ ÆÉÌÍÓ. *Polymer Testing*, 34, 211-219, 2014.

[13] Ë ÆÏ Ð ÕÉÔÆÁÏÅ 9ħ ÉÓÁ ÄÅÚ 7ÁÇ :ħ reduced graphene oxide/polypyrrole composite for supercapacitor electrodes. *Electrochimica Acta*, 88, 519-525, 2013.

[14] Kamisan AL Kamisan AS, Ali RMd, Tunku Kudin TI, Hassan ÇĘÕÁÕÌÅÎÅħÉÎÇ 8ħ Þ0ÁÅÚÁ ÓÁ Þτ 8ο 2 ' / ÉëÅÒÅÎ ËÌÍÐÒÚÉÔÌÅÒÉ ÄÌÇÕÕÚ (h 06# ÕÚÅ ÇĘÕÅ ħ ÓÁÅÚÁ ÖÅ Þτς ÌÒÁÎÌÁÒą ÎÄÁ ëÅËÍÅ ÍÕËÁÒÁÌÁÒÌÁÒÉÌÉÌÁÒÕÇą ÂÅÌÉÒÌÅÎÉħÔÉÒ8 ' / ÉëÅÒÅÎ ËÌÍÐÒÚÉÔÌÅÒÉ ÄÌÇÕÕÚ ÂÉÒ ÍÁÄÄÅÄÇÅÚÌÅÎÍÅÚ ÉËÅÎħ 2 ' / ÉëÅÒÅÎ ÁÚÁÌÍÁ ÇĘÚÌÅÎÍÉħÔÉÒ8 3ÅÒÔÌËË ÓÌÐ ËÌÍÐÒÚÉÔÌÅÒÉ ÄÌÇÕÓÕÚ ÐÌÌÉÍÅÒÅ ÇĘÇÁÐÁÚÌÅÒÉ ËÌÍÐÒÚÉÔÌÅÒÉ ÉÓÅ Þωψ ÄÁÈÁ ÓÁÒÒÔ ÓÁÒÒÔÌÉË ÈÅÍ ÄÅ Þ ÕÚÁÇÇÁÓÕÕÚ ÕÕÚ ÕÕÚ ËÌÍÐÒÚÉÔÌÅÒÉ ÄÌÇÕÕÚ ÇÒÁÆÅÎ ÂÁÓÅÄ ÇÒÁÆÅÎ ÓÕÒÆÁÇÅ ÍÏÄÉÆÉÅÄ ÇÒÁÆÅÎ ÏØÉDE/ÔÉÔÁÎ ÄÉØÉDE ÎÁÎÏÃÏÍÐÏÓÉÔÅ ÆÏÒ ÈÉÇÈ ÐÅÒÆÏÒÍÁÎÃÅ ÓÕÐÅÒÃÁPACITORS8

[15] Wang Y, ÓÈÅÎ Þ, ÇÕÁÎ ÁØÉÁÎ, ÌÉ ÈÕÁ, ÈÕÁÎÇ ÈÁÏ, ÚÈÏÕ ÈÏÎÇ. ÅÌÅÃÔÒÏÃÈÅÍÉÃÁÌ ÓÙÎÔÈÅÓÉÓ ÏÆ ÇÒáÐÈÅÎÅ ÂÁÓÅÄ ÍÁÔÅÒÉÁÌÓ via a green reduction of graphene oxide in tea solution and ÉÔÓ ÁÐÐÌÉÃÁÔÉÏÎ ÉÎ ÓÕÐÅÒÃÁPACITORS. *ACS Applied Materials & Interfaces*, 3, 4127-4133, 2011.

[16] Fernandez-Merino MJ, Guardia L, Paredes JI, Villar-Rodil S, Solís-Fernandez P, Martinez-Alonso A, Tascon JMD. Ó6ÅÔÁÉÎ # ÉÓ ÁÎ ÉÄÅÁÌ ÓÕÂÓÔÒÁÔÅ ÆÏÒ ÇÒáÐÈÅÎÅ ÂÁÓÅÄ ÅÌÅÃÔÒÏÄÅÓ. *Journal of Physical Chemistry C*, 114, 6426-6432, 2010.

[17] (ÕÉÌÁÓÕ 73ħ /ÆÅÁÉÁÎ 2%8 ÓÕÓÁ ÏØÉDE. *Journal of the American Chemical Society*, 80(6), 1339, 1958.

[18] Gurunathan S, Han JW, Kim E, Kwon DN, Park JK, Kim JH. Ó%ÎÁÎÏÓÈÅÅÔ ÇÒáÐÈÅÎÅ ÂÁÓÅÄ ÍÁÔÅÒÉÁÌÓ ÆÒÏÍ ÇÒáÐÈÅÎÅ ÏØÉDE ÂÙ ÍÅÄÉáÔÅÄ ÓÙÎÔÈÅÓÉÓ. *Journal of Nanobiotechnology*, 12(41), 2014.

[19] Vadukumpully S, Paul J, Mahanta N, Valiyaveettil S. Ó&ÌÅØÉÂÌÅ ÃÏÍÐÏÓÉÔÅ ÇÒáÐÈÅÎÅ composite thin films with high mechanical strength and ÈÉÇÈ ÃÏÎÄÕÃÔÉÖÉÔÙ. *Carbon*, 49, 1199-1205, 2011.

[20] Bora C, Bharali P, Baglari S, Dolui SK. Ï-ÎÁÎÏÃÏÍÐÏÓÉÔÅ and conductive reduced graphene oxide/polyester resin composite films with improved mechanical strength, ÔÈÅÒÍÁÌ ÓÔÁÂÉÌÉÔÙ ÁÎÄ ÅÌÅÃÔÒÉÃÁÌ ÃÏÎÄÕÃÔÉÖÉÔÙ. *Composites Science and Technology*, 87, 1-7, 2013.

[21] Safarpour M, Khataee A, Vatanpour V. Ó68 Ó4ÈÅÎ nanocomposite reverse osmosis membrane modified by reduced graphene oxide/TiO2 with improved ÄÅÓÁÌÉÎÁÔÉÎÇ ÐÅÒÆÏÒÍÁÎÃÅ. *Journal of Membrane Science*, 489, 43-54, 2015.