Packaging Plastics and Nanotechnology

Prof. Dr. Yusuf Z. Menceloğlu,
Faculty of Engineering and Natural Sciences
Materials Science and Nanoengineering
Sabancı University
Founder Member
Nanotego Co.

PAGEV Sponsored

Polymer Processing School

PAGEV
TÜRK PLASTİK SANAYİCİLERİ ARAŞTIRMA, GELİŞTİRME VE EĞİTİM VAKFI

Two days Polymer Processing Course will be held on May 25-26, 2019, the topics are

Raw Materials and Rheology on May 25th

Rheology- C Macosco -Univ Minnesota and G Fuller- Stanford Univ

Compounding -I Manas -Case Vestern Univ

Process Technologies on May 26th

Injection Molding - M Çakmak Purdue Univ, Y Ülçer, Ravago and M Bilgili-Consultant

Rubber Processing - A I Isaev - Univ of Akron

Extrusion- D Kalyon- Stevens Inst of Technology

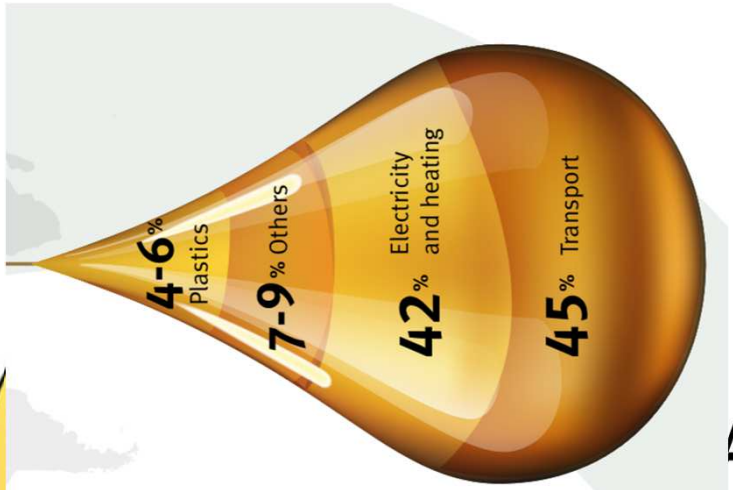
Composite Processing - C Altan-Univ Oklahoma

Sabancı Üniversitesi

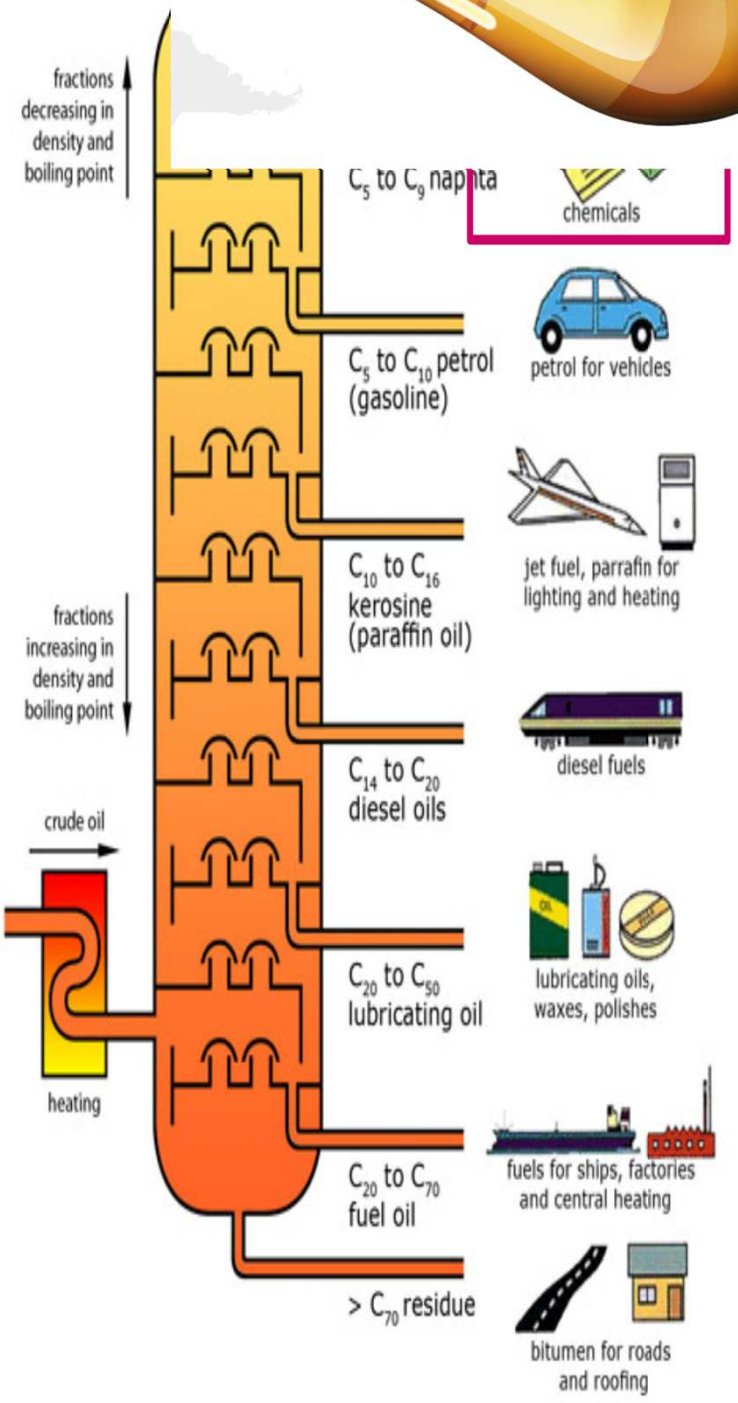
THE NEW PLASTICS ECONOMY: RETHINKING THE FUTURE OF PLASTICS

- The New Plastics Economy — Rethinking the future of plastics (2016, http://www.ellenmacarthurfoundation.org/publications).
- Plastics – the Facts 2017
  - An analysis of European plastics production, demand and waste data
- American Chemistry Council (https://plastics.americanchemistry.com/default.aspx)

Sabancı Üniversitesi



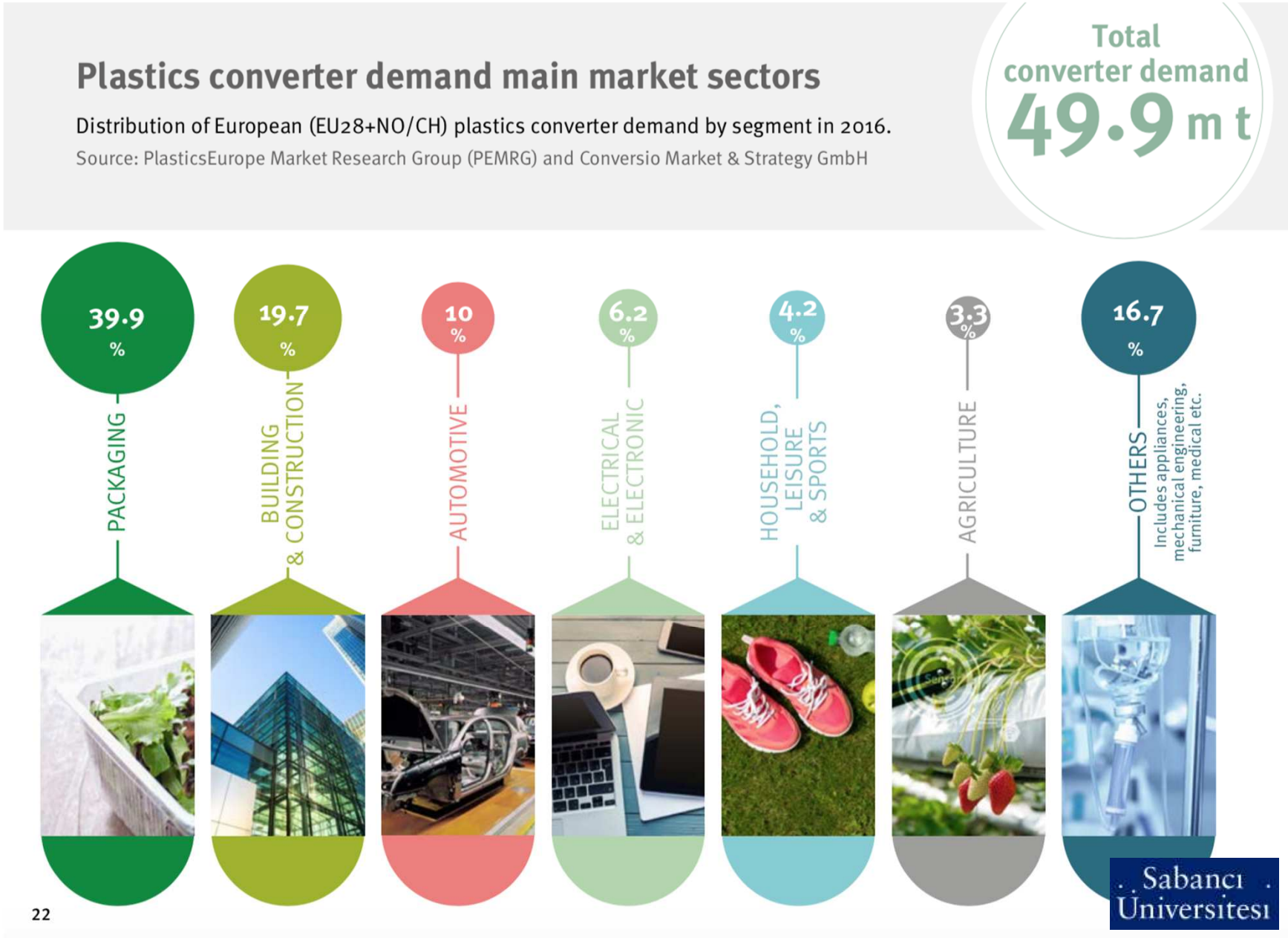
4% from crude oil



crude oil 100%

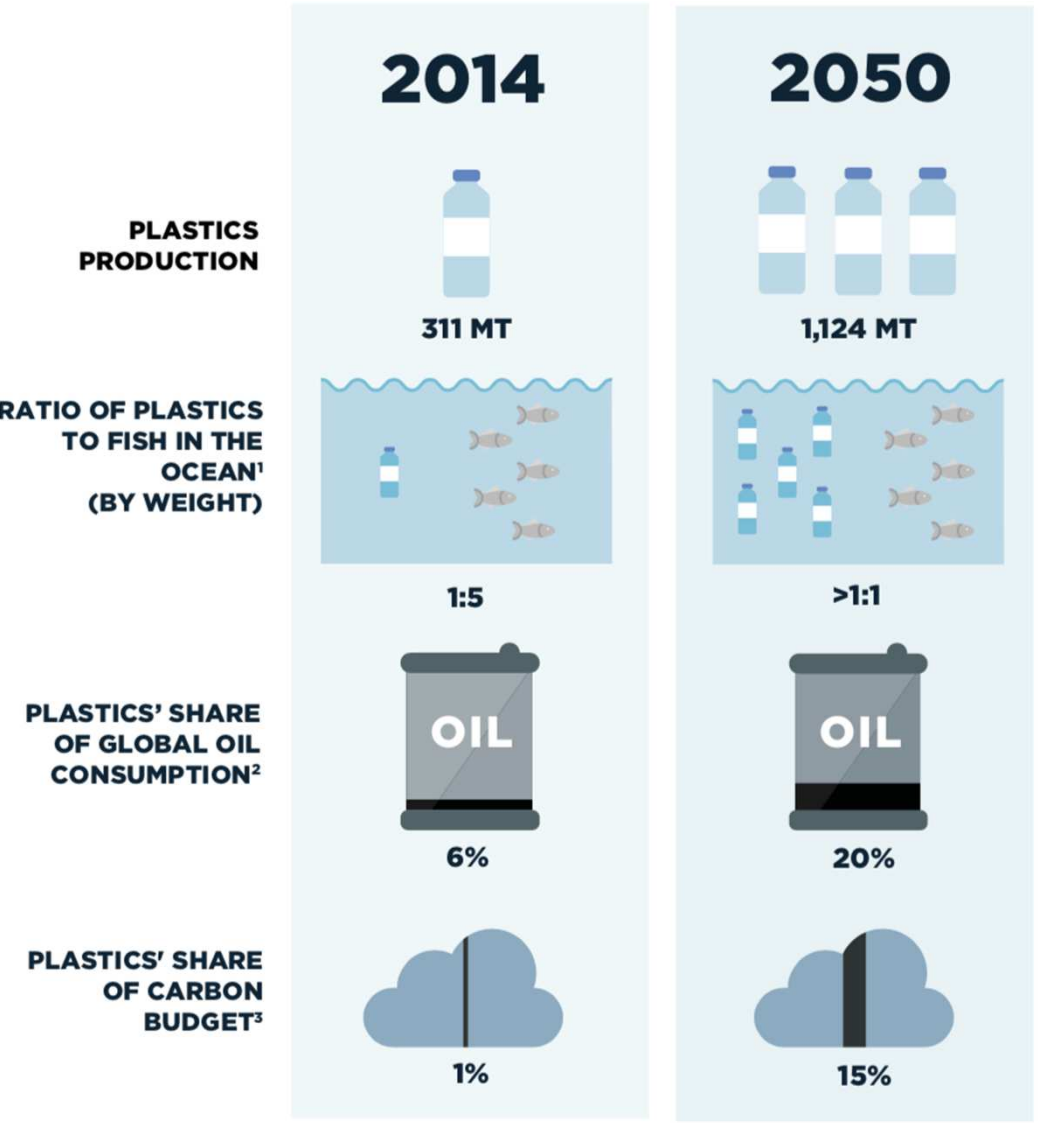
PACKAGING

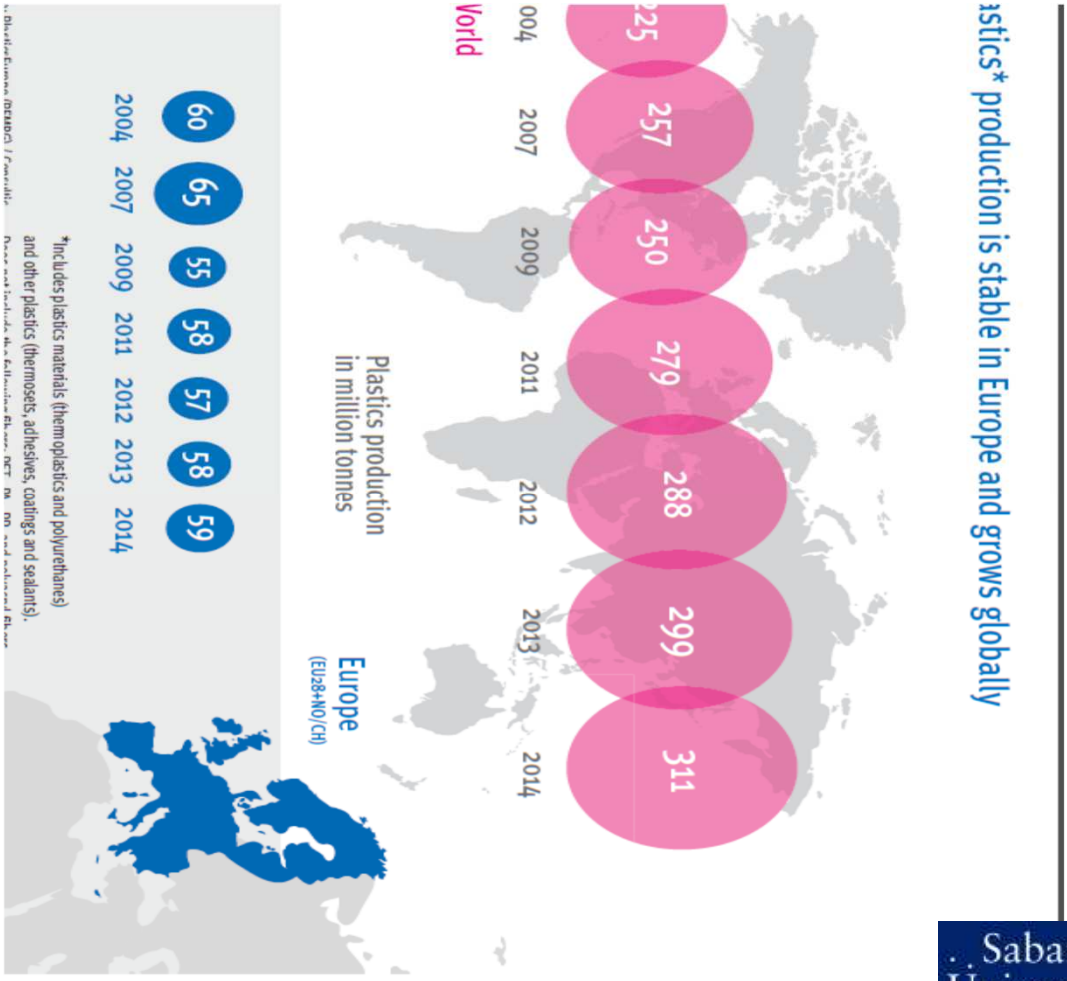
- Its Primary Role is to contain, protect and preserve
- Delivery System for Products
- Environmental impact is much, much less than that of the damage that would arise without it



Sabancı Üniversitesi

Europe Plastic Demand





Sabancı Üniversitesi

Examples of How Plastics Are Helping Reduce the Environmental Footprint of Consumer Goods

Using plastics instead of alternative materials makes vehicles lighter so they use less fuel

323 million liters (89 million US gallons) of gasoline and diesel are saved over the lifetime of vehicles in North America[1]

Which means a saving to the North American economy of

$2.4 billion

in environmental costs over the lifetime of cars sold in 2015[2]

This represents net environmental savings of $162 per car in North America[3]

Modern plastic packaging for sirloin steak can **cut food waste by almost half** compared to conventional plastic packaging

This is a reduction of **34% waste to 18% waste**

And a net environmental saving of **$606 per tonne** of beef sirloin sold in North America

And **over $2.18 million** in environmental savings to the North American economy for every additional 1% of sirloin steak sold in modern plastic packaging

Notes/Assumptions
1. Fuel savings over 13 year operating life of gasoline and diesel passenger vehicles sold in North America in 2015.
2. Environmental cost savings include avoided life cycle water consumption, greenhouse gas and air, land and water pollutant emissions associated with fuel production, distribution and combustion.
3. Assumes 13.8 million vehicles sold in North America in 2015.

All dollar values are in USD
Source: Trucost Plastics and Sustainability: *A Valuation of Environmental Benefits, Costs and Opportunities for Continuous Improvement*

Reducing Food Waste Through Plastic Packaging

Food waste presents significant financial and environmental impacts. But plastic food packaging has the ability to help prevent food waste, save money, and reduce environmental effects. Plus it helps keep foods fresh and sanitary.[1]

Preventing Food Waste

Foods without packaging are thrown out uneaten more often than foods protected by packaging.

Think about the items in a typical refrigerator. Fruit and veggies tightly sealed in protective plastic are more likely to reach the dinner table than unpackaged fruit and veggies.

The strong correlation between food packaging and waste is backed by research.

U.S. Fresh Food Sales: Percentage Sold Packaged vs Wasted (%)[2]

By safeguarding food with plastic packaging, it stays fresh longer and has less risk of going to waste.

Stays Fresh Longer

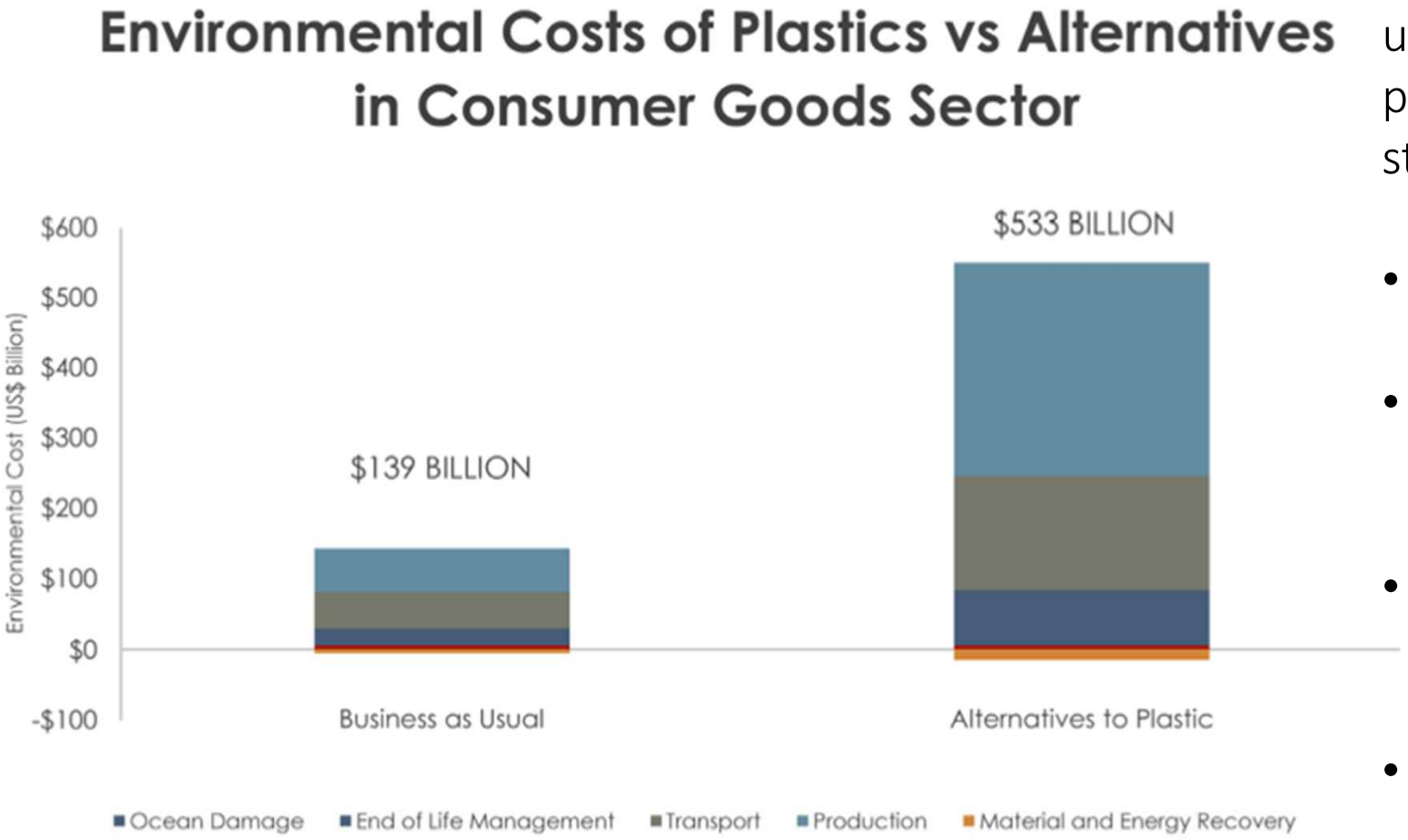
Cucumbers **11 days longer**

Bananas **21 days longer**

Beef **26 days longer**

[1] Study: "Quantifying the Value of Packaging as a Strategy to Prevent Food Waste in America," AMERIPEN, 2018. http://c.ymcdn.com/sites/www.ameripen.org/resource/resmgr/files/AMERIPEN-WhitePaper-FoodWast.pdf

[2] Adapted: Euromonitor International, 2017 & ReFED 2016



use and disposal of plastic packaging across the six studied areas per year saves:

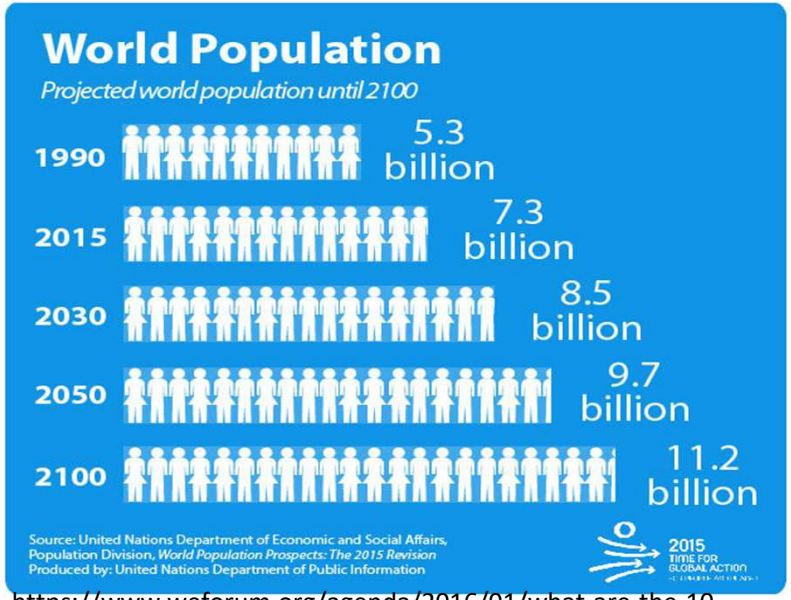
- enough energy to fuel 18 million passenger vehicles,
- enough water to fill 461,000 Olympic swimming pools,
- waste equivalent to the weight of 290,000 Boeing 747 airplanes, and
- the acidification potential of 292,000 railcars of coal.

Allyson Wilson ACC (202) 249-6623

Sabancı Üniversitesi

Food Loss and Waste

- 4 billion tons of food are produced to feed 7.6 billion people
- 30-50% of consumers are suffering from loss before reaching.
- 2 billion tons of food loss per year
- Economic losses ($ 750 billion)
- Climate change (carbon footprint ...)
  - 3.3-5.6 billion tons of greenhouse gas
- Water reserves are depleted
  - loss of water up to the Nile River
- Loss of soil and biodiversity
  - 2 million m^2 area
- Time, Labor and Energy Loss



https://www.weforum.org/agenda/2016/01/what-are-the-10-biggest-global-challenges/

Sabancı Üniversitesi

- Packaging protects food from environmental influences such as
  - heat, light,
  - presence or absence of moisture,
  - oxygen, pressure,
  - enzymes, spurious odors, microorganisms, insects, dirt and dust particles,
  - gaseous emissions, and so on
- Prolonging shelf life involves
  - retardation of enzymatic, microbial, and biochemical reactions
    - temperature control;
    - moisture control;
    - addition of chemicals
    - removal of oxygen;
    - or a combination of these with effective packaging

- Oxygen scavengers
- Carbon dioxide absorbers and emitters
- Ethylene absorbers and adsorbers
- Antimicrobials
- Moisture control agents
- Temperature control: self-heating and cooling (PCM)
- Flavor and odor absorbers
- High chemical barrier material innovations
- Sustainable food packaging

Sabancı Üniversitesi

Nanotechnology has the potential to transform food packaging

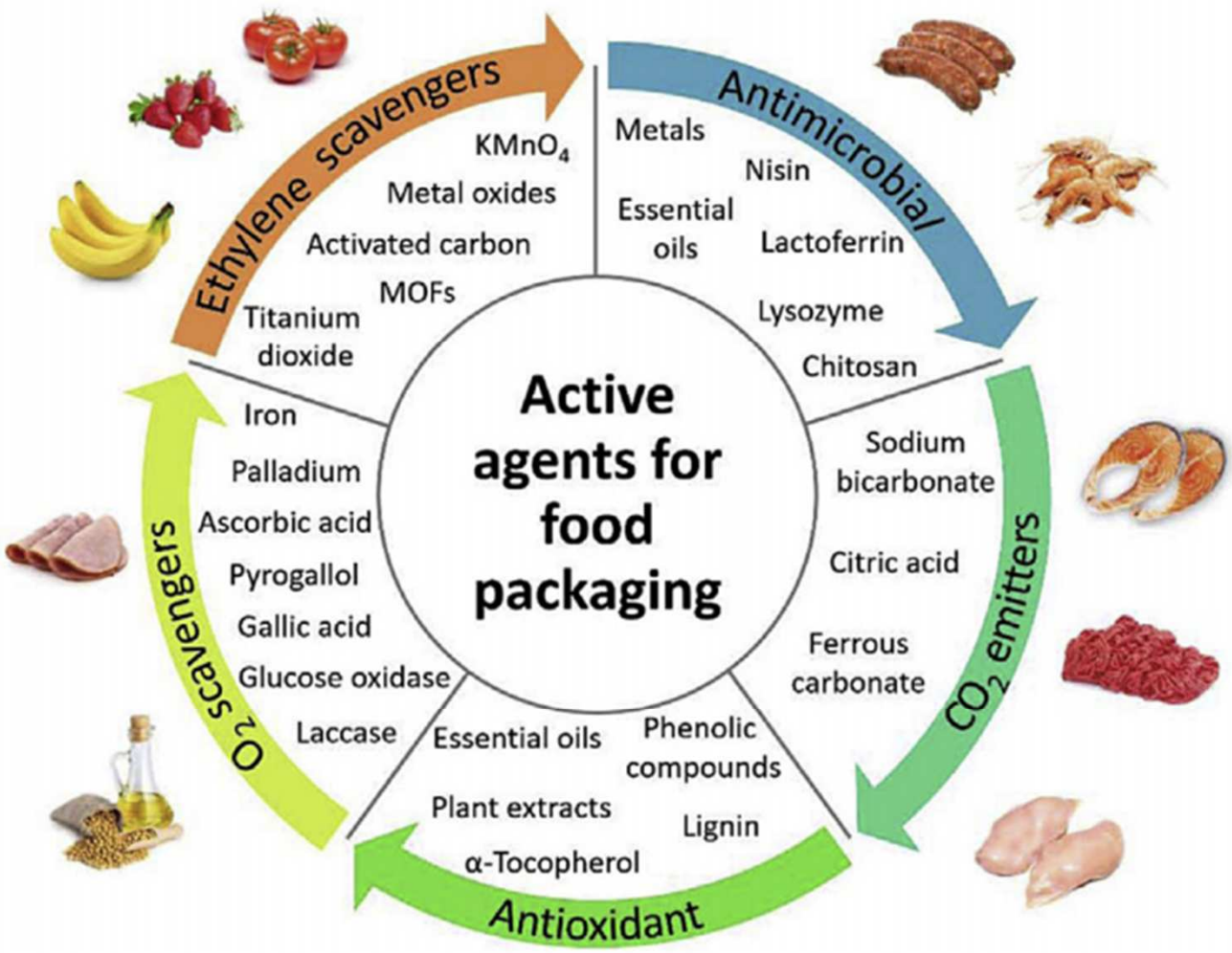
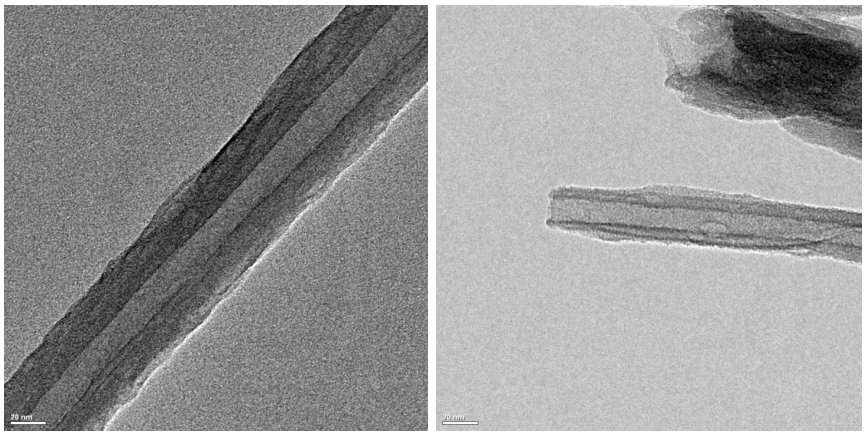
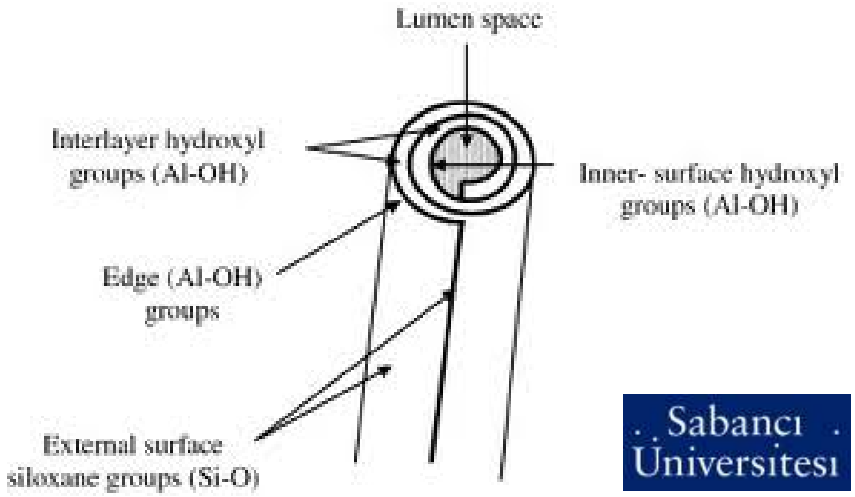


Fig. 2. Active agents for active food packaging.

Trends in Food Science & Technology 80 (2018) 212–222





Sabancı Üniversitesi

Composite

HNTs are nanotubes with high L/D ratio and possess a low density of surface hydroxyl groups compared with other silicates. Consequently it is expected that HNTs will be promising as reinforcing fillers for polymer materials

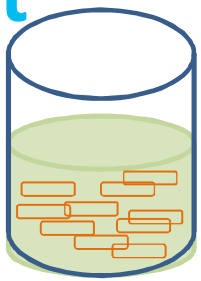
- Multiple Function
  - Mechanical (strength and modulus)
  - Antimicrobial
  - Absorbent
  - Antistatic
  - Barrier
  - Thermal balance
- Light Weight
- Low Gauge

Responsible Consumption and Production

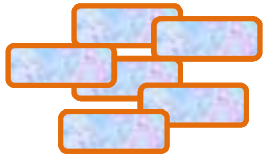
Sabancı Üniversitesi

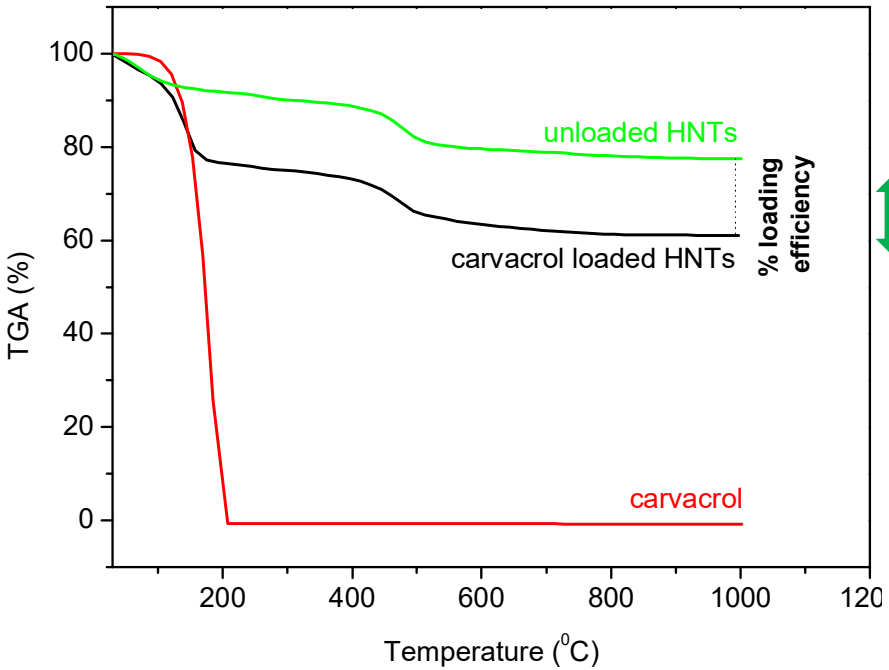
Carvacrol Loaded Halloysite Nanotubes, as Antimicrobial and Antioxidant

Carcvacrol/HNT mixture



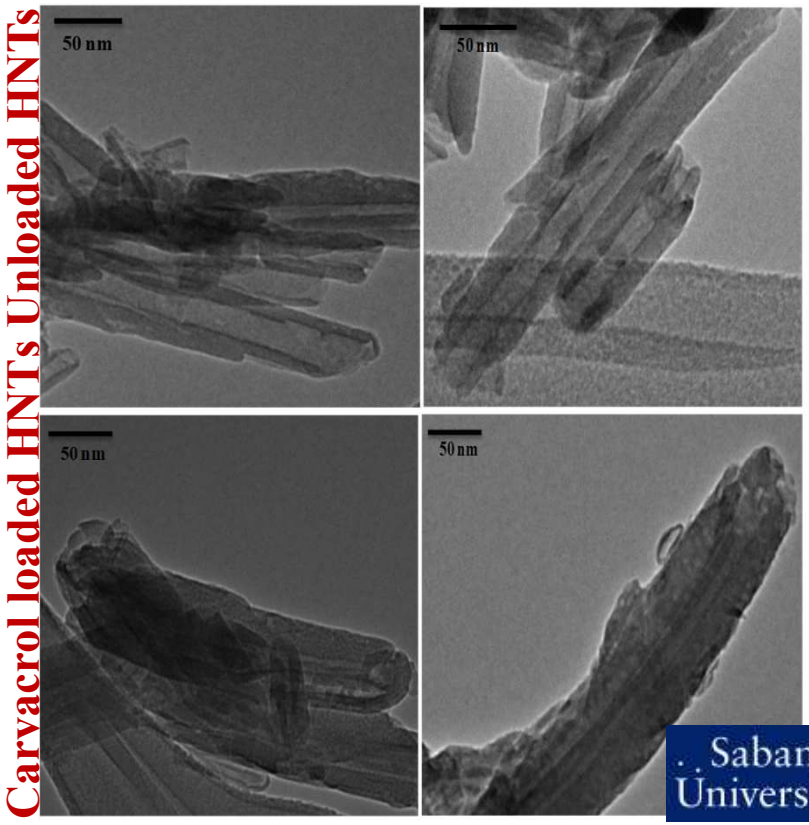
1) Ultrasonication
2) Vacuum application
3) Removing excess carvacrol
4) Washing to remove surface adsorbed carvacrol
5) Drying into powder





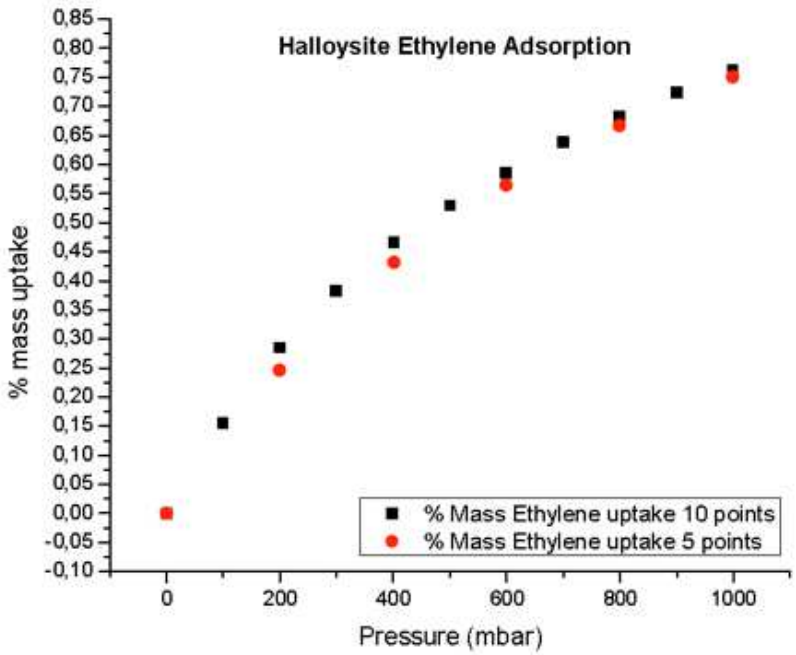
17.40 ± 3.05 %

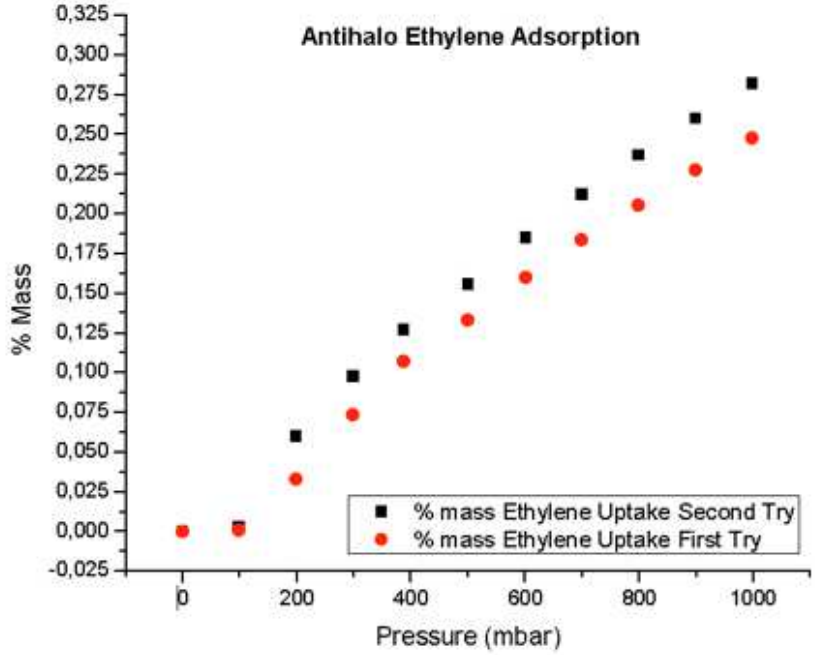
Ünal *et al.*, Progress in Organic Coatings, 2016, 101, 253-261.



Sabancı Üniversitesi

Ethylene adsorption capacity of Halloysite Nanotubes

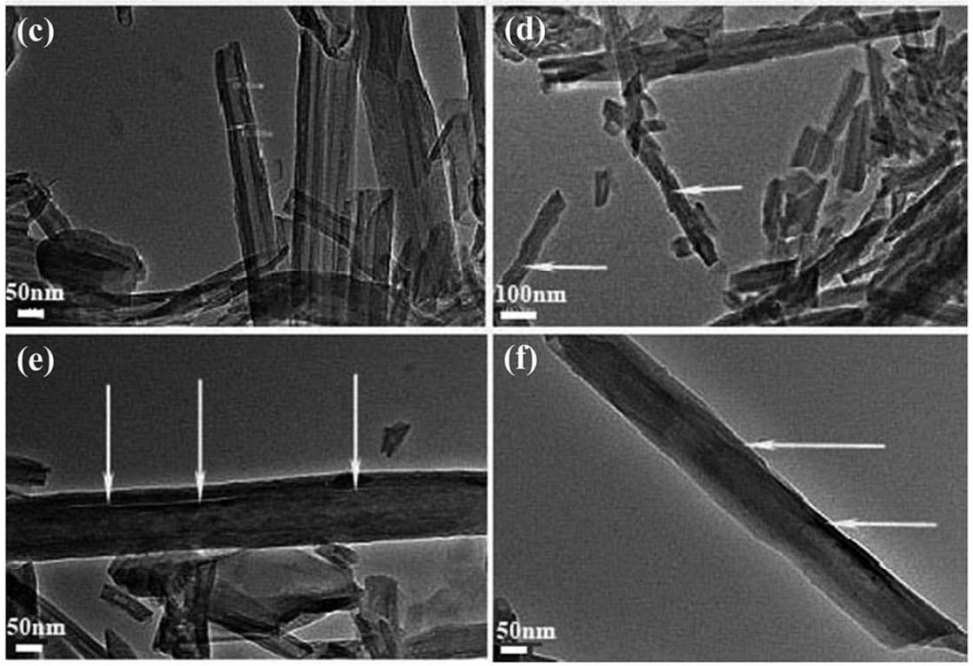




Halloysite adsorption experiments were performed by using Hiden Isochema Intelligent Gravimetric analyzer (IGA-003) with ethylene gas

Regular Ethylene scavengfers capacity is around 2500 microliter/g, functionalized HNT varies between 3000-8000 microliter/g

PCMs are passive thermal energy storage materials used in the thermal packaging industry to maintain a temperature-sensitive product within the manufacturer's required temperature range during all transportation phases



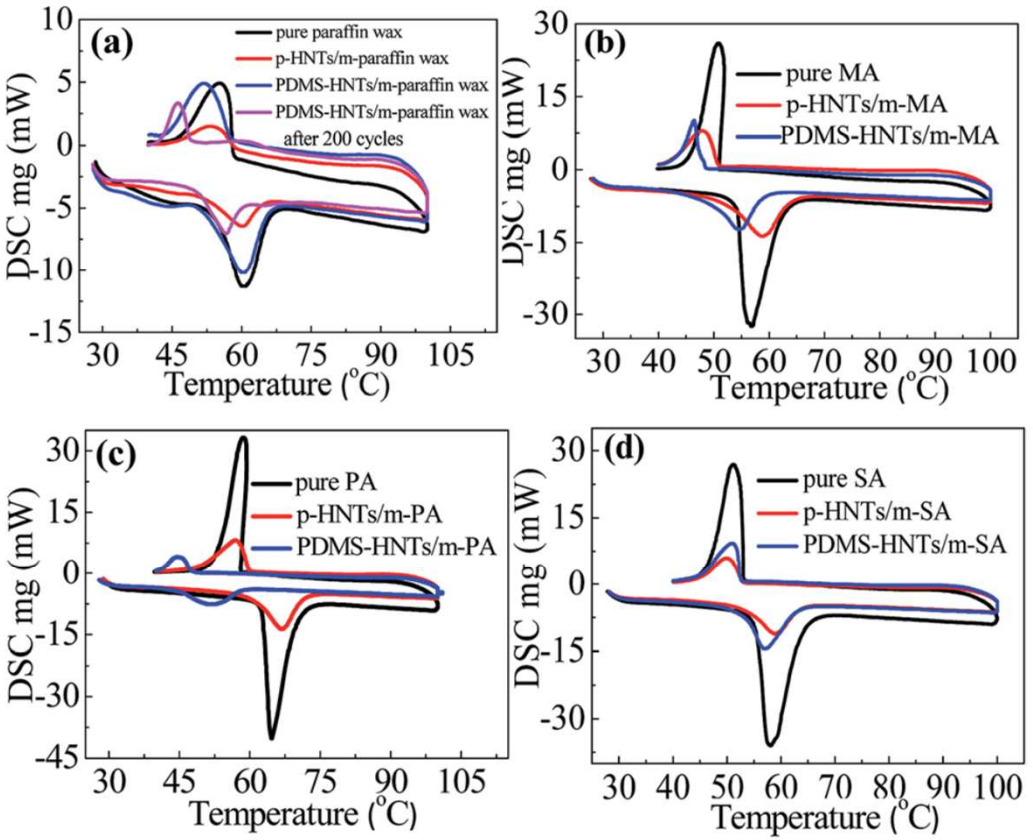


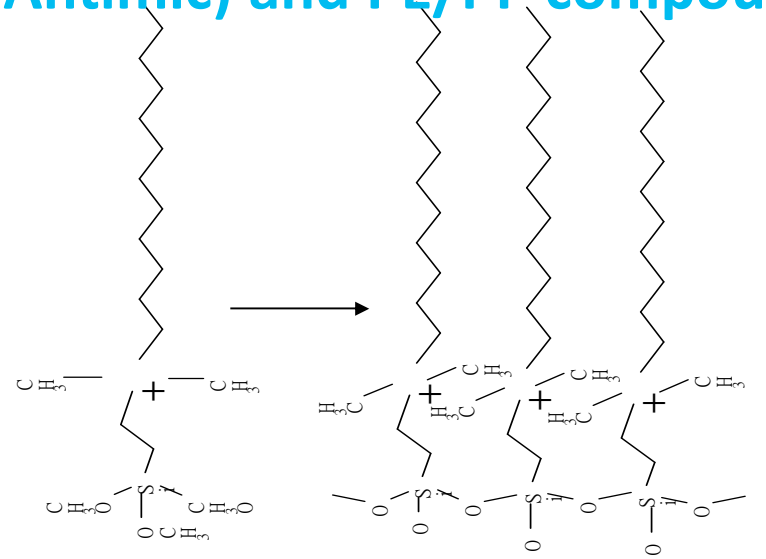
Fig. 1 SEM images of (a) p-HNTs and (b) PDMS–HNTs. TEM images of (c) PDMS–HNTs, (d) PDMS–HNTs/m-paraffin wax composite, (e) PDMS–HNTs/m-MA composite and (f) PDMS–HNTs/v-MA composite. Scale bar: (a, b, d) 100 nm and (c, e, f) 50 nm.

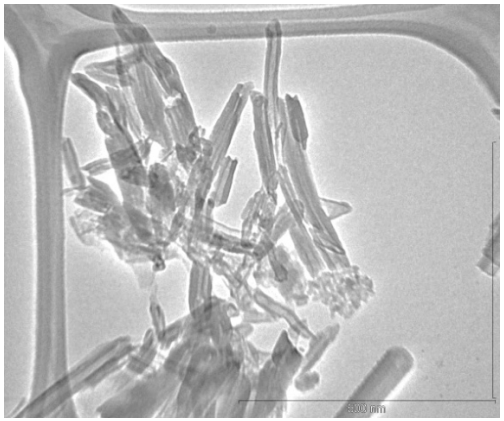
RSC Adv., 2016, 6, 19669–19675

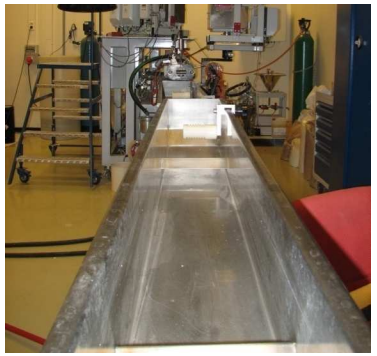
Energy removal to lower [1kg] of liquid water from (+5°C) to (+2°C) = 12.6 kJ x 20=240
Energy removal to lower [1kg] of liquid PCM (+5°C) to frozen PCM (+2°C) = 233.3 kJ

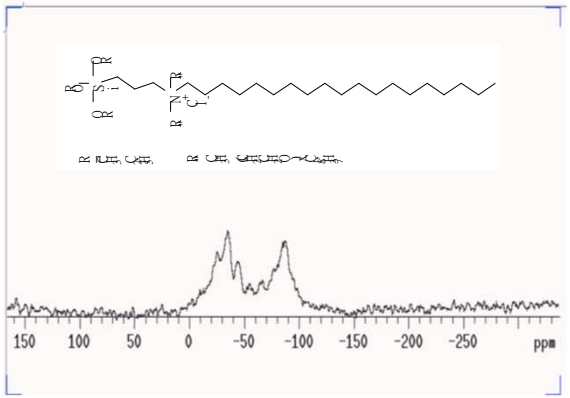
Sabancı Üniversitesi

HNT coated w [3-(trimethoxysilyl)-propyl, alkyldimethylammonium chloride] (Antimic) and PE/PP compound

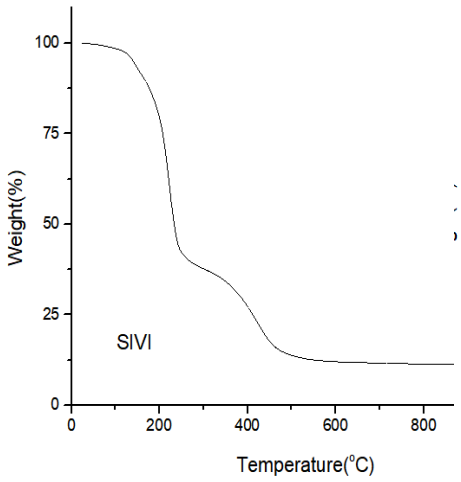


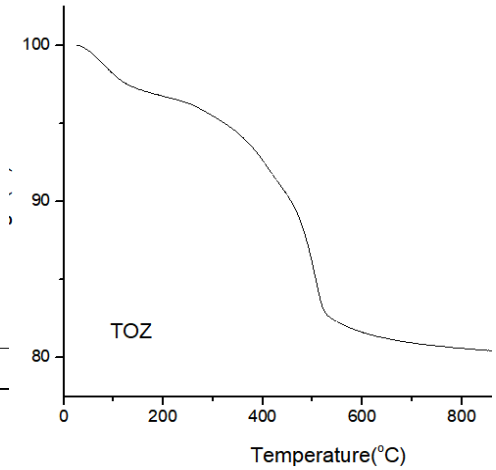


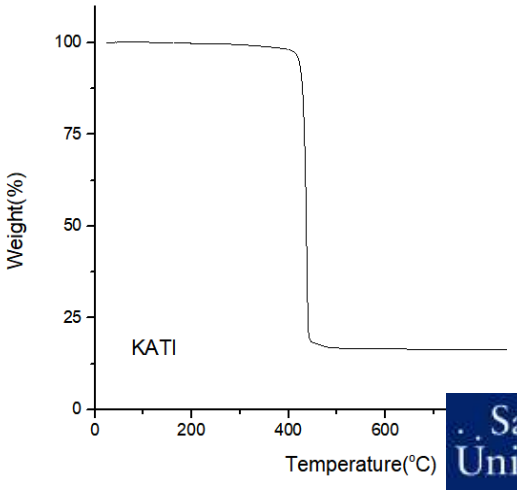




Si^{29}-NMR (Single Pulse-MAS)







Sabancı Üniversitesi

Antimic-Powder PE Nanocomposite Film Preparation and Properties

- 20 % wt Antimicrobial powder used for Masterbatch preparations
- 1, 3, 4, 5 % wt masterbatch used for poliethylene blown/cast film production
- Polypropylene-injection molding
- Polyurethane-coatings and injection molding
- Polyamide-injection molding and film
- Polyesters-blown molding, injection molding, film etc…

Sabancı Üniversitesi

Mechanical properties of PE film w Antimic coated HNT Powder

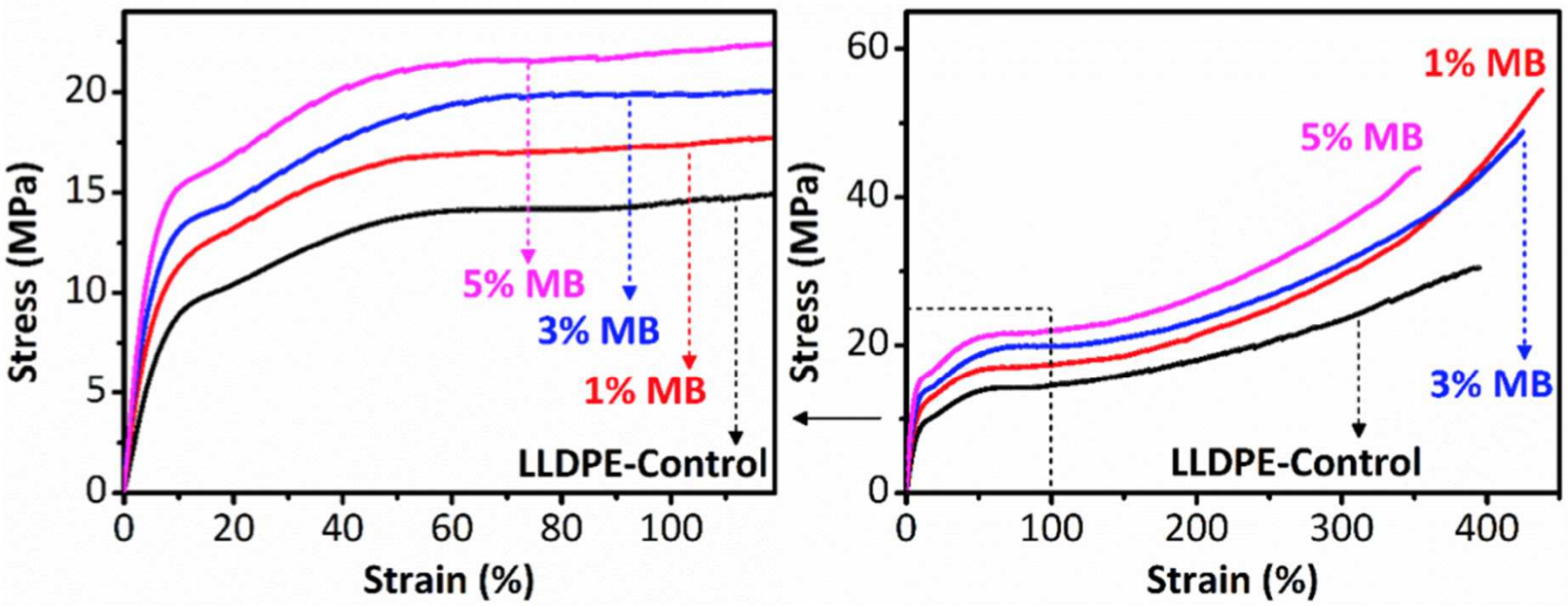


Figure 2. Stress-strain curves of LLDPE/MB film samples (right) along with expanded linear region (left).

Sabancı Üniversitesi

% Increase Mechanical Properties Machine and Transverse Direction

Mechanical properties of LLDPE/MB film samples (machine direction)

Sample	E (MPa)	$\sigma_{100\%\ strain}$ (MPa)	σ_{max} (MPa)	ε (%)	W (MJm^{-3})
LLDPE-Control	109±8	14.5±0.7	30.4±1.9	390±20	75±7
1% MB	243±6	17.3±0.4	54.4±2.1	440±10	114±6
3% MB	277±13	19.9±0.6	48.8±1.7	420±10	113±9
5% MB	312±11	22.0±0.7	43.9±1.2	350±10	95±8

Mechanical properties of LLDPE/MB film samples (transverse direction)

Sample	E (MPa)	$\sigma_{100\%\ strain}$ (MPa)	σ_{max} (MPa)	ε (%)	W (MJm^{-3})
LLDPE-Control	125±22	9.01±0.3	15.6±2.9	407±104	46±12
1% MB	144.6±27	8.27±0.2	10.6±1.6	275±40	25±6
3% MB	166.4±40	8.27±0.1	9.87±2.5	281±131	27±17
5% MB	172.6±11	8.47±0.1	10.0±0.9	292±21	28±3

Sabancı Üniversitesi

Antimicrobial Performance of PE film w Antimic Powder- JIS Z 2801:200 method

S. Aureus

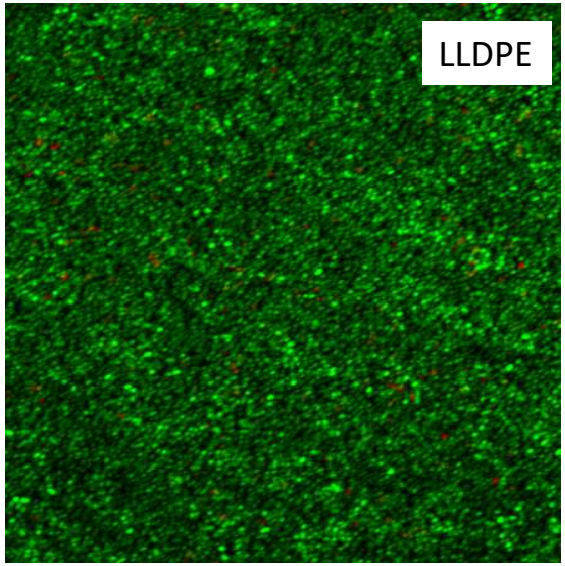
Örnek	*S. aureus* ATCC 6538 Mikrobiyal yük *kob/ml	% Öldürme Oranı	R değe
	24.saat	**24.saat**	**24.saa**
% 1 MB Uygulanmış Malzeme	$1.25x10^2$	99.967	**3.49**
	$1.00x10^2$	99.974	**3.59**
	$0.8x10^2$	99.979	**3.68**
% 3 MB Uygulanmış Malzeme	7.5x10	99.980	**3.71**
	50	99.987	**3.89**
	$1.20x10^2$	99.969	**3.51**
% 5 MB Uygulanmış Malzeme	$1.10x10^2$	99.971	**3.54**
	$9.90x10^2$	99.746	**2.59**
	$5.78x10^3$	98.517	**1.82**
Kontrol	$2.70x10^5$ (0. Saat)	____	____
	$3.90x10^5$ (24. Saat)		
Bakteri Kontrol	$2.0x10^5$		

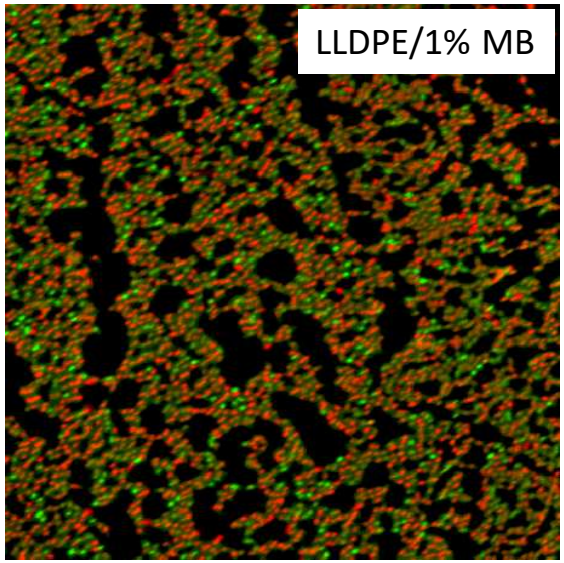
E. Coli

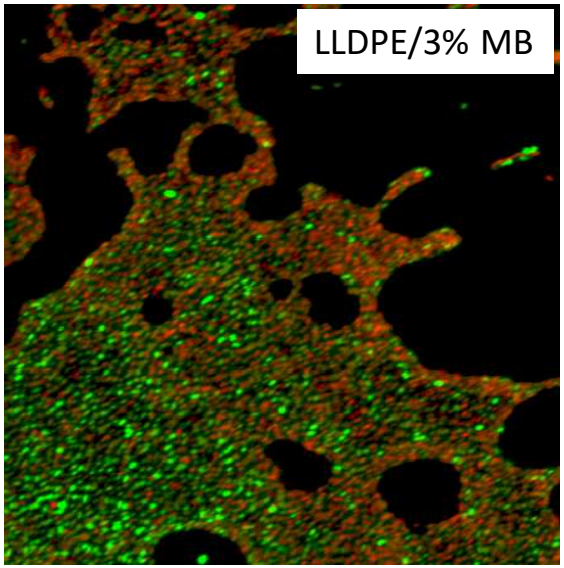
Örnek	*E. coli ATCC 8739* Mikrobiyal yük *kob/ml	% Öldürme Oranı	R değe
	24.saat	**24.saat**	**24.saa**
% 1 MB Uygulanmış Malzeme	$1.24 x10^4$	99.436	**2.24**
	$2.77x10^3$	99.874	**2.89**
	$6.65x10^3$	99.697	**2.51**
% 3 MB Uygulanmış Malzeme	$1.01x10^3$	99.954	**3.33**
	$2x10^3$	99.909	**3.04**
	$7x10^2$	99.968	**3.49**
% 5 MB Uygulanmış Malzeme	$2.13x10^5$	99.318	**1.01**
	$1.30x10^4$	99.409	**2.22**
	$2.10x10^4$	99.045	**2.02**
Kontrol	$5.41x10^5$ (0. Saat)	____	____
	$2.20x10^6$ (24. Saat)		
Bakteri Kontrol	$4.0x10^5$		

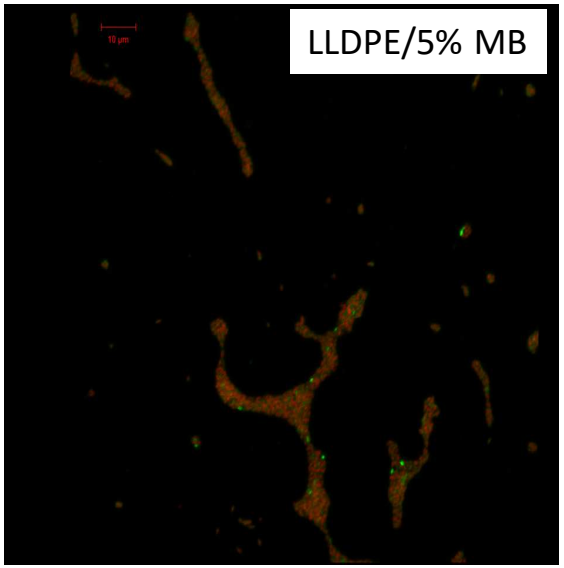
Sabancı Üniversitesi

Films incubated with *Pseudomonas aeruginosa* for 48 h









Sabancı Üniversitesi

Controlled Release

As the lumens of HNTs could be loaded with drugs or other chemicals, HNTs are expected to be ideal materials for controlled or sustained release of drugs, other bioactive molecules or other additives

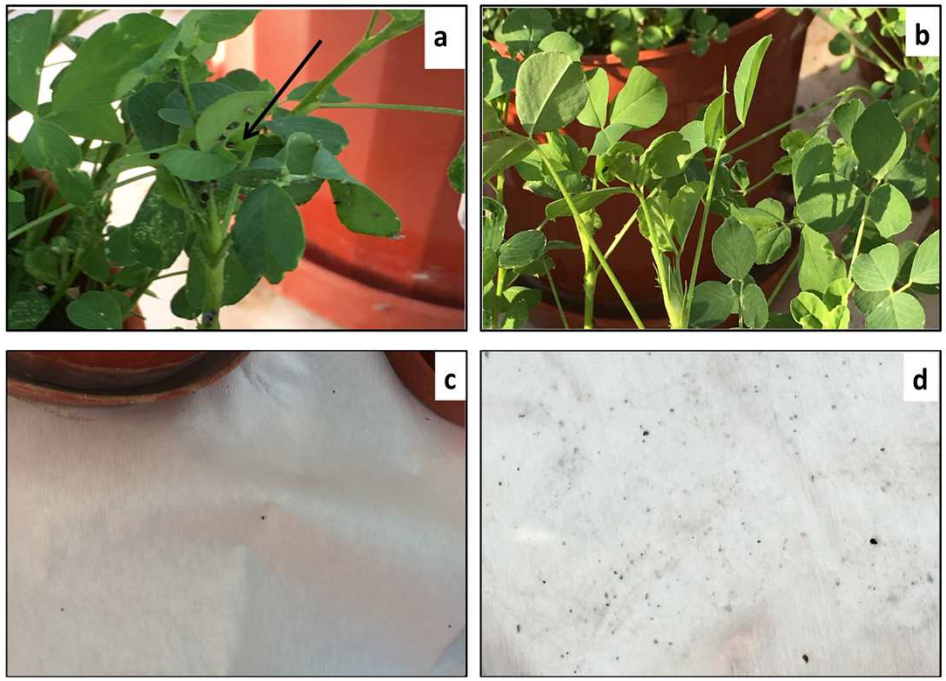
Food security and Sustainable agriculture

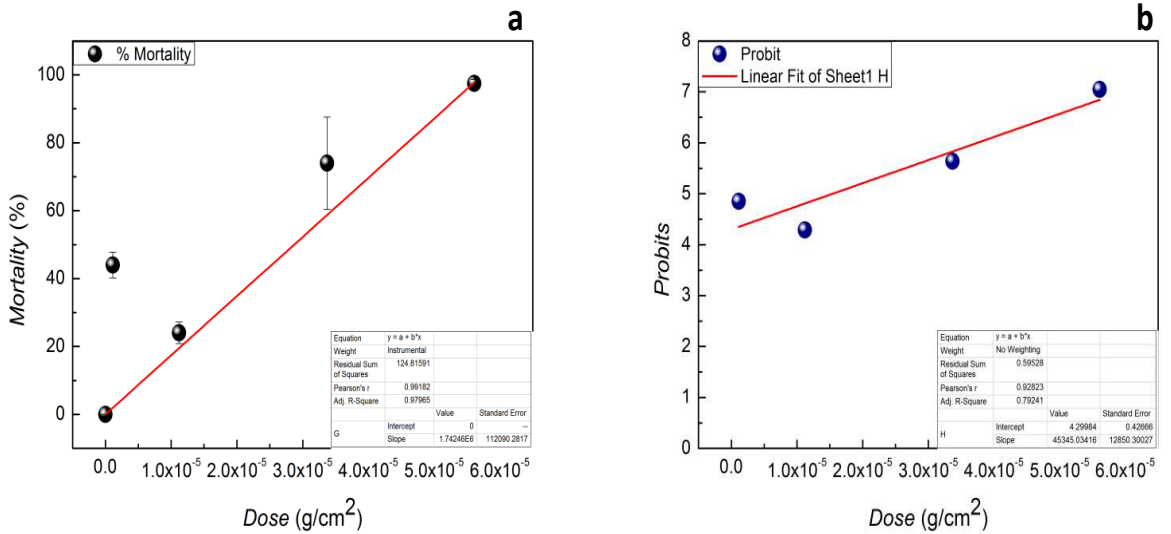
- Antifouling
- Antibacterial
- Antifungal
- Pesticides

Zero Hunger

Sabancı Üniversitesi

There are 600,000 da greenhouse, 200,000 da low tunnel cultivation of it,
Total of 7 million tons of vegetable production, 1/3 low tunnel production
10 kg of pesticides are used per da means 2 tons of pesticides and 0.1% of it reaches the target,
Approx 60,000 tons of greenhouse cover film needed 0.3-1% insecticide loaded HNT sufficient

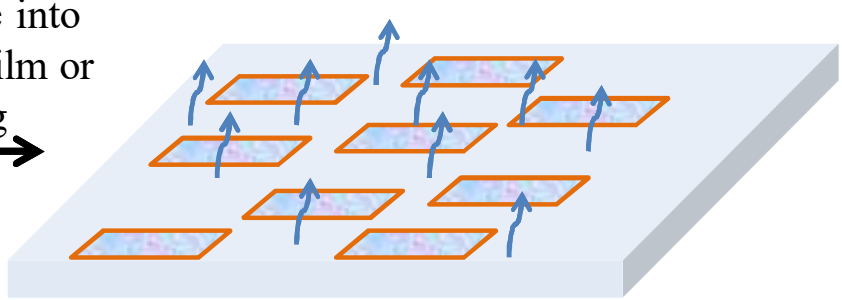




(a) Insect mortality graph, (b) Probit line responses. % values represent mortality levels that are transformed to probit for statistical analysis.

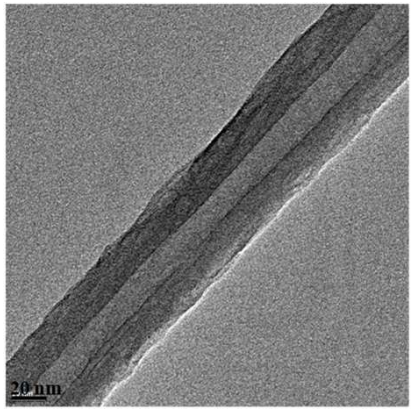
Multi-Functional Polymeric Nanocomposites using Halloysite Nanotubes

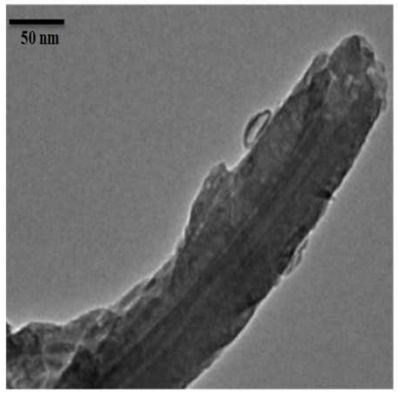
Incorporate into polymeric film or coating



Natural, nontoxic nanocontainer loaded with **natural antibacterial agent**

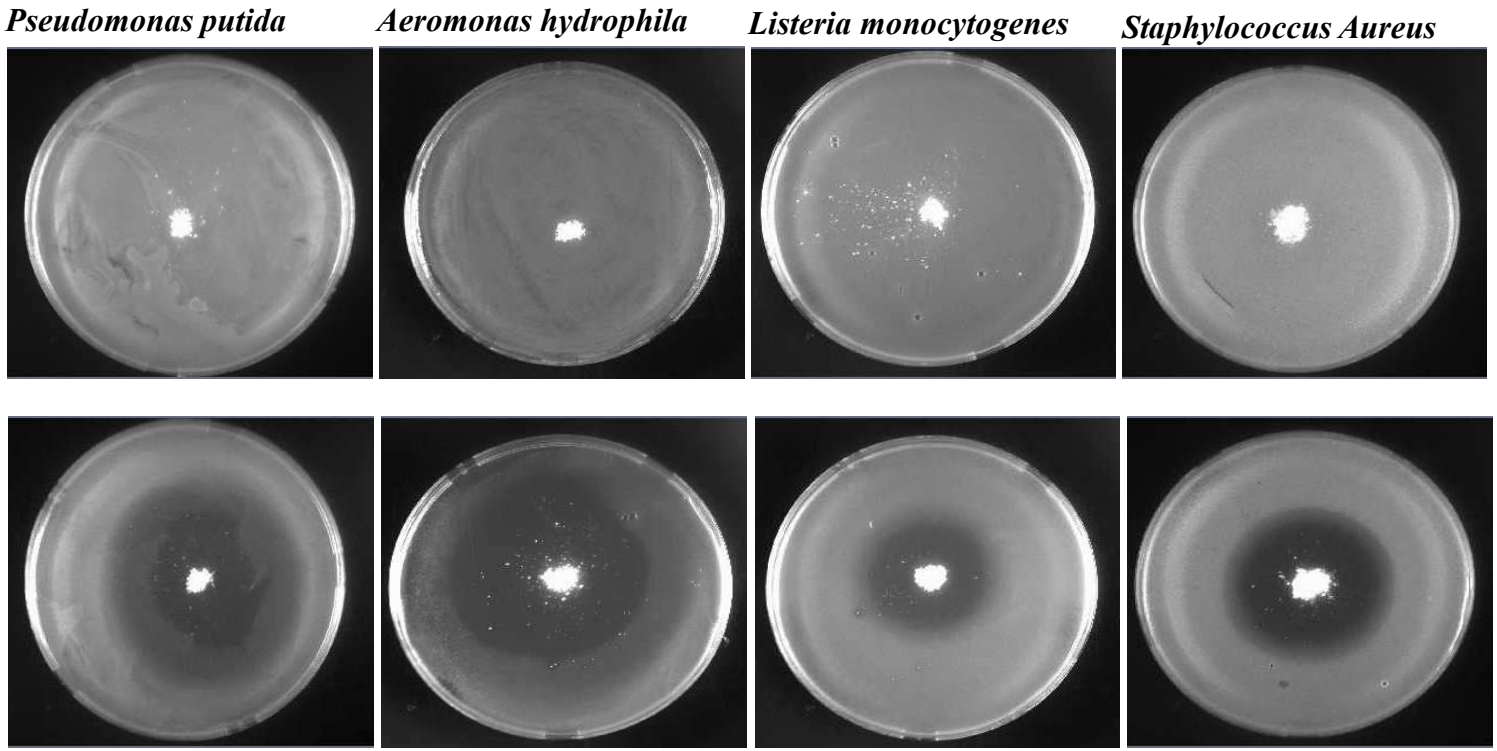
Polymeric coating or film with enhanced anti-bacterial and/or barrier properties





Sabancı Üniversitesi

Antibacterial Activity of Carvacrol Loaded HNTs



Sabancı Üniversitesi

Antimicrobial Performance of PE film w Carvacrol Powder-JIS Z 2801:200 method

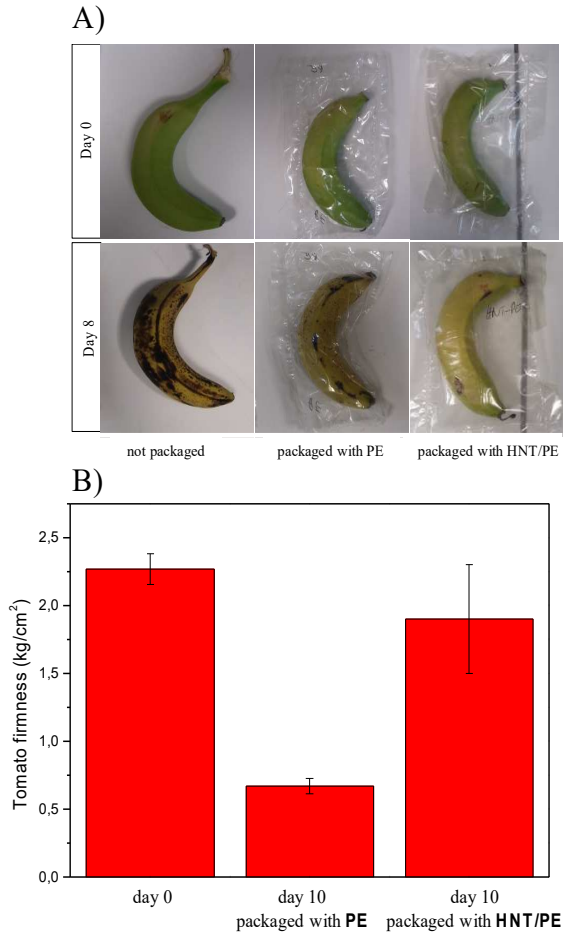
S. Aureus

Örnek	*S. aureus* ATCC 6538 Mikrobiyal yük *kob/ml	% Öldürme Oranı	R değe
	24.saat	**24.saat**	**24.saa**
% 2 Carvacrol Uygulanmış Malzeme	< 10	99.997	**4.59**
	< 10	99.997	**4.59**
	< 10	99.997	**4.59**
% 5 Carvacrol Uygulanmış Malzeme	$6.15x10^3$	98.423	**1.80**
	< 10	99.997	**4.59**
	$2.40x10^2$	99.938	**3.21**
% 10 Carvacrol Uygulanmış Malzeme	< 10	99.997	**4.59**
	< 10	99.997	**4.59**
	< 10	99.997	**4.59**
% 25 Carvacrol Uygulanmış Malzeme	$9.50x10^2$	99.756	**2.61**
	7x10	99.982	**3.74**
	8x10	99.979	**3.68**
Kontrol	$2.70x10^5$ (0. Saat)	——	——
	$3.90x10^7$ (24. Saat)		
Bakteri Kontrol	$2.0x10^5$		

E. Coli

Örnek	*E. coli ATCC 8739* Mikrobiyal yük *kob/ml	% Öldürme Oranı	R değe
	24.saat	**24.saat**	**24.saa**
% 2 Carvacrol Uygulanmış Malzeme	$1.20 x10^3$	99.945	**3.26**
	4.0x10	99.998	**4.74**
	$4.45x10^2$	99.979	**3.69**
% 5 Carvacrol Uygulanmış Malzeme	$2.80x10^3$	99.872	**2.89**
	$2.33x10^4$	98.940	**1.97**
	$3.5x10^2$	99.984	**3.79**
% 10 Carvacrol Uygulanmış Malzeme	< 10	99.999	**5.34**
	< 10	99.999	**5.34**
	< 10	99.999	**5.34**
% 25 Carvacrol Uygulanmış Malzeme	$1.40x10^5$	93.636	**1.19**
	$1.35x10^3$	99.938	**3.21**
	$1.00x10^3$	99.954	**3.34**
Kontrol	$5.41x10^5$ (0. Saat)	——	——
	$2.20x10^6$ (24. Saat)		
Bakteri Kontrol	$4.0x10^5$		

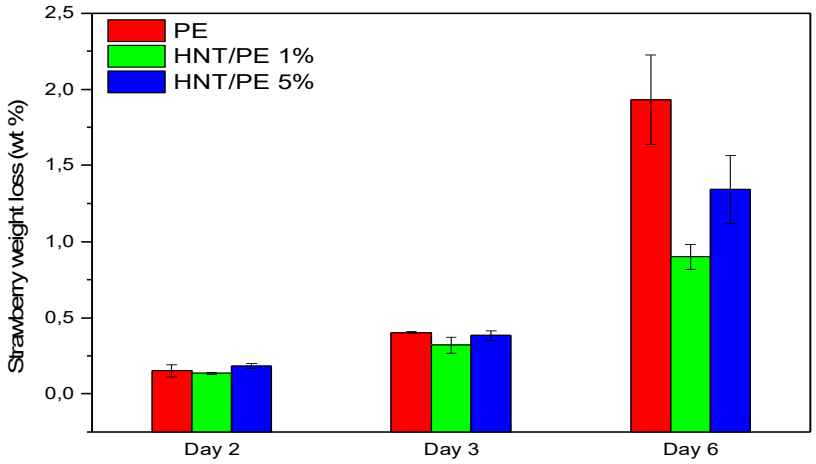
Sabancı Üniversitesi



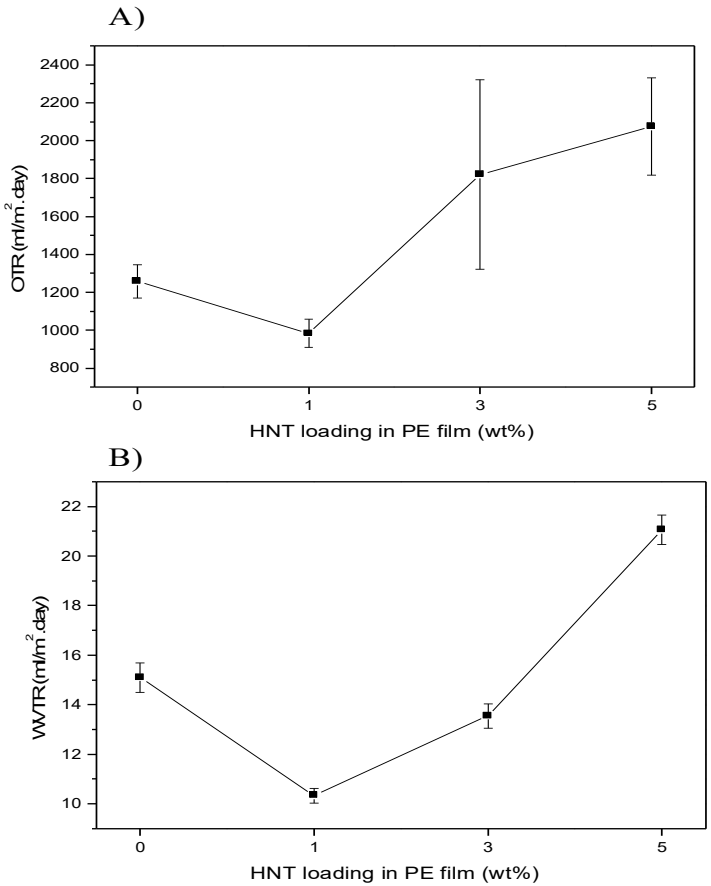
Photographs of banana samples packaged with PE films and HNT/PE films containing 5 wt % HNTs B) Firmness of tomato samples packaged with PE films and HNT/PE films containing 5% HNTs.

By Courtesy of Dr. Hayriye Ünal-SUNUM

Sabancı Üniversitesi



Time based weight loss of strawberries packaged with neat PE films (red), nanocomposite films loaded with 1 wt % (green) and with 5 wt % HNTs (blue).



Oxygen transmission rate (OTR) (A) and water vapor transmission rate (WVTR) (B) of nanocomposite films at different loading ratios.

By Courtesy of Dr. Hayriye Ünal-SUNUM

Sabancı Üniversitesi

UPCYCLING

PLA/XPU/WCF TERNARY BLENDS

65% increase in stiffness, 42% increase in strength by using 15% waste cellulose fiber and waste vulkollan

PLA/XPU/WCF Ternary Blends

Poly(lactic acid)
(PLA)

+

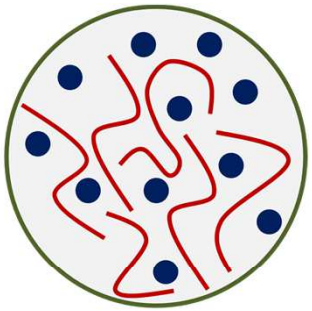
Waste Crosslinked
Polyurethane (XPU)

+

Waste Cellulose Fiber
(WCF)

High-shear
Thermo-kinetic Mixing

5000-6000 rpm

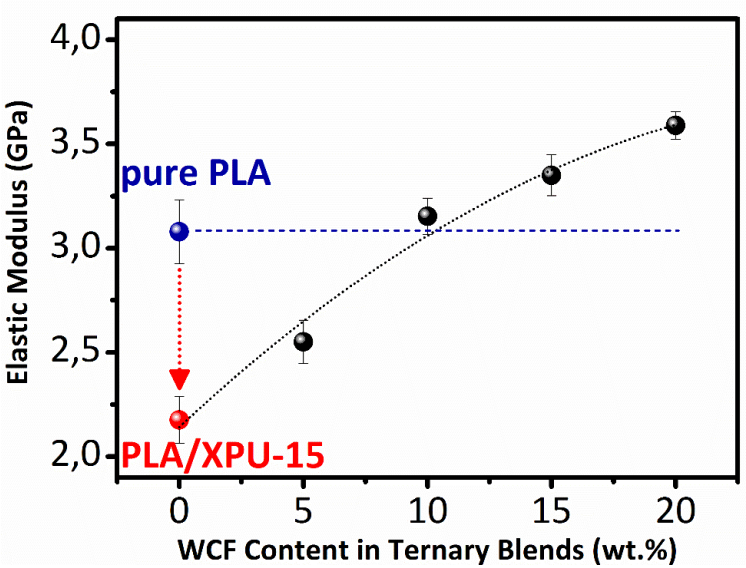


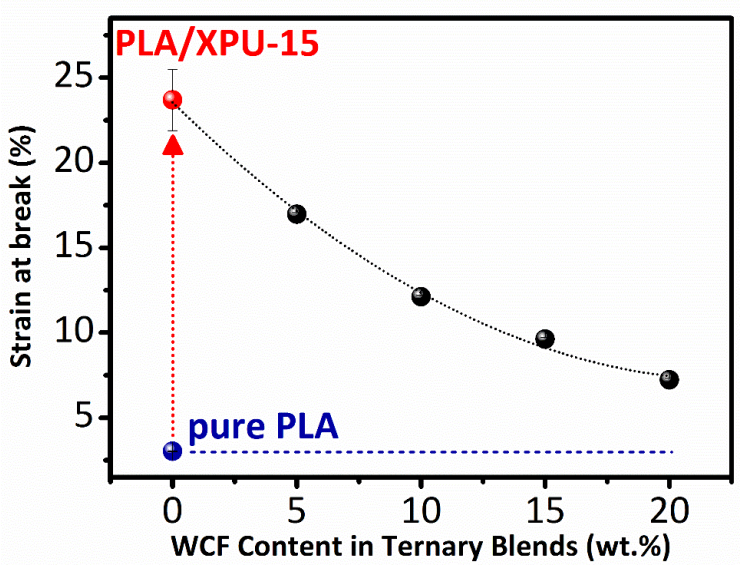
XPU
15 wt.%
Impact Resistance

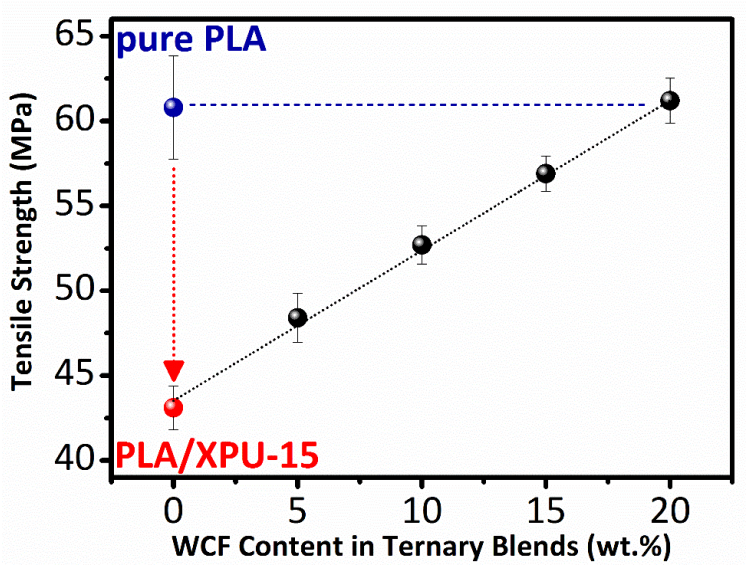
WCF
5, 10, 15, 20 wt.%
Stiffness & Strength

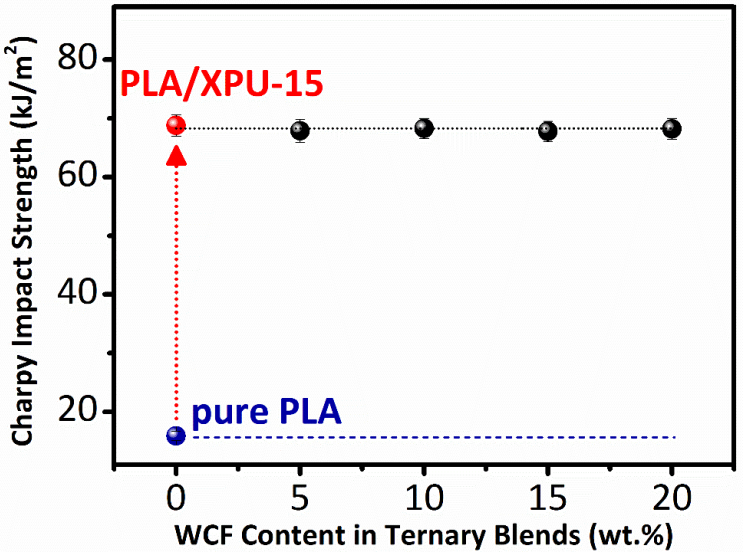
Sabancı Üniversitesi

Ternary Blends: Mechanical Properties









Sabancı Üniversitesi

Plastics recycling with a difference

by Haritz Sardon, and Andrew P. Dove

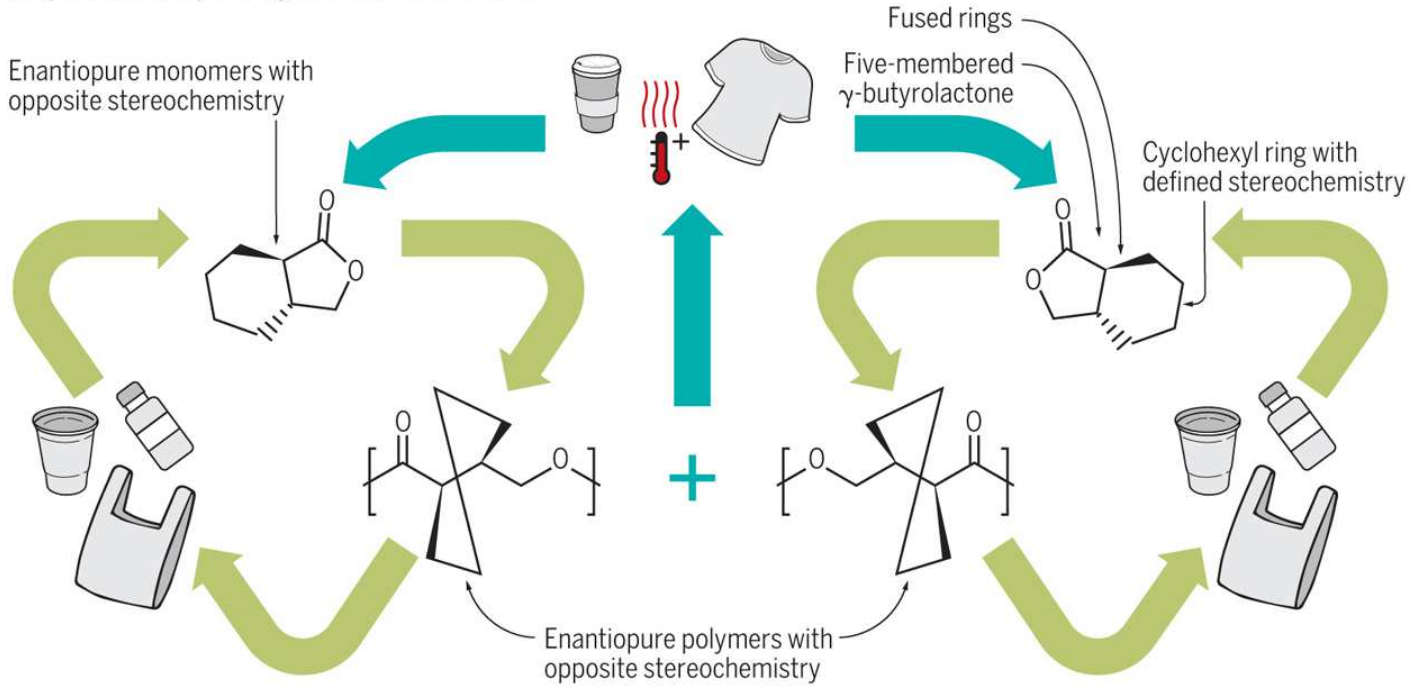
Science
Volume 360(6387):380-381
April 27, 2018

Published by AAAS

Repeatedly recyclable polymers

Repeatedly recyclable polymers

Zhu *et al*. report production of a plastic that can be recycled repeatedly through chemical methods without loss of function. Blending of the two enantiopure polymers yields a plastic that can withstand higher temperatures, expanding its usefulness further.



Haritz Sardon, and Andrew P. Dove Science 2018;360:380-381

No documents available for this priority number.

Espacenet

Bibliographic data: SG184970 (A1) — 2012-11-29

PREPARATION OF SUBSTANTIALLY QUATERNIZED AMMONIUM ORGANOSILANE COMPOSITION AND SELF-STABILIZING AQUEOUS SOLUTION THEREOF

Inventor(s): TARALP ALPAY [TR]; MENCELOGLU YUSUF [TR]; SIMSEK EREN [TR]; ACATAY KAZIM [TR] ± (TARALP, ALPAY, ; MENCELOGLU, YUSUF, ; SIMSEK, EREN, ; ACATAY, KAZIM)

Applicant(s): SABANCI UNIVERSITESI [TR] ± (SABANCI UNIVERSITESI)

Classification: - international:
- cooperative: C07F7/1892

Application number: SG20120007812 20100421

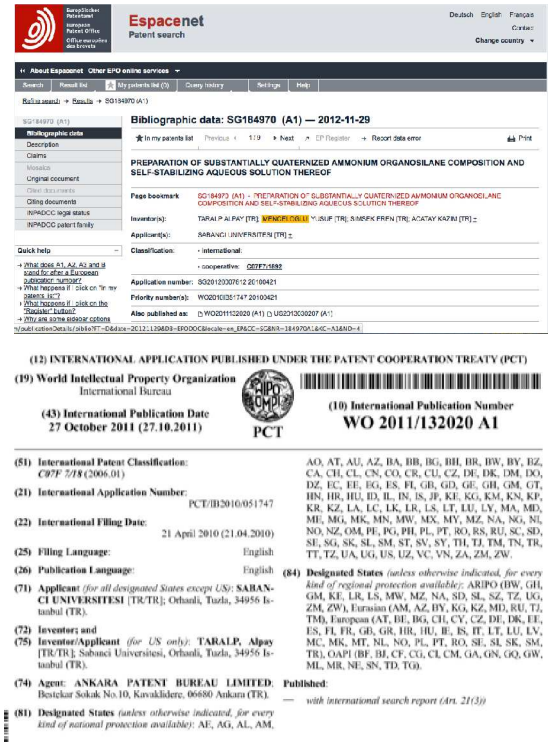
Priority number(s): WO2010IB51747 20100421

Also published as: WO2011132020 (A1) US2013030207 (A1)

Abstract of SG184970 (A1)

This invention relates to the preparation of a partially quaternized ammonium organosilane composition, and a self-stabilizing aqueous solution of said composition, which serves to yield an antimicrobial polysilsesquioxane coating upon thermal curing. By way of this invention, an aqueous solution is prepared, comprised in part by a partially

THANKS.....



Espacenet
Patent search

Bibliographic data: SG184970 (A1) — 2012-11-29

PREPARATION OF SUBSTANTIALLY QUATERNIZED AMMONIUM ORGANOSILANE COMPOSITION AND SELF-STABILIZING AQUEOUS SOLUTION THEREOF

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 October 2011 (27.10.2011)

PCT

(10) International Publication Number
WO 2011/132020 A1

(51) International Patent Classification:
C07F 7/18 (2006.01)

(21) International Application Number:
PCT/IB2010/051747

(22) International Filing Date:
21 April 2010 (21.04.2010)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: SABANCI UNIVERSITESI [TR/TR]; Orhanli, Tuzla, 34956 Istanbul (TR).

(72) Inventors; and

(75) Inventor/Applicant *(for US only)*: TARALP, Alpay [TR/TR]; Sabanci Universitesi, Orhanli, Tuzla, 34956 Istanbul (TR).

(74) Agent: ANKARA PATENT BUREAU LIMITED; Bestekar Sokak No.10, Kavaklidere, 06680 Ankara (TR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 965 623 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.01.2016 Bulletin 2016/02

(51) Int Cl.:
A01N 25/04 *(2006.01)* ***B65D 75/00*** *(2006.01)*
A01N 25/34 *(2006.01)* ***A01N 65/22*** *(2009.01)*

(21) Application number: **14176379.7**

(22) Date of filing: **09.07.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **Sabanci Universitesi**
34956 Istanbul (TR)

(72) Inventors:
- **Unal, Hayriye**
  34956 Istanbul (TR)
- **Unal, Serkan**
  34956 Istanbul (TR)
- **Menceloglu, Yusuf Ziya**
  34956 Istanbul (TR)
- **Cebeci, Fevzi Cakmak**
  34956 Istanbul (TR)

(74) Representative: **Mutlu, Aydin**
Invokat Intellectual Property Services
Agaoglu My Office 212-D:241
Basin Ekspres Yolu Tasocagi
Cad. No: 3 Bagcilar
34218 Istanbul (TR)

(54) **Food packaging material with antibacterial, ethylene scavenging and barrier properties**

(57) The present invention provides an use of polymeric films comprising halloysite nanotubes as a packaging material for food products. Said halloysite nanotubes are incorporated with active agents such as antibacterial agents preferably of natural type for providing antibacterial, barrier and ethylene scavenging properties.

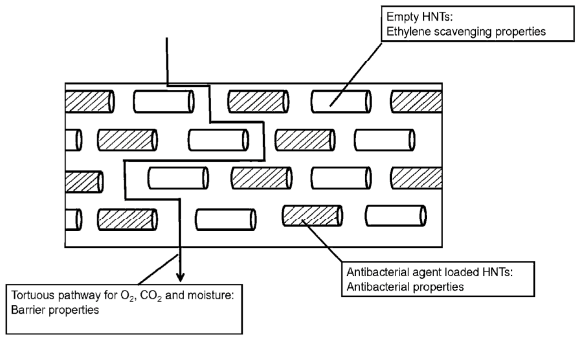
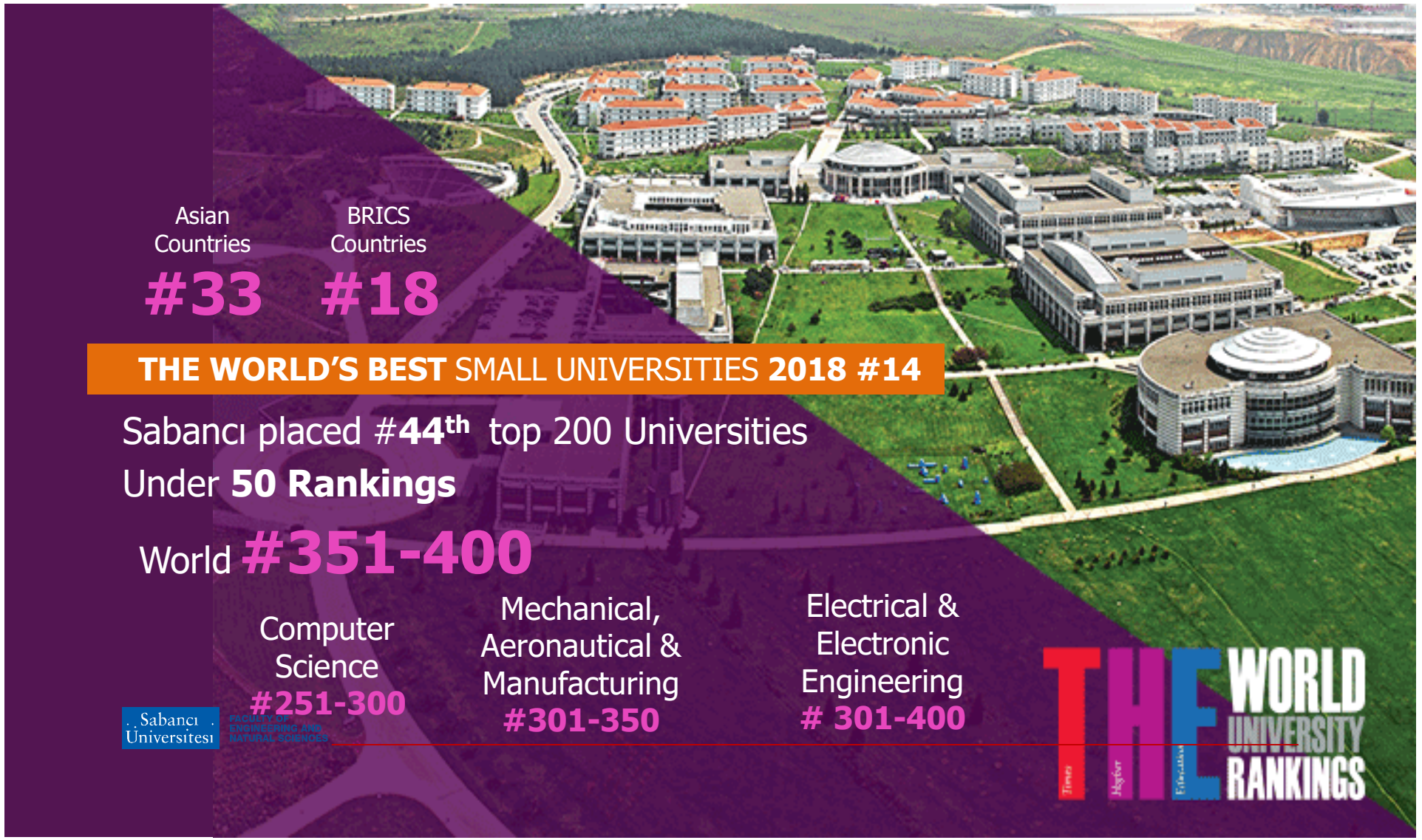


Fig. 4

EP 2 965 623 A1

Printed by Jouve, 75001 PARIS (FR)

Sabanci Universitesi


Asian Countries
#33
BRICS Countries
#18
THE WORLD'S BEST SMALL UNIVERSITIES 2018 #14
Sabancı placed #44th top 200 Universities
Under 50 Rankings
World #351-400
Computer Science
#251-300
Mechanical, Aeronautical & Manufacturing
#301-350
Electrical & Electronic Engineering
301-400
Sabancı Üniversitesi
FACULTY OF ENGINEERING AND NATURAL SCIENCES
THE WORLD UNIVERSITY RANKINGS