Fernando Galembeck
University of Campinas
Inomat (INCT for Complex Functional Materials)
GG & FG

Costa Ribeiro Memorial Lecture

17th B-MRS/SBPMat Meeting

Materials for a Better Future

Synopsis

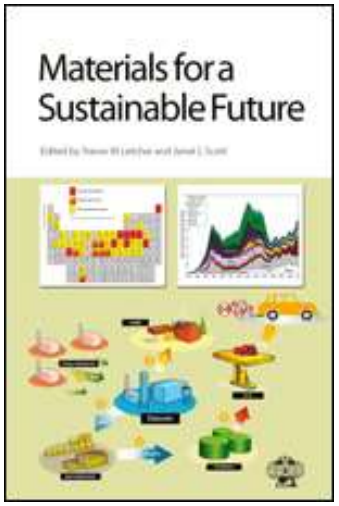
- A Golden Age OR Decline of Humankind?
- Biomass: Food, energy and raw materials
  - Materials from biomass
- Chemical Electrostatics
- Perspectives

What is ahead?

- Every epoch is marked by transformation mediated by materials.
- What are the upcoming new materials and how will they transform our lives?
- Will the needed materials still be available, in the coming decades?

A Golden Age?

- Prospect: unlimited supply of energy
  - Inexpensive solar energy, competitive wind power, biomass…
  - Fusion, in twenty years (?)
- Inexpensive energy is the key to abundant raw materials
  - e.g. lithium
    - Largest reserves in the world are in: Argentina, Bolivia, Chile, China, US, Australia, Canada.
    - Largest current producers are Australia, Chille, Argentina, China, Zimbabwe…
  - Mg from seawater, Au from "urban mining"…
  - H_2O from seawater



Materials for a Sustainable Future Scott, J. L. (ed.) & Letcher, T. (ed.) 2012 Cambridge: Royal Society of Chemistry. 828 p.*Research output: Book/Report › Book*

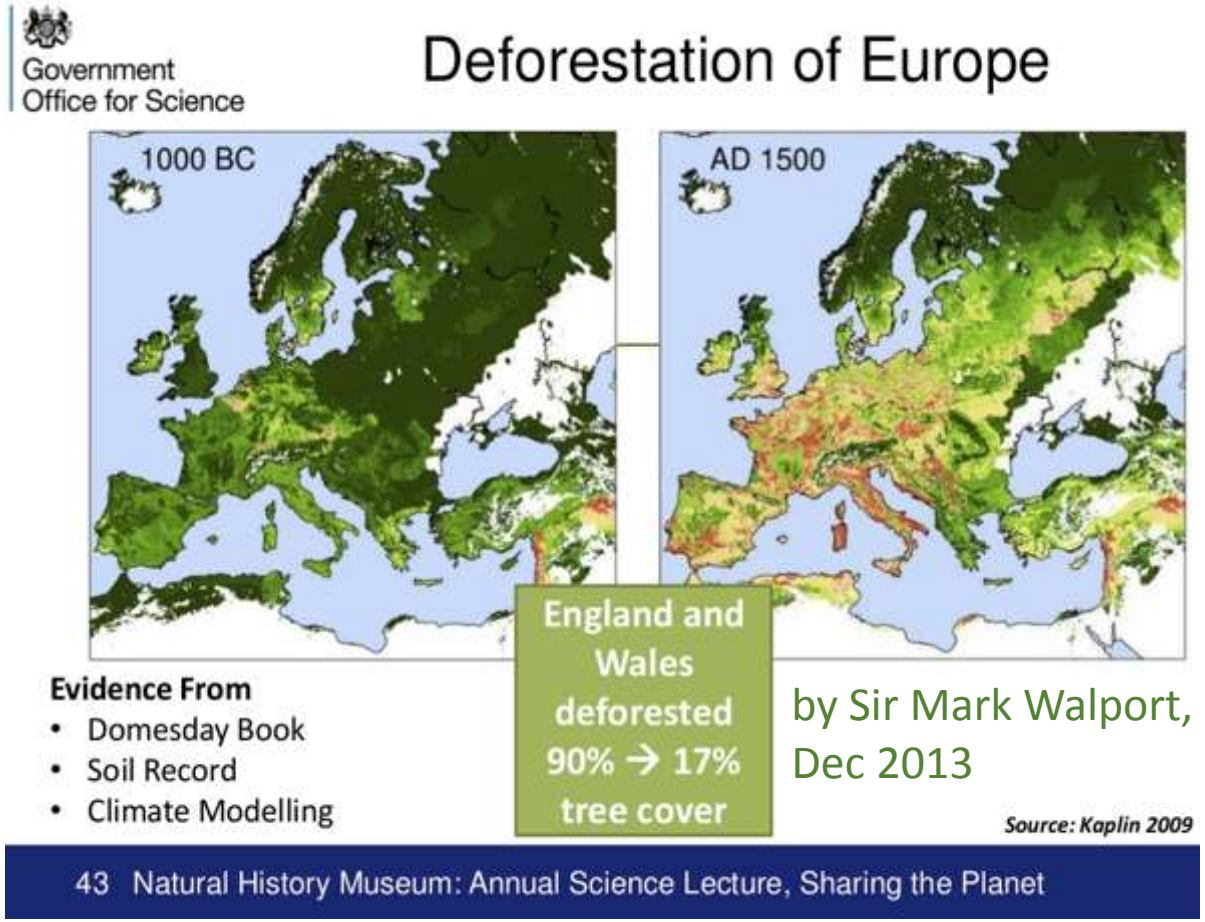
In the past: biomass provided food, energy and raw materials

Food: 100%

Energy: wood

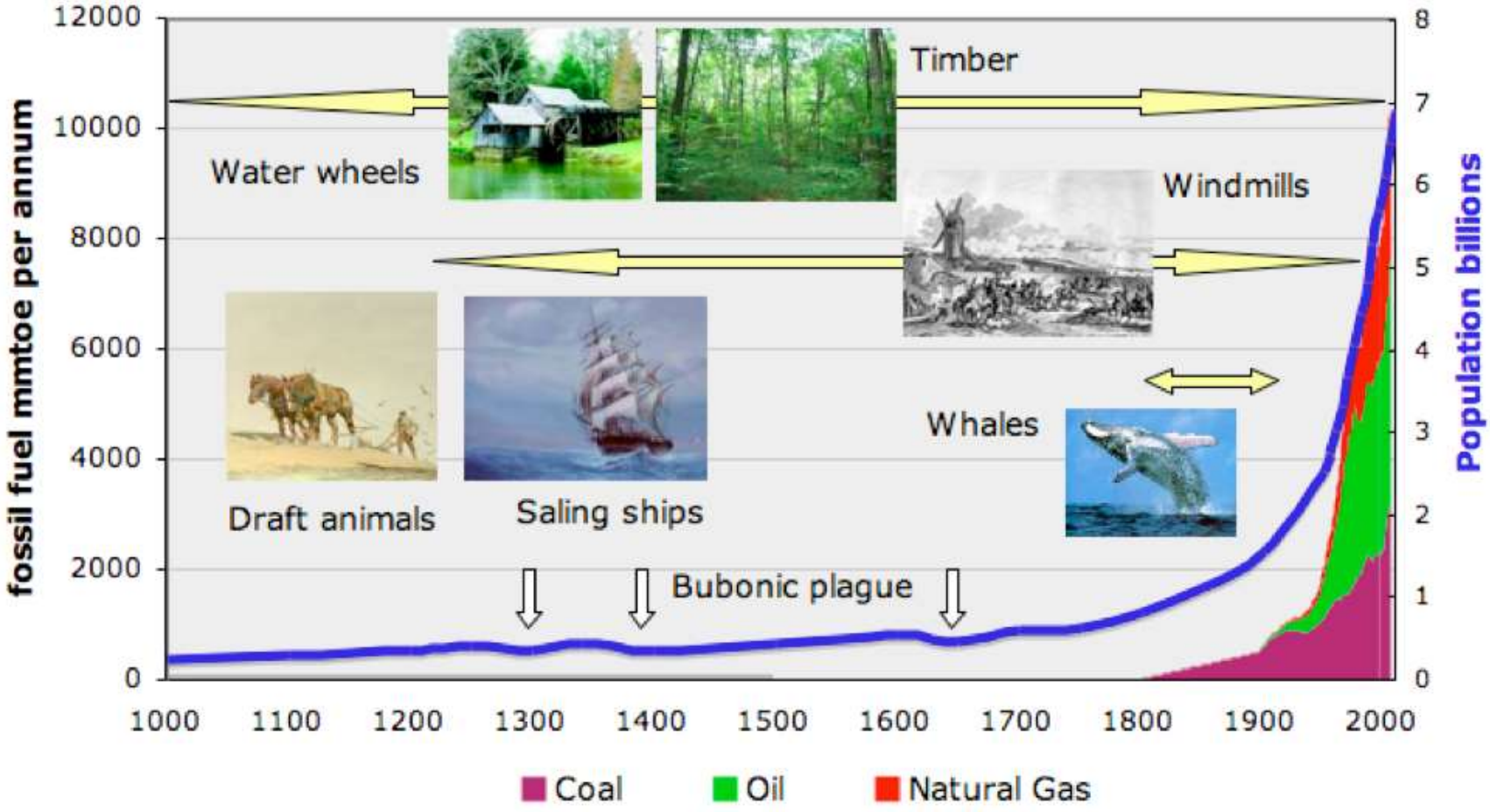
Raw materials: wood, natural fibers + minerals

Consequence: land change



http://www.slideshare.net/bis_foresight/natural-history-museum-annual-science-lecture-2013

Then came coal, oil and gas



https://notable.files.wordpress.com/2007/04/energy-per-capita.png

Abundant oil? Make food from oil!

- Use of hydrocarbon fractions for production of single-cell protein
  - Nine plants in the Soviet Union ranged from 50 to 240,000 tons/year.
  - http://www.nytimes.com/1973/11/10/archives/soviet-plant-to-convert-oil-to-protein-for-feed-use-of-yeast.htm
- Unesco Science Prize, 1976

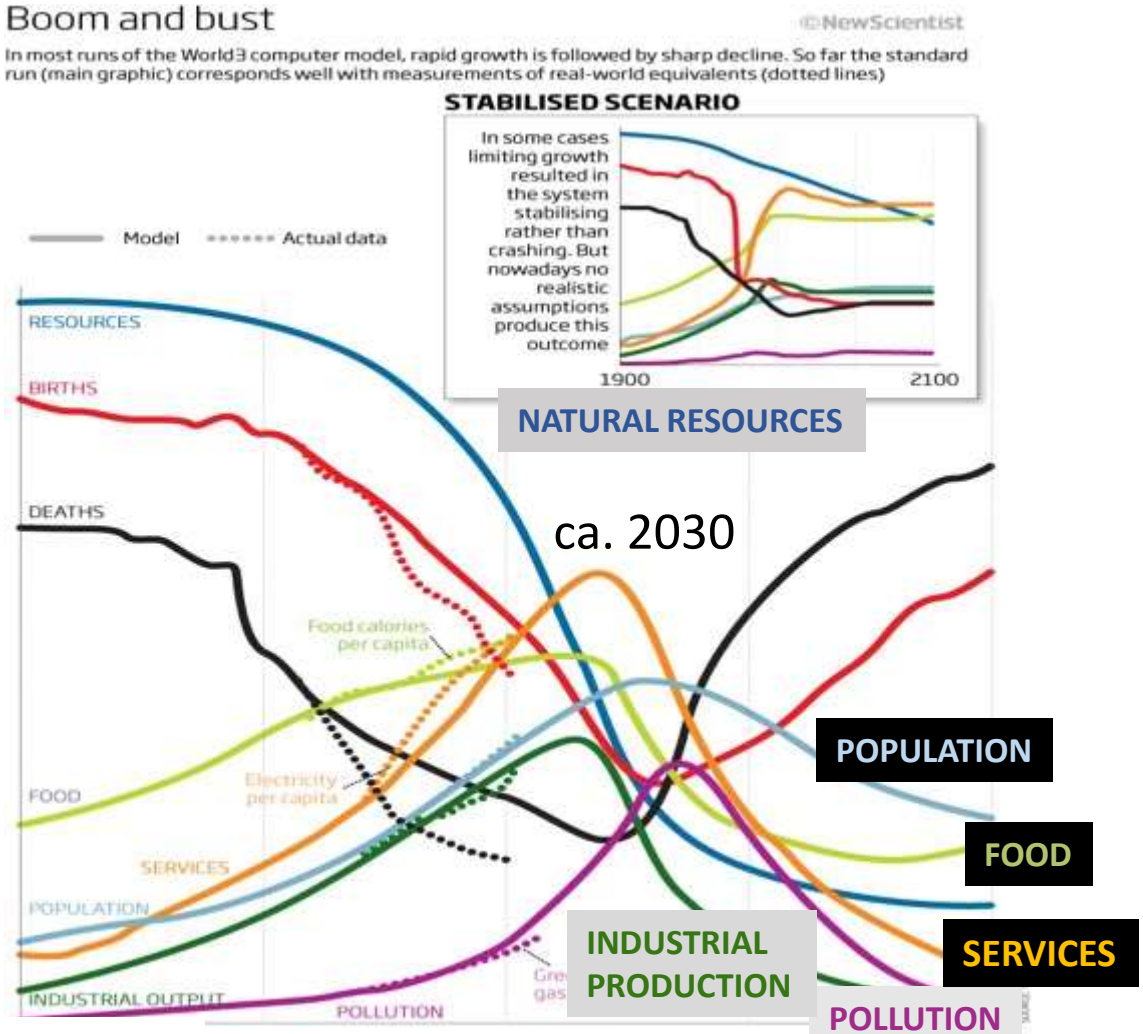
France
Alfred Champagnat
BP's Lavera Oil Refinery in France

"pour ses conclusions sur la production à la chaîne et à bas coût de nouveaux proteines provenant du pétrole"

"for his findings on the low-cost mass production of new proteins from petroleum"

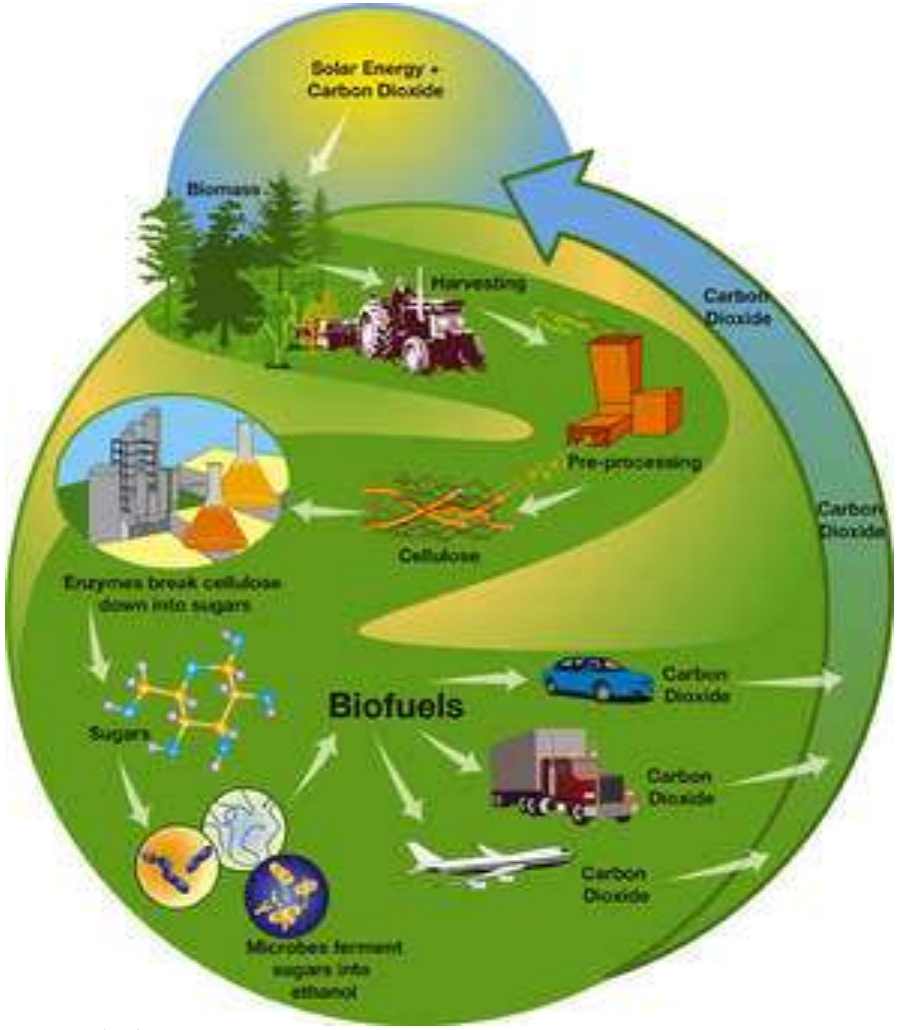
http://unesdoc.unesco.org/images/0011/001111/111158E.pdf

Concern: resource depletion. World 3 model



http://polynomial.me.uk/tag/science/

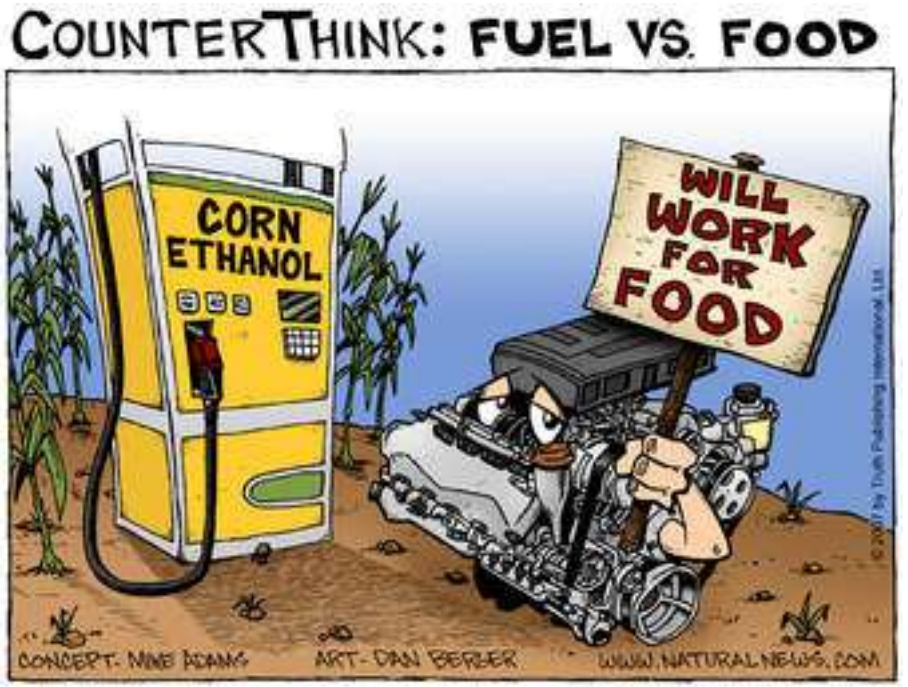
Solution: energy from renewable resources. Biofuels



https://media5.picsearch.com/is?H6ocSV7tIiUeAfGxI4BIToSfopEZjZSEhfqT6DjV5ac&height=341

Solution: energy from renewable resources. Biofuels

New Problem



https://media5.picsearch.com/is?H6ocSV7tIiUeAfGxI4BIToSfopEZjZSEhfqT6DjV5ac&height=341

The Food Crisis (2007)

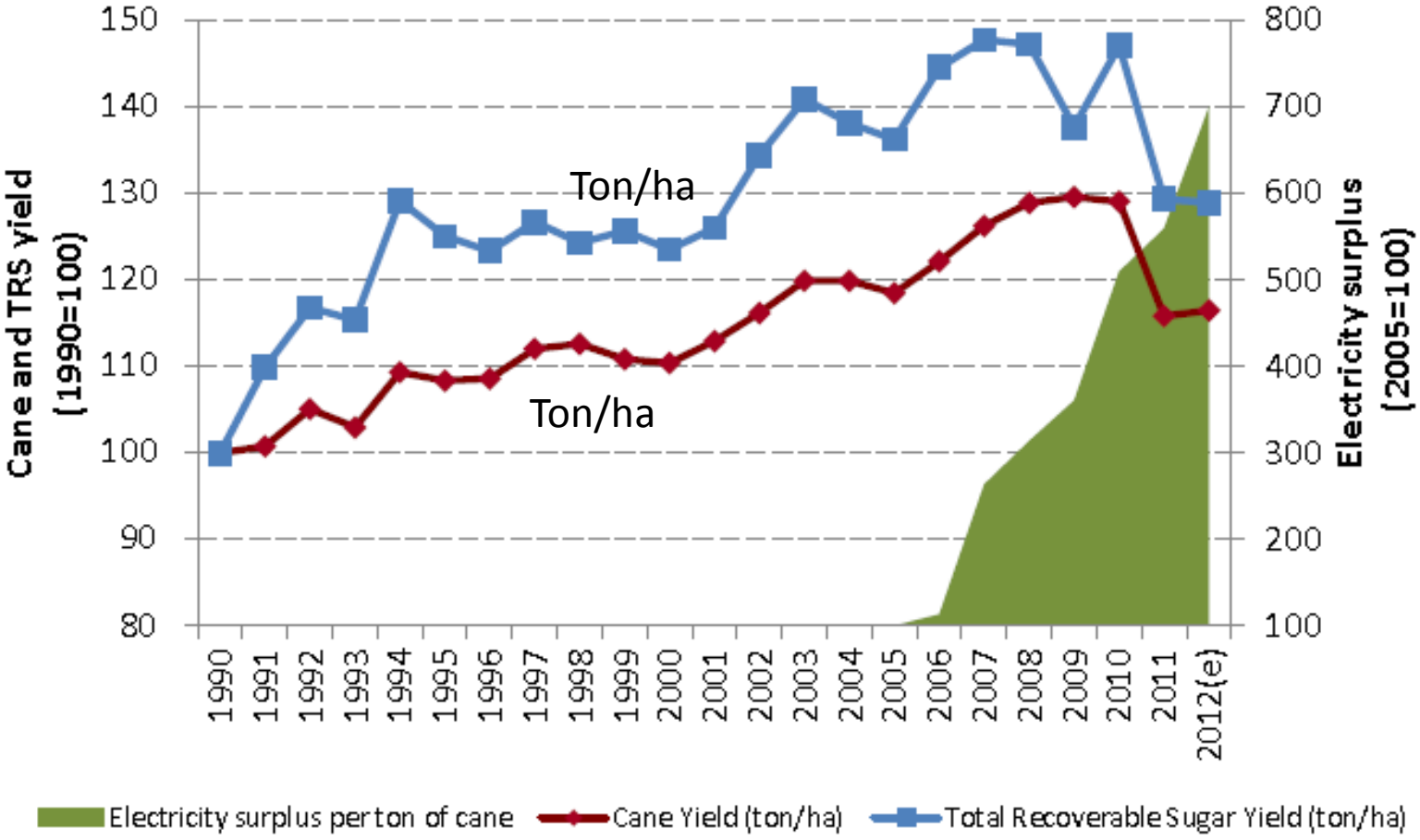
- The ”Food riots”
  - FAO Food Price Index rose to 220 (Jul 2008) and 238(2011)
- Causes:
  - Rising biofuel production from corn, sugarcane, palm oil
  - Wild commodity speculation, pre 2008 financial crisis
  - Climate, drought

By Jashuah - Own work by uploader, data from Food and Agriculture Organization, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19394247

FAO Hunger Map, 2015

http://www.fao.org/3/a-i4674e.pdf

Production and efficiency gains: sugarcane



Total recoverable sugar: +39 % from 1990 to 2012.
Electricity surplus: 1 to 11 Twh/year, from 2005 to 2012

Nassar, A. M., Moreira, M. Evidences on sugarcane expansion and agricultural land use changes in Brazil. Institute for International Trade Negociations

Products from sugarcane

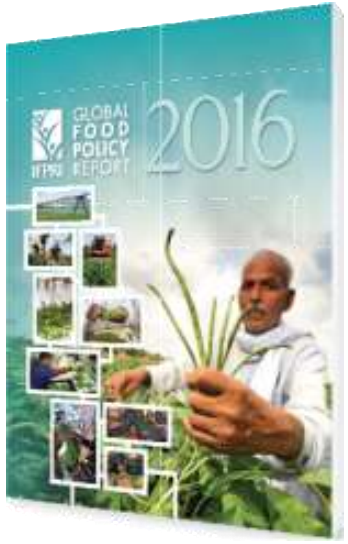
- Introduced in South and Central America in the 16th century, to produce sugar.
- Sugar crystallization residues were fermented to produce ethanol.
- In 1976: subsidized fuel ethanol production.
- In 1990: subsidies were eliminated in 90% of the producing areas.
- Sugarcane is the biomass input for making ethanol, butanol, polyethylene, wax, green solvents and surfactants, nanosilica, cellulose, paper and pulp, microcrystalline cellulose, PHB- and other thermoplastics, lysine (>600,000 tons/year), electricity.
- Galembeck, Csordas "Chemicals from Sugarcane", in Fletcher and Scott "Materials for a Better Future", RSC 2012

Biofuels contribute to food security

"…biofuels may offer an opportunity to improve food security.

Yet, for many poorer countries in Africa and elsewhere, biofuels may be better viewed as a potential export or as a means for reducing fossil fuel imports.

…producing conventional biofuels in low-income countries could raise rural incomes beyond what is required to offset rising food prices.



Studies in Ethiopia: … farmers' participation in biofuel programs encouraged greater use of fertilizers and improved farming technologies, leading to higher food-crop productivity and better food security during the year.

One precondition for success, however, was farmers' access to high-quality, productive biofuel crops."

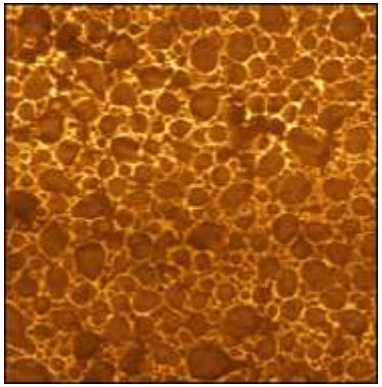
C. Arndt et al., Fueling the path to food security, IFPRI Global Food Policy Report 2016 p.63
F. Galembeck, Synergy in food, energy and advanced materials production from biomass. Energy and Environmental Science 2010 and Pure and Applied Chemistry 2018.

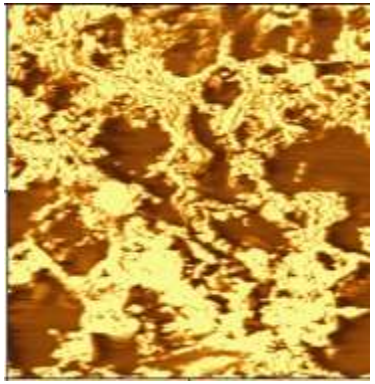
A note on policy

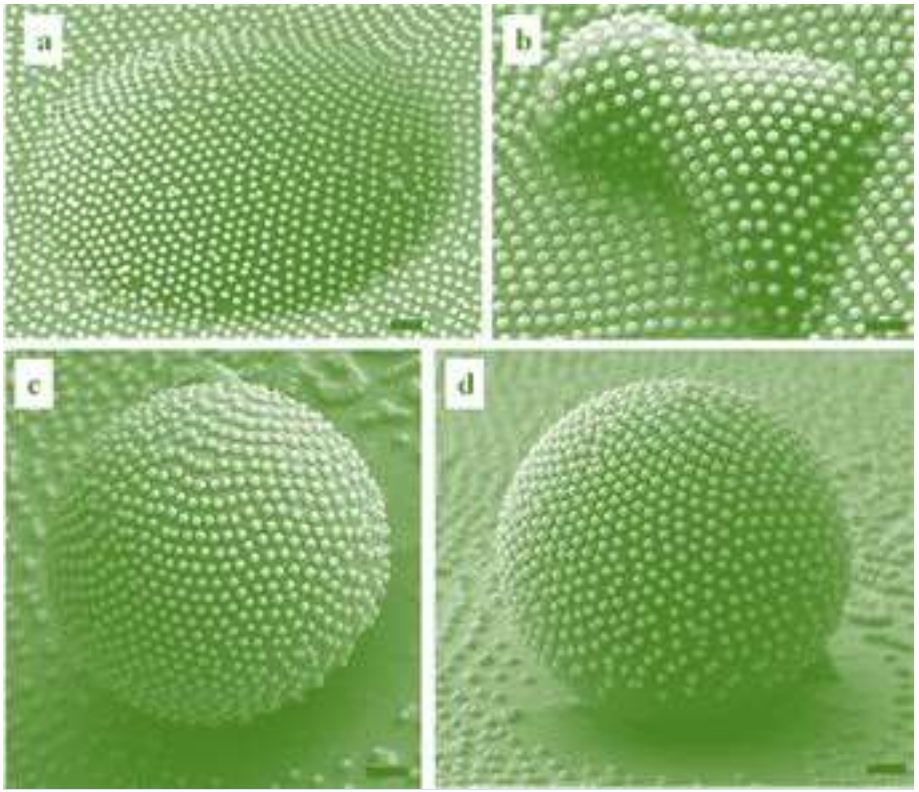
- What do policymakers expect from scientists?
  - Not much.
  - Few citations in "The UN Sustainable Development Goals Report" 2018. "science" 3 times; "scientific": 1; "research": 2": technology/ical/ies": 21.
- Brazilian science concentrates on explaining, modelling, theorizing…
  - Much smaller effort on making.
- Result: small number of significant new products and processes,
  - …although all the competitive economic sectors rely heavily on S&T.

Materials from Biomass: Well-known or Ever-surprising?

- Natural Rubber
- Cellulose
- Electrostatic Adhesion



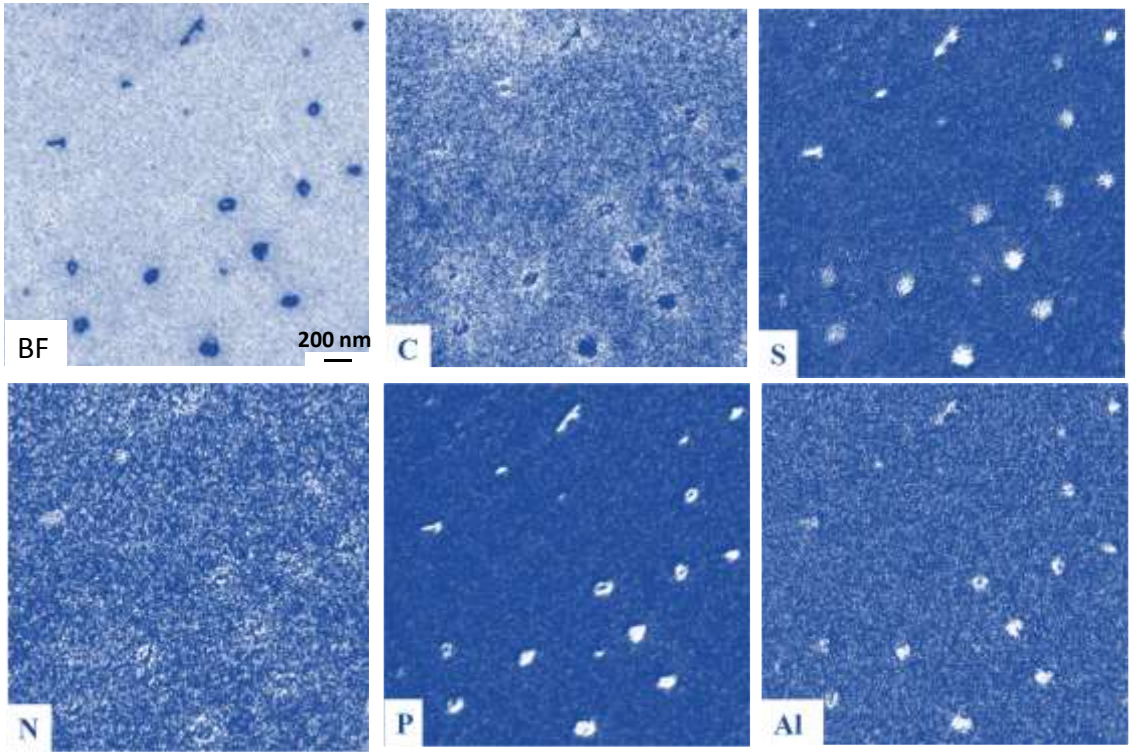




Natural Rubber

- Accounts for 42% of global elastomer consumption
- Essential in transportation and many industrial products Rubber Statistical Bulletin April-June edition, quoted by S. Rolere, et al. in European Polymer Journal (2016)
- The "mistery of natural rubber"
  - *"…as the tire size increases and the level of punishment the tire will take goes up, the amount of natural rubber increases…" (Josh Velson)*
- Which is the role of the non-rubber constituents (inorganics, proteins and phospholipids NR properties?

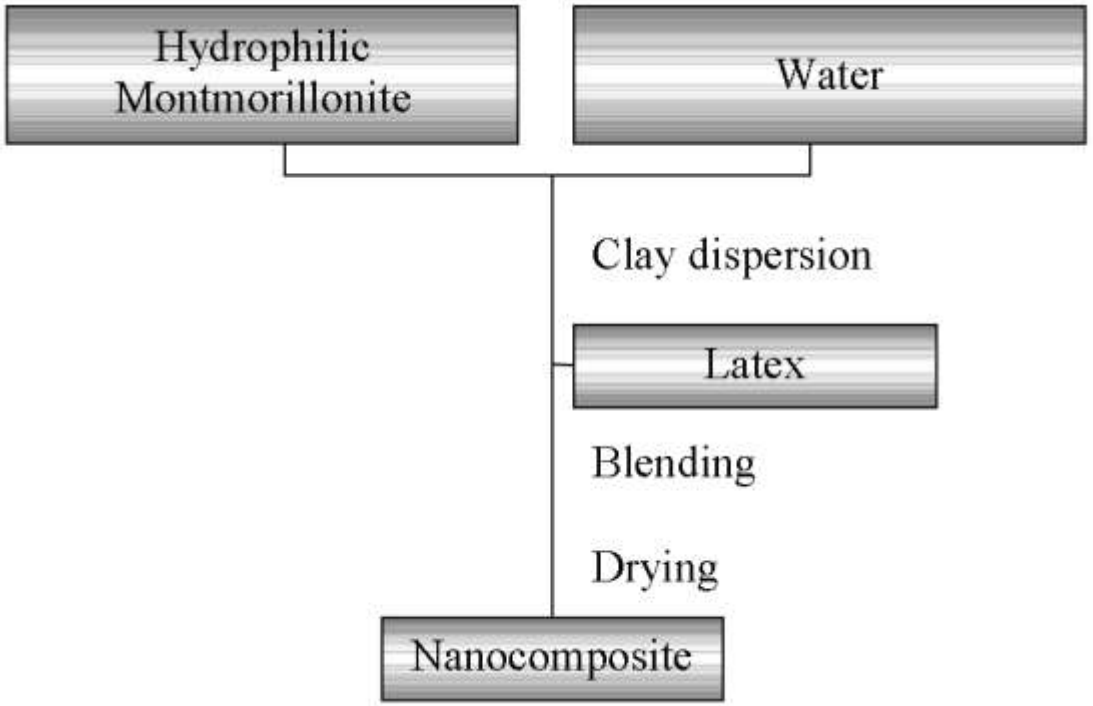
ESI-TEM thin film elemental maps of dialyzed natural rubber latex film



- Adherent mineral nanoparticles in natural rubber
- C, N densification around the inorganic particles: adhesion

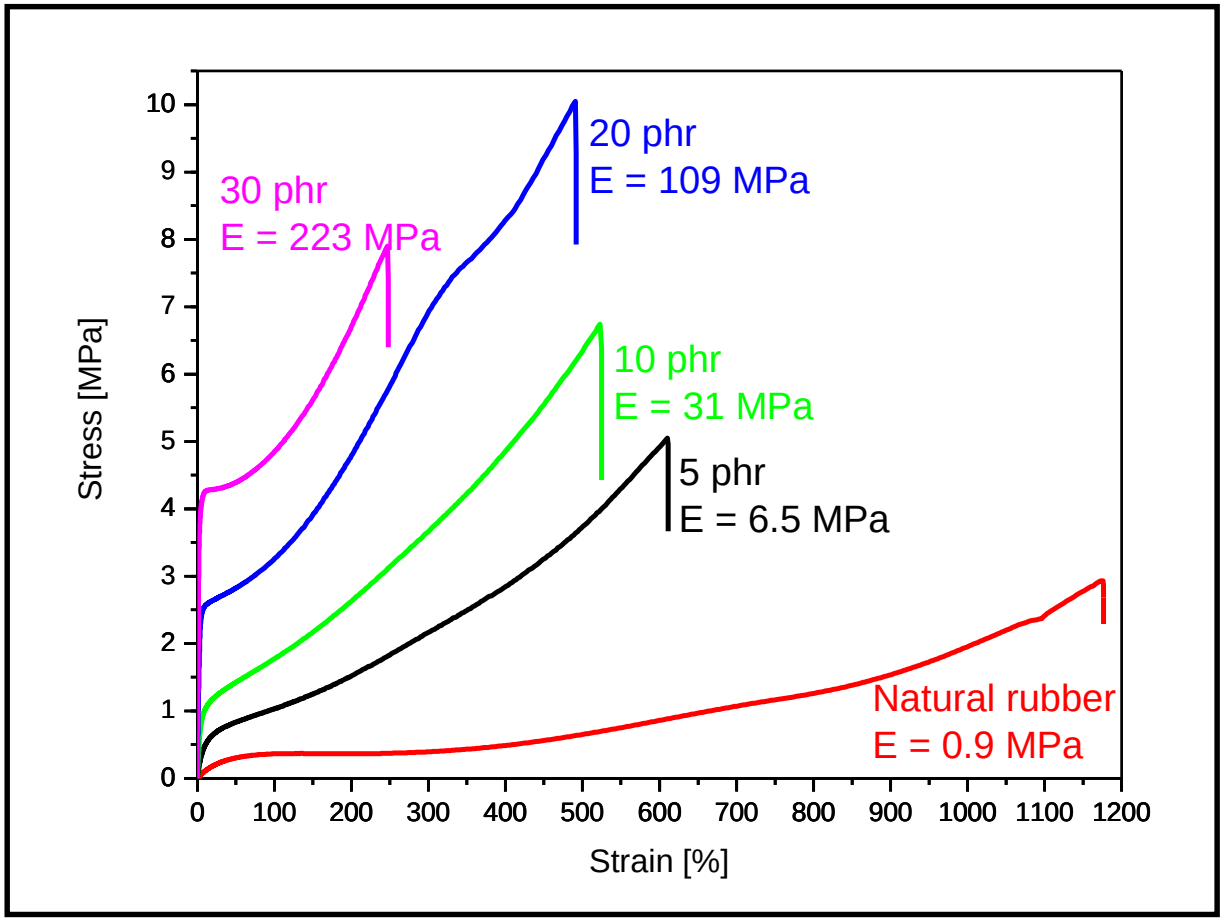
Rippel, M.M. et al. *Analytical Chemistry*, 2002

Learning from Nature
Preparation of nanocomposites in aqueous media using latex



Varghese, S., Karger-Kocsis, J., ***Polymer*, 2003**, 44, 4921.
Wu, Y.P., Wang, Y.Q., Zhang H.F. *et al.* ***J. Compos. Sci. Tech.* 2005**, 65, 1195
Valadares, L. F., Leite, C. A. P., Galembeck, F., ***Polymer*, 2006**, 47, 672.
Valadares, L. F., Murakami, M. M., Rippel, M. M., Galembeck, F., PI0301193-3, **INPI, 2003.**

Tuning-up mechanical properties



Tensile testing:

Modulus increases *ca.* 250 times

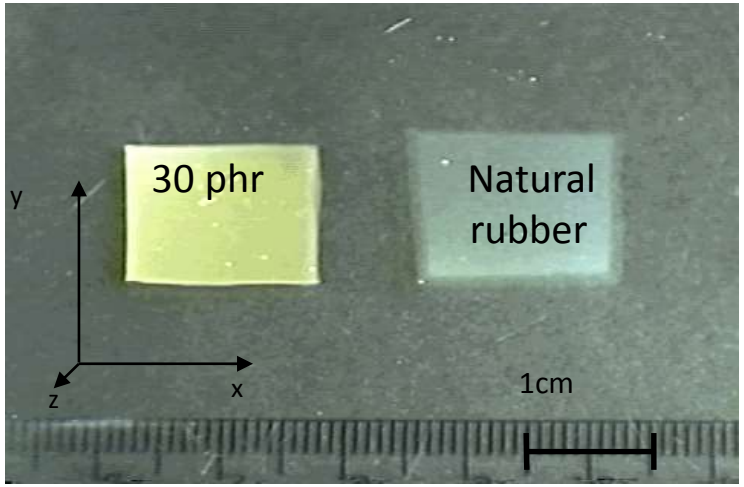
Maximum stress increases up to 3.5 times

Valadares, L. F., Leite, C. A. P., Galembeck, F., ***Polymer***, 2006, 47, 672.

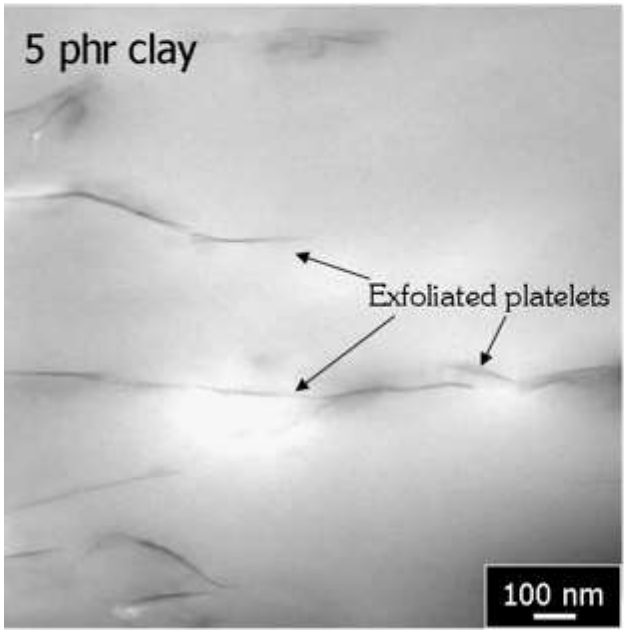
Strong polymer – clay adhesion

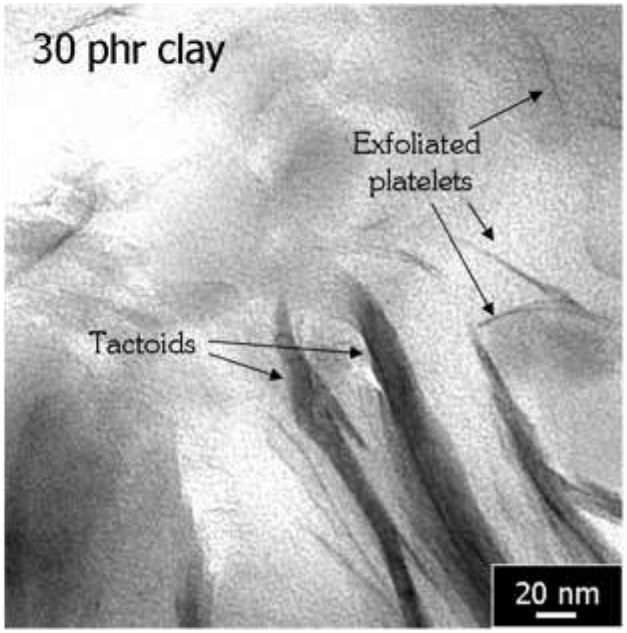
Formation of a polymer-particle network

Resistance to solvents



Transmission Electron Microscopy

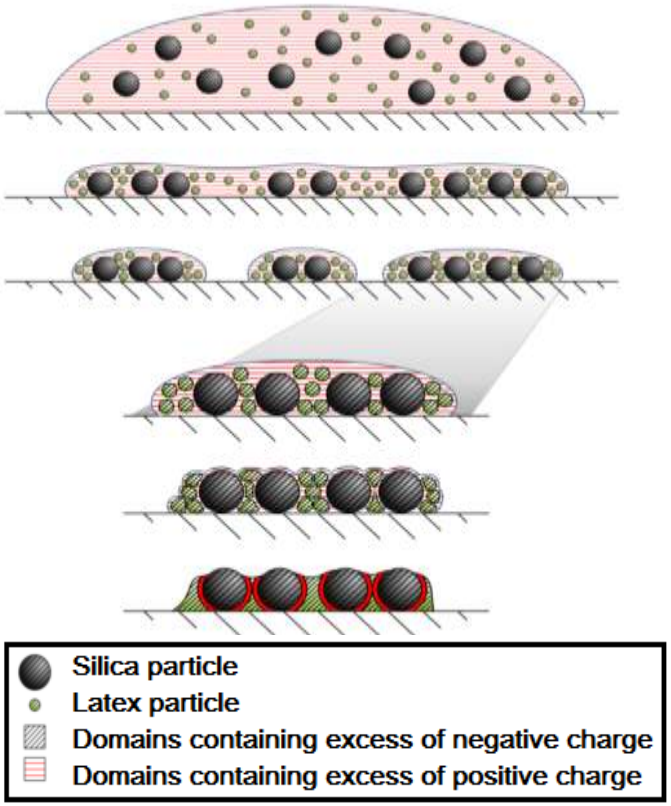




Valadares, L. F., Leite, C. A. P., Galembeck, F., ***Polymer*, 2006**, 47, 672.

Composite formation and stability

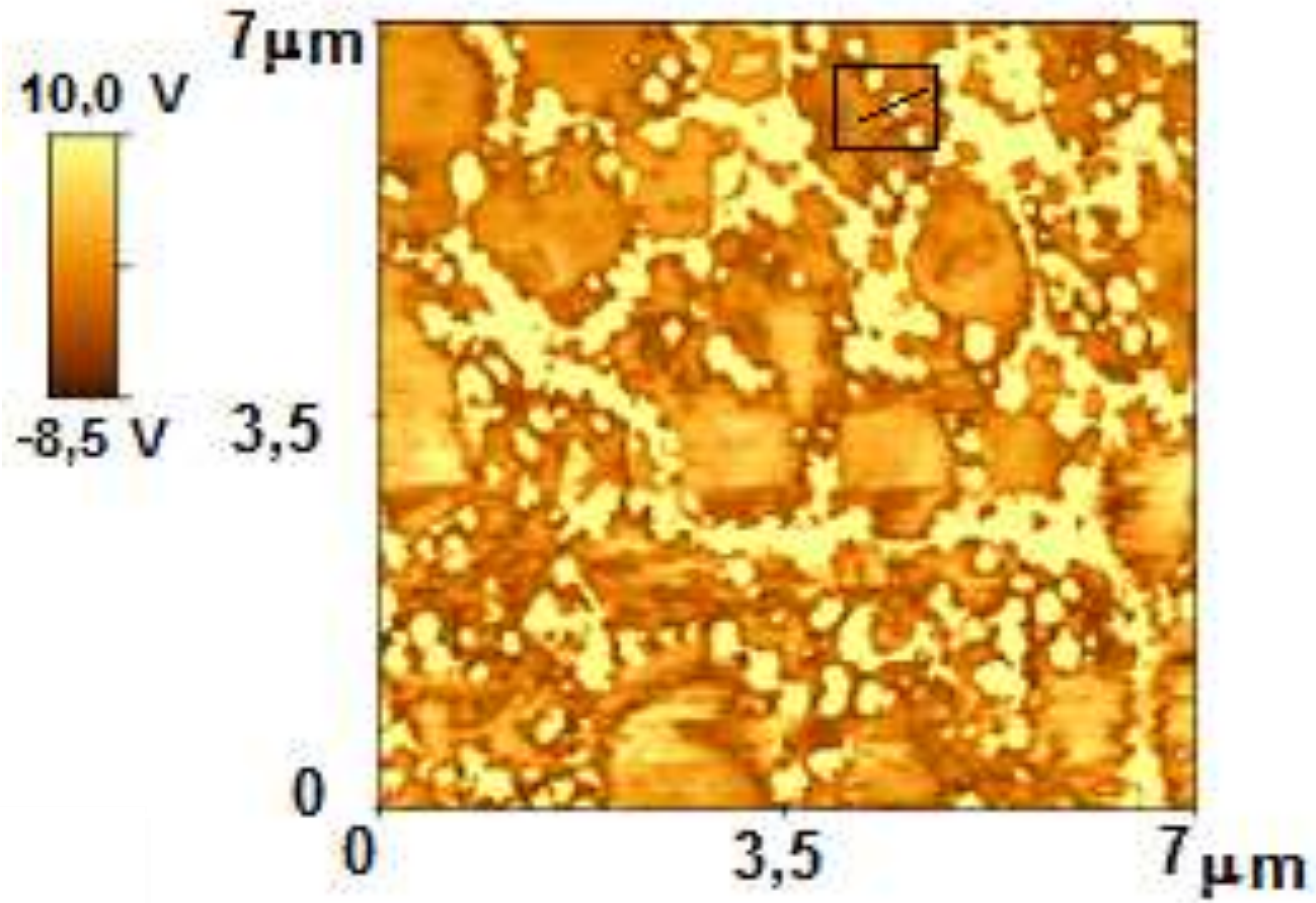
- Capillary adhesion during drying
- Electrostatic adhesion in the dry monolith
- Both are controlled by interfacial properties
- Water-based processes for making composites from incompatible materials



Valadares, L.F et al.. *J. Phys Chem C* (2008); Bragença, F. C. ; et al. Chemistry of Materials, (2007)

Kelvin micrograph from PVC / natural rubber blend

Electrostatic contribution to cohesion



Linares et al., Langmuir 2008

Overcoming limits to miscibility: conductive "green" rubber

Kampioti, Matos et al., ACS Omega 2018

Conductive inks, paints and adhesives

- Usually made of silver
  - Also: copper, PEDOT, graphite, carbon nanotubes, graphene.
- US$ 3 Billion/year market
  - CAGR = 4 – 6 %, depending on the market or product segment
- Broad range of users
  - Auto industry: window and seat heaters
  - Hardware and displays: screens, contacts
  - Touch screens: ITO, graphene, carbon nanotubes

- Rao R, V. K., Abhinav K, V. et al. (2015).Conductive silver inks and their applications in printed and flexible electronics. RSC Adv. 5, 77760–60.
- Yang, W. and Wang, C. (2016) Graphene and the related conductive inks for flexible electronics. J. Mater. Chem. C 4, 7193– 207.

THE MAIN PLAYERS

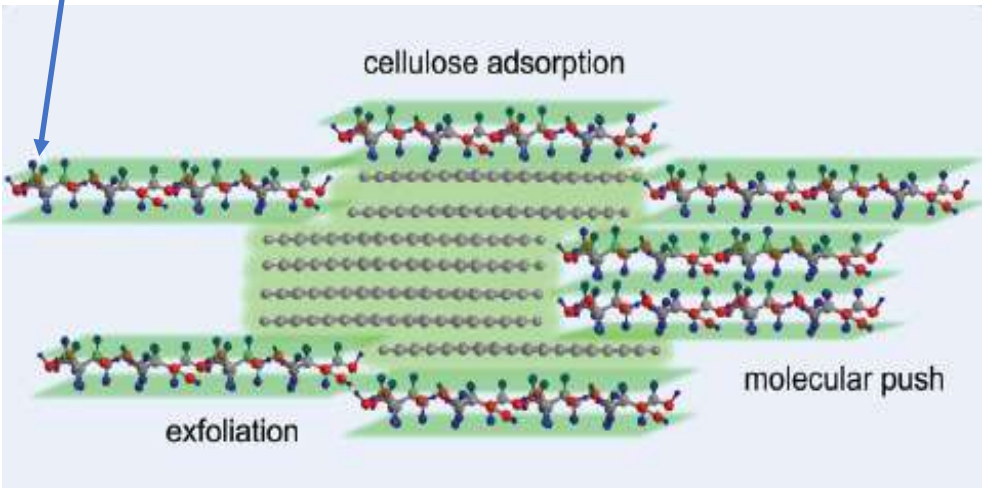
Material	Resistivity (Ω.m)	Resistance (Ω/sq)	Thickness (m)
graphene *monolayer*	10^{-8}	33	$3.\ 10^{-10}$ (single sheet)
graphene *nanosheet*	10^{-6}	33 (1)	$3.\ 10^{-8}$ (100 sheets)
graphite (basal)	2.10^{-6}	0.3	$6.\ 10^{-6}$ (20K sheets)
graphite (microfluidized)	$2.5x10^{-4}$	2 (2)	
silver	$1x10^{-8}$	10^{-3}	10^{-5}
silver ink	$12.5x10^{-8}$	$5x10^{-3}$	$2.5x10^{-5}$

(1) Fang, X. Y., Yu, X. X. et al. (2015) Temperature and thickness-dependent electrical conductivity of few-layer graphene and graphene nanosheets, Physics Letters A, 379, 2245-51.
(2) P. G. Karagiannidis, S. A. Hodge, L. Lombardi et al., Microfluidization of Graphite and Formulation of Graphene-Based Conductive Inks, ACS Nano 2017, 11, 2742-2755.

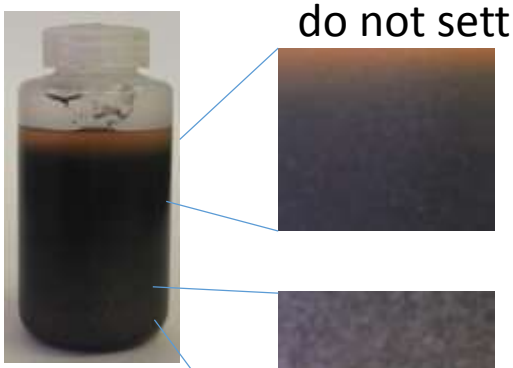
Cellulose is soluble in water + alkali

- Simple procedure: Isogai et al. *Cellulose*, **5 (***1998)* 309
- Insolubility in pure liquids derives from its amphiphilic structure (the Lindman hypothesis)
- Shows the usual properties of polyelectrolytes. Adhesive for paper, cloth, wood.
  - E. S. Ferreira et al, *ACS Applied Materials & Interfaces (2015)*

- Excellent dispersant and exfoliating agent for graphite.
  - E. S. Ferreira et al, *Nanoscale (2017)*



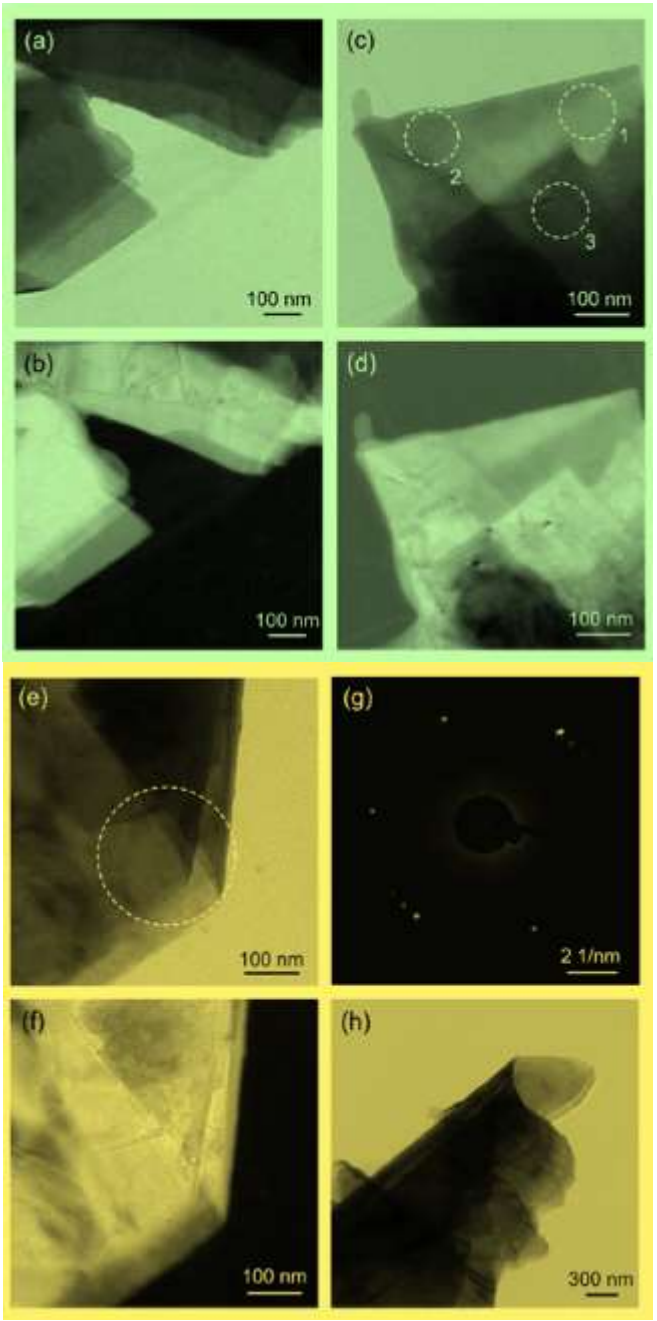
Graphite exfoliated in alkaline aqueous cellulose solution



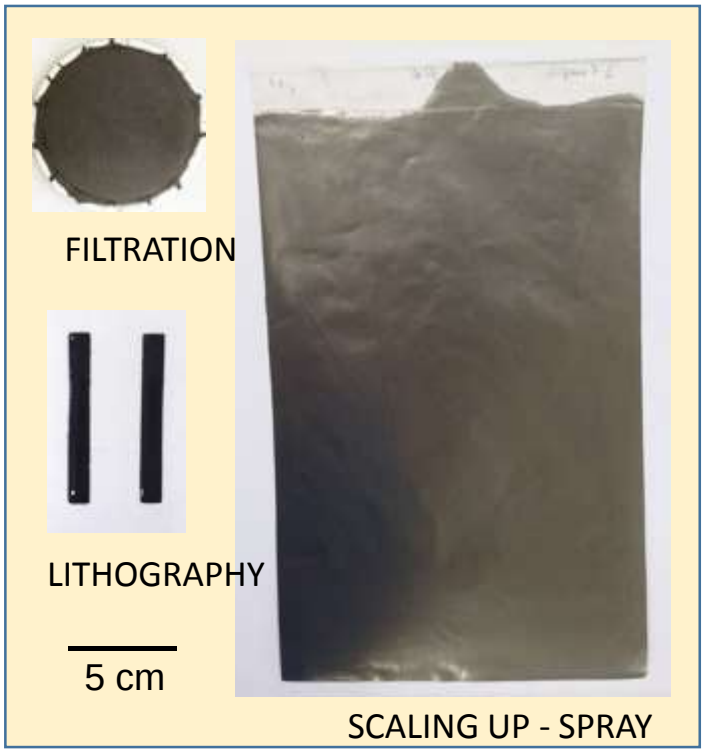
Black particles, do not settle

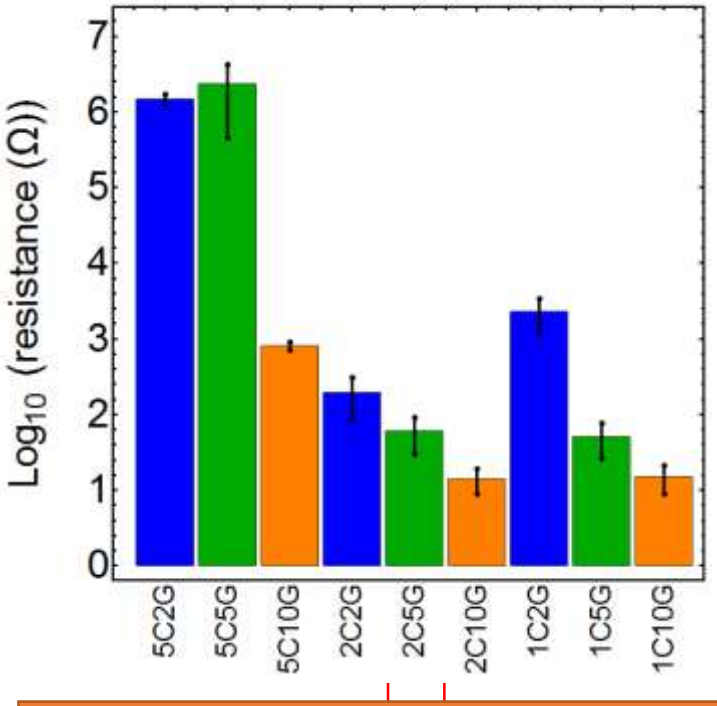
Shiny particles

E. S. Ferreira et al, *Nanoscale (2017)*



Graphite coatings on paper, cloth and ceramics

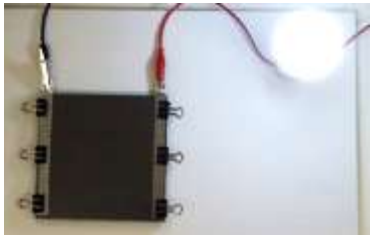




Broad resistance range depending on cellulose/graphite ratio

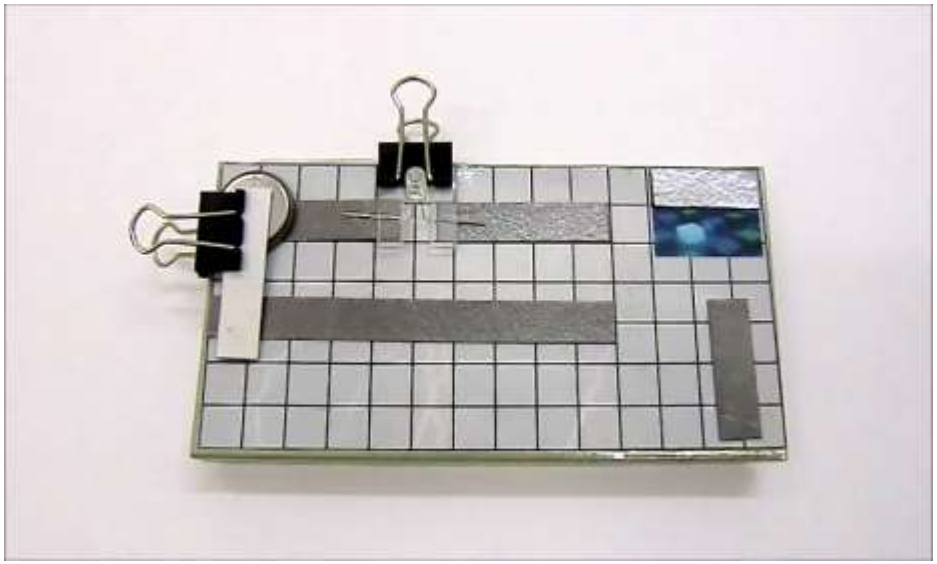
Typical thickness: 10 – 100 µm

Benchmarking



Material	Resistivity (Ω.m)	Resistance (Ω/sq)	Thickness (m)
graphene *monolayer*	10^{-8}	33	$3.\ 10^{-10}$ (single sheet)
multilayer graphene	10^{-6}	33	$3.\ 10^{-8}$ (100 sheets)
graphite (basal)	2.10^{-6}	0.3	$6.\ 10^{-6}$ (20 K sheets)
graphite/cellulose	$3.7x10^{-5}$	0.3	125.10^{-6} (total)
microfluidized graphite	$2.5x10^{-4}$	2	
commercial silver ink	$12.5x10^{-8}$	$5x10^{-3}$	$2.5x10^{-5}$

Inexpensive, safe circuit boards…



…electrodes, sensors, supercapacitors, heaters…

Electrostatics and Friction: Fundamental but Snubbed

Well-stablished knowledge

OR

Unsolved problems?

Neglected as scientific topics in the 20th century

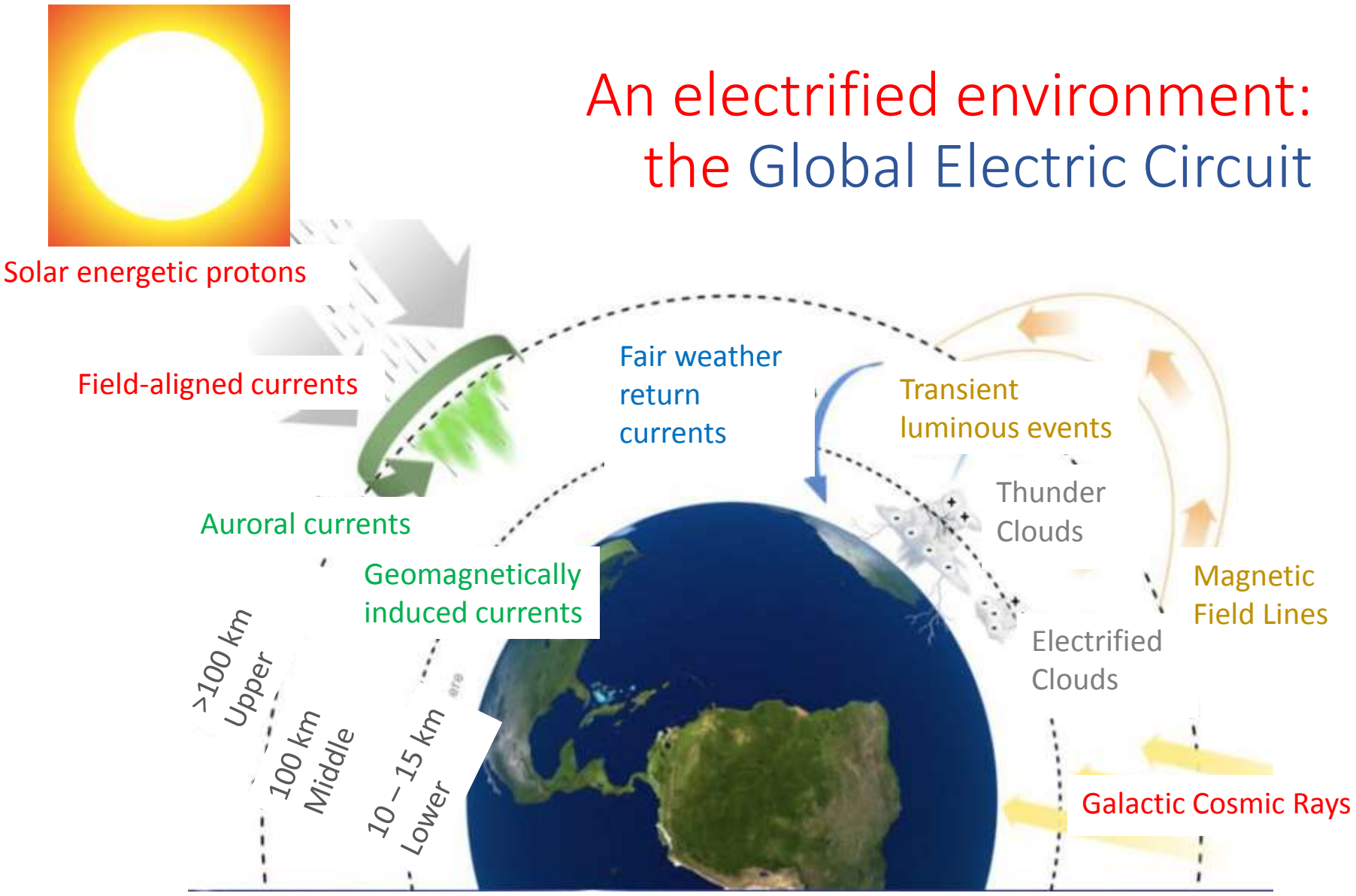
Disconnected from atomic-molecular theory

Revived interest since the first decade of this century

Electrostatics is Alive, Again

- We live in an electrified environment
- Electricity is produced within the Earth capacitor
- Electroneutrality is the exception, anywhere
- The charge carriers
- Chemical electrostatics
- The atmosphere is a charge reservoir
- Fires, explosions, safety
- Outlook: new science, new technology

An electrified environment: the Global Electric Circuit

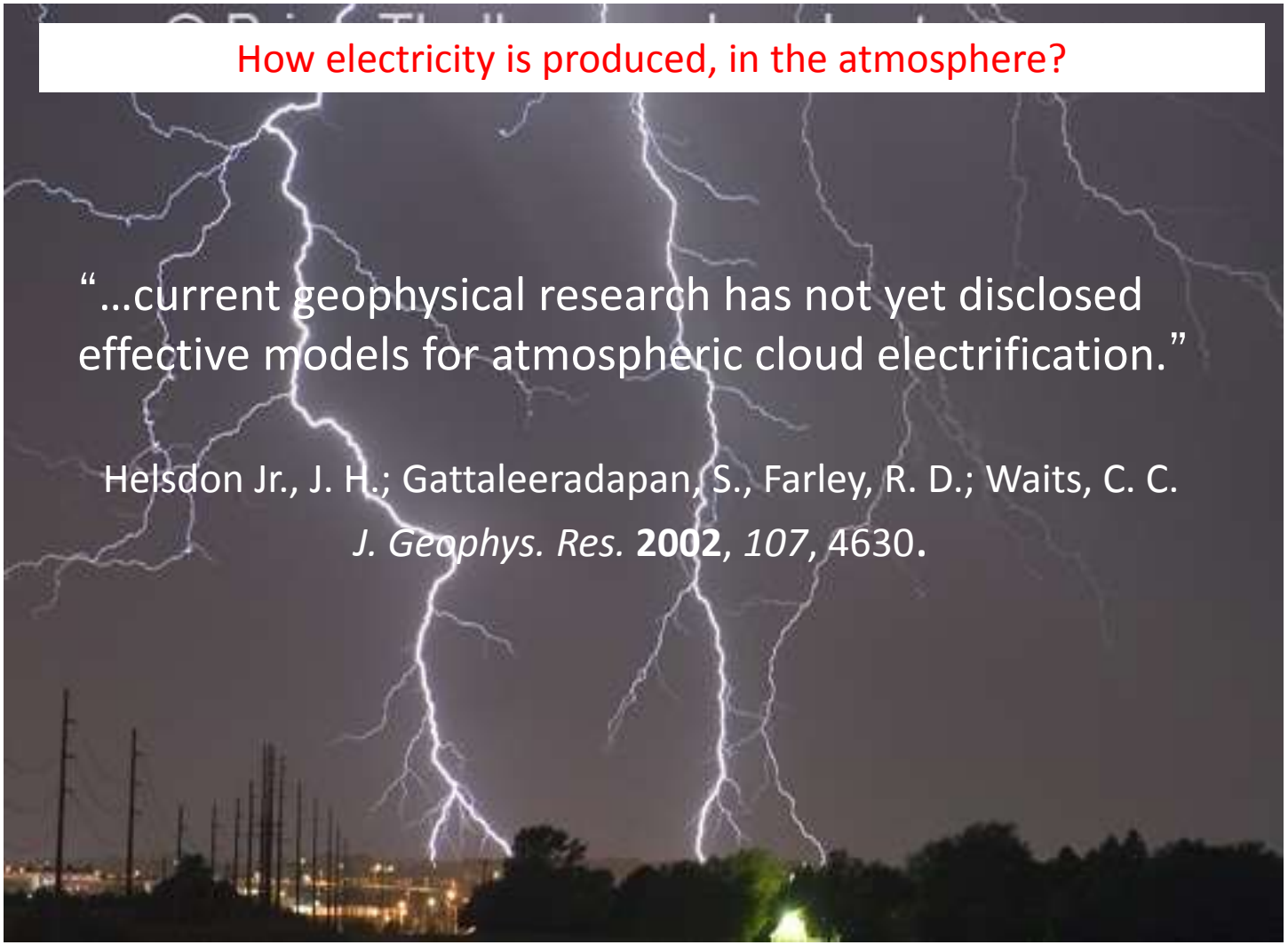


Electric potential gradients at Kew Observatory, London, 1966 to 1979):

50 – 1200 V m $^{-1}$

Rycroft and Harrison, Space Sci Rev 2008

How electricity is produced, in the atmosphere?



"…current geophysical research has not yet disclosed effective models for atmospheric cloud electrification."

Helsdon Jr., J. H.; Gattaleeradapan, S., Farley, R. D.; Waits, C. C.

J. Geophys. Res. **2002**, *107*, 4630.

friction and wear

We add electricity to the environment
(beyond power plants and the grid)

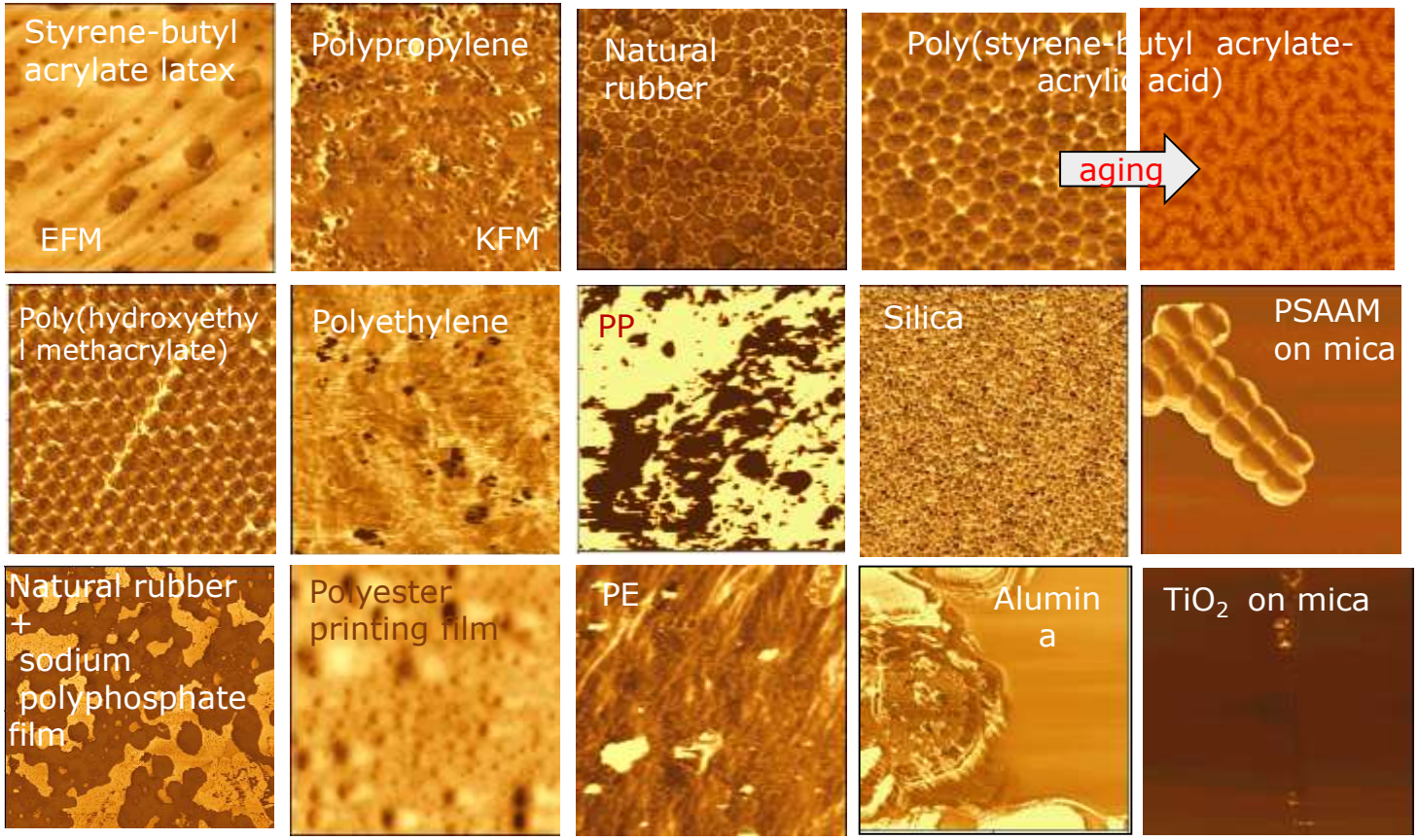
Charge separation/ interfacial effects:

Maxwell-Wagner-Sillars

Costa Ribeiro

Workman-Reynolds

Unexpected: Complex charge distribution in dielectric solids

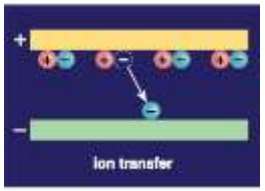


A Galembeck, CAR Costa, et al., *Polymer*, 2001, 42, 4845; F Galembeck, CAR Costa, et al., *An. Acad. Bras. Cienc.*, 2001, 73, 495; FG, C Rezende, RF Gouveia, MA da Silva Journal of Physics – Condensed Matter, 21, 2009, 26300

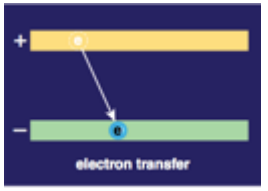
Why? Water ion partition/adsorption and mechanochemical reactions

Charge carriers are electrons or ions?

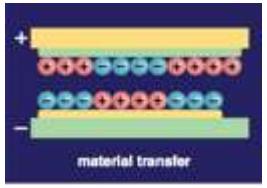
Ions: McCarty and Whitesides, *Electrostatic Charging due to Separation of Ions at Interfaces: Contact Electrification of Ionic Electrets*, **Angew. Chem. Int. Ed.** 2008, 47, 2188-2207. Ions, Baytekin, Grzybowski, et al., *The Mosaic of Surface Charge in Contact Electrification*, **Science** 2011, 333, 308-312.



Electrons: Liu and Bard, *Electrostatic electrochemistry at insulators*, **Nat. Mater.** 2008, 7, 505–509.



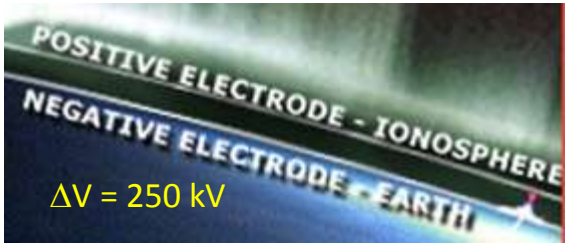
Ions, Mass Transfer: Burgo, Galembeck et al., *Triboelectricity: Macroscopic charge patterns formed by self-arraying ions on polymer surfaces.* **Langmuir** 2012.



Critical analysis: Meurig W. Williams (2012)
American Scientist 2012, 100(4), 316-325.
Feature Article: What Creates Static Electricity?

"Traditionally considered a physics problem, the answer is beginning to emerge from chemistry and other sciences."

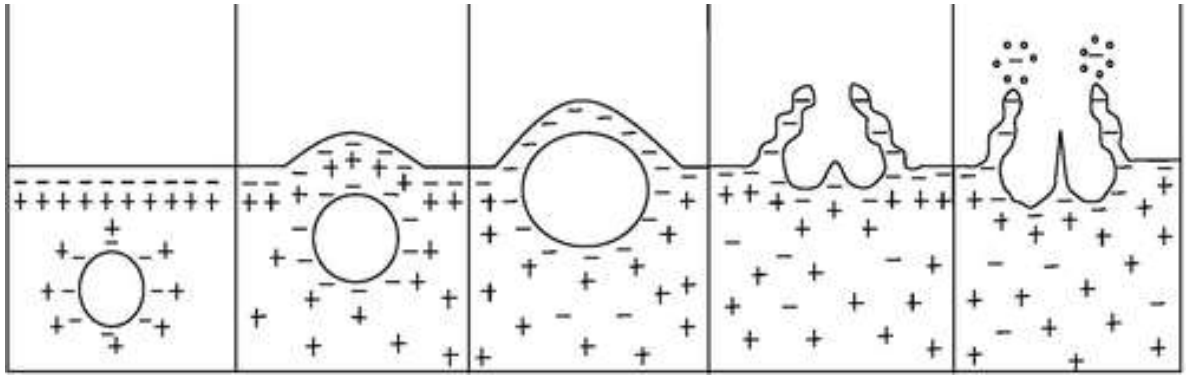
Electroneutrality: exception, not the rule



- "Electroneutrality principle: The principle expresses the fact that all pure substances carry a net charge of zero." (IUPAC Gold Book)
  - Can only happen under zero electric potential: $\mu_- = \mu_-^\circ + RT (\ln x_-) + zFV$
  - Pauling's Electroneutrality Principle of molecular structure: unduly extrapolated to macroscopic matter in introductory science courses.
- Charge partition and accumulation are expected in any interface: Maxwell-Wagner-Sillars effect.
- Charge patterns are observed in any material system.
- The discovery tools: Kelvin electrode, Kelvin force microscopy and other techniques derived from AFM.

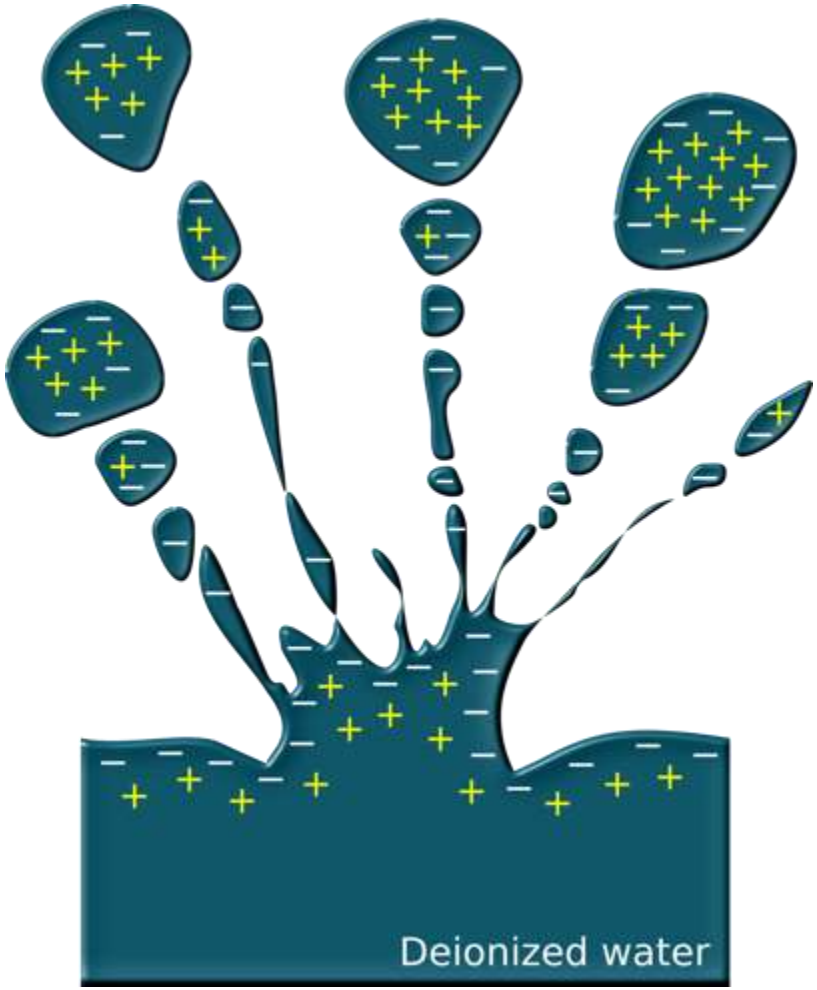
Is water electroneutral? Seldom.

- Ovchinnikova, K.; Pollack, G. H. *Langmuir* 2009, 25, 542: **Can water store charge?**
- Corti, H. R.; Colussi, A. J. *Langmuir* 2009, 25, 6587: criticism to Pollack.
- Amin, M. S.; Peterson, T. F.; Zahn, M. *J. Electrostatics* 2006, 64, 424: **water from different sources carries excess negative charge.**
- McCarty, L. S.; Whitesides, G. M. *Angew. Chem. Int. Ed.* 2008, 47, 2188: **non-electroneutrality should be considered.**
- I. Bhattacharyya, J. T. Maze, G. E. Ewing,* and M. F. Jarrold*, *J. Phys. Chem. A*, 2011, *115*, 5723: **bursting droplets are negative.**



Water and electricity

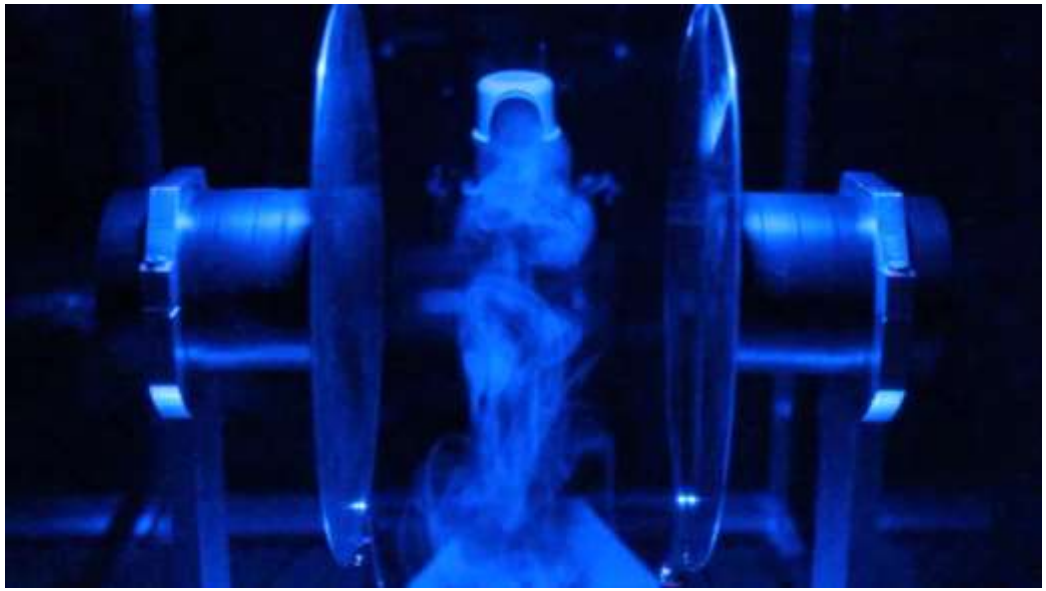
- Steam electricity
  - Discovered in 1840 by Lord Armstrong: vapor is charged opposite to the remaining liquid.
    - M. Faraday, Phil. Trans. 1843, 133, 17.
- Schrödinger (Ph.D. Thesis)
  - Passive role for water in static electricity dissipation
- Water ion partition at interfaces
  - Gas bubbles and pure hydrocarbon drops in water hold negative charge
    - Beattie, J. K. *Angew. Chem. Int. Ed.* 2004, 43, 3568. Marinova, K. G. *Langmuir* 1996, *12*, 2045. Healy, T. W.; Fuerstenau, D. W. *J. Colloid Interface Sci.* 2007, 309, 181. I. Bhattacharyya et al., *J. Phys. Chem. A*, 2011, *115*, 5723.
  - Kelvin dropper
    - http://ocw.mit.edu/...demonstration: kelvin water dropper

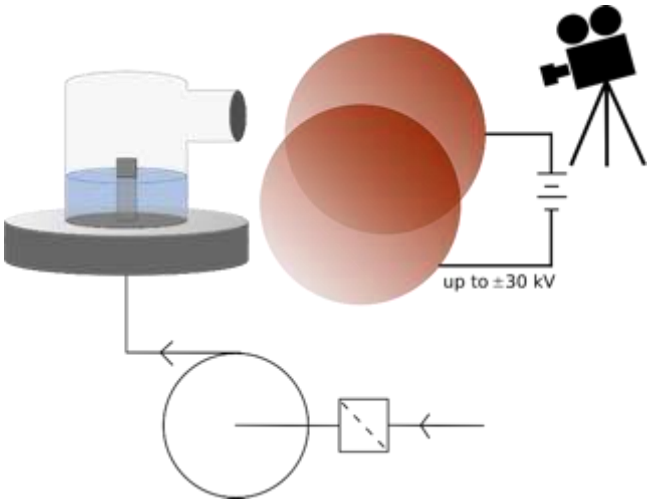


Charge separation due to H_2O partition at interfaces

- expansion of wet steam:
  - J. Finke, J. Electrostat. 1989, 23, 69.
- adsorption-desorption:
  - R. F. Gouveia and F. Galembeck, J. Am. Chem. Soc. 2005; J. Phys. Chem C 2005, 2008; Anal. Chem. 2011.
- water ion partition:
  - T. A. L. Burgo, F. Galembeck, G. H. Pollack, J. Electrost. 2016, 80, 30–33; T. R. D. Ducati, L. H. Simões, F. Galembeck, Langmuir 2010, 26, 13763–13766; T. A. L. Burgo, F. Galembeck, J. Braz. Chem. Soc. 2016, 27, 229–238; T. A. L. Burgo, T. T. D. Ducati, K. R. Francisco, K. J. Clinckspoor, F. Galembeck, S. E. Galembeck, Langmuir 2012, 28, 7407–7416
- splashing and bubble breaking:
  - P. Lenard, Ann. Phys. 46, 584, 1892; Z. Levin, P. V. Hobbs, Phil. Trans. 269, 555, 1971. P. Kolarž et al., Atmos. Chem. Phys. 2012, 12, 3687. I. Bhattacharyya et al., J. Phys. Chem. A 2011, 115, 5723. T. L. Burgo et al., Coll. Interf. Sci. Comm. 2015, 7, 7-11

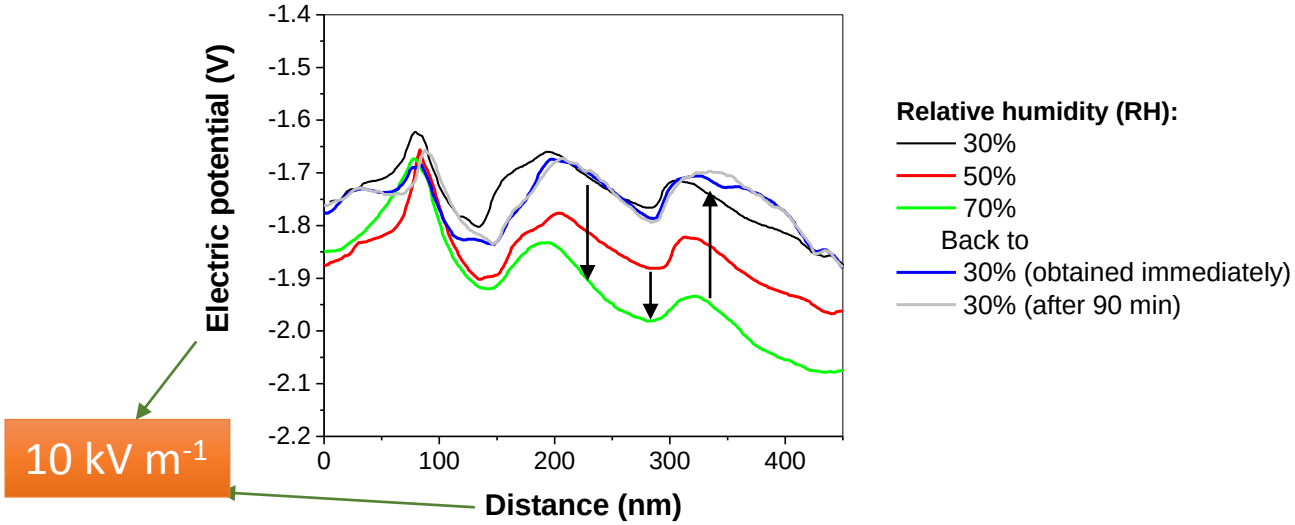
Charge on Aerosol
Positive + negative droplets





Aerosol	Collected liquid weight (g)	
	Electrode (+)	Electrode (-)
Deionized water	0.053± 0.025	0.139 ±0.040
NaCl solution	0.205± 0.066	0.085± 0.017

Water vapor adsorption contributes charge to solids

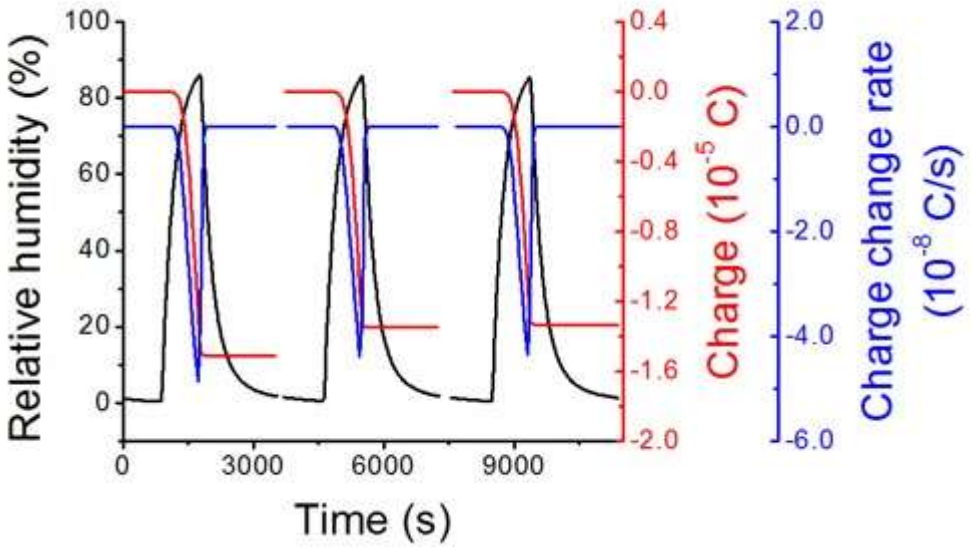


Stöber silica is more negative under high humidity. Reversible.
Atmosphere is a charge reservoir for insulators.

Gouveia, R. F.; Galembeck, F. *J. Am. Chem. Soc.* 131(32), 2009, 11381

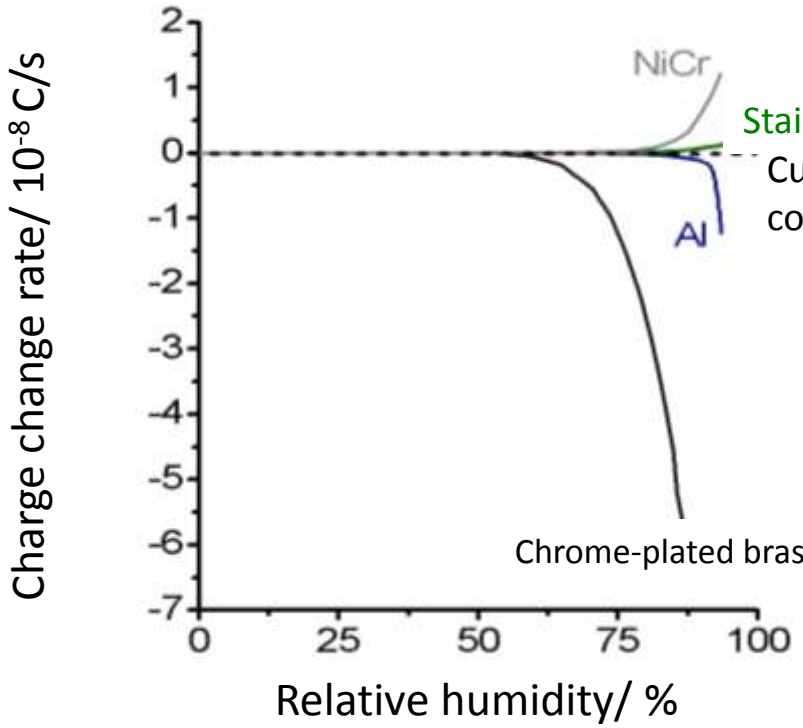
Water vapor adsorption contributes charge to isolated metals

Chrome-plated brass cylinders acquire negative charge under high humidity



"Charge Partitioning at Gas-Solid Interfaces: Humidity Causes Electricity Buildup on Metals"
Telma R. D. Ducati, Luís H. Simões, Fernando Galembeck. *Langmuir*, **2010**, *26*, 13763-13766.

Water vapor adsorption contributes charge to isolated metals



Charge pick-up by isolated metals within a Faraday cup

"Charge Partitioning at Gas-Solid Interfaces: Humidity Causes Electricity Buildup on Metals"
Telma R. D. Ducati, Luís H. Simões, Fernando Galembeck. *Langmuir*, **2010**, *26*, 13763-13766.

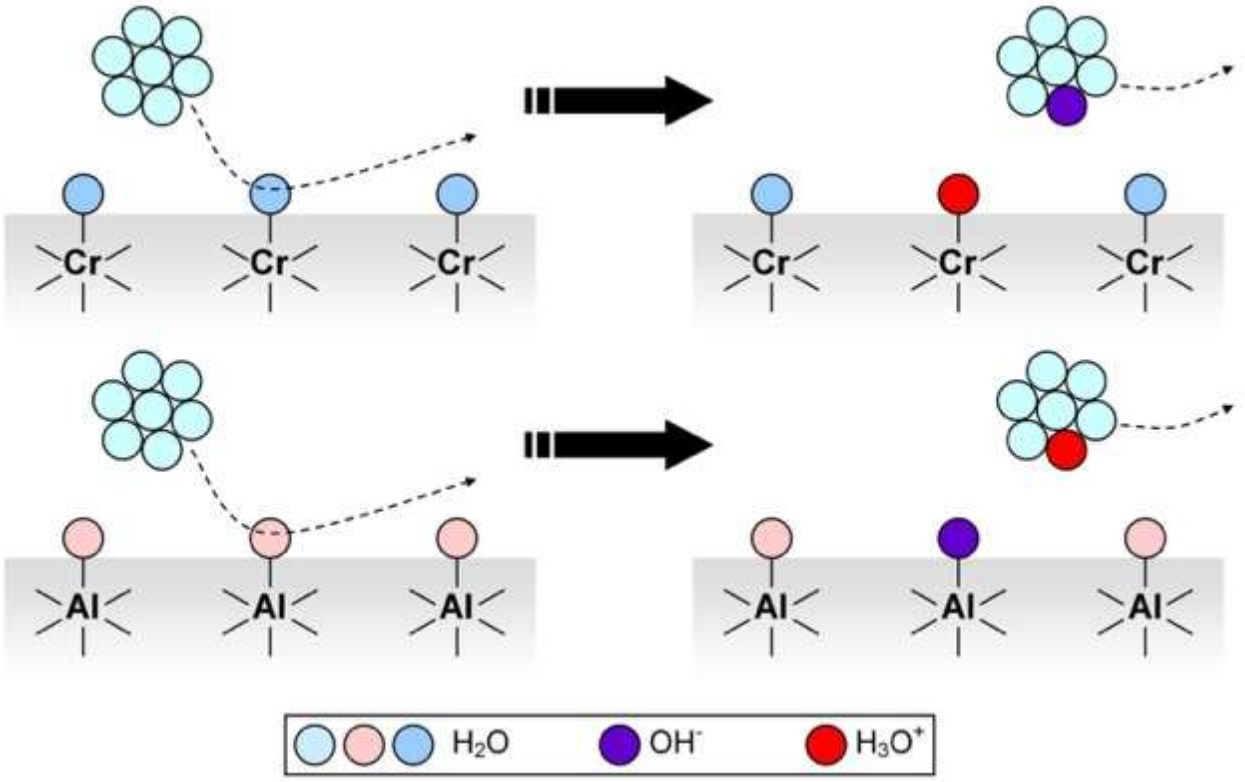
Acidic surfaces become more negative when the humidity changes from 30 to 70%

Basic surfaces become more positive.

Substance	ΔV_m	$(\Delta V)^2_m$	$(\Delta V_m)^2/(\Delta V)^2_m$	
Iron oxide@Fe	-0.464 ± 0.004	0.217 ± 0.004	0.99	Acid
Magnesium sulfate	-0.229 ± 0.008	0.063 ± 0.009	0.83	Acid
Silica	-0.172 ± 0.015	0.033 ± 0.005	0.90	Acid
Cellulose	-0.104 ± 0.007	0.011 ± 0.001	0.98	Acid
Aluminum oxide@Al	-0.055 ± 0.016	0.004 ± 0.002	0.76	Acid
Calcium oxide	+1.657 ± 0.11	2.811 ± 0.33	0.98	Base
MgO (30- 50% RH)	+0.195 ± 0.062	0.096 ± 0.021	0.40	Base
Nickel oxide	+0.060 ± 0.017	0.005 ± 0.002	0.72	Base
Aluminum phosphate	+0.039 ± 0.007	0.002 ± 0.001	0.76	Base

R. Gouveia et al. Analytical Chemistry **2012**

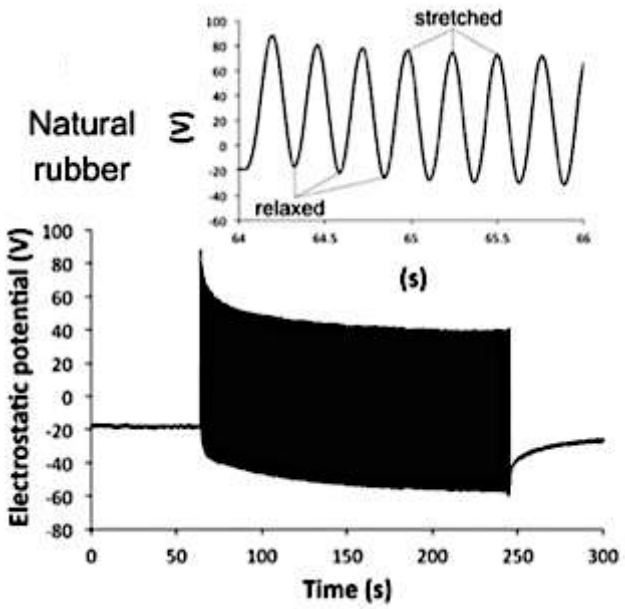
Charge transfer during H_2O adsorption

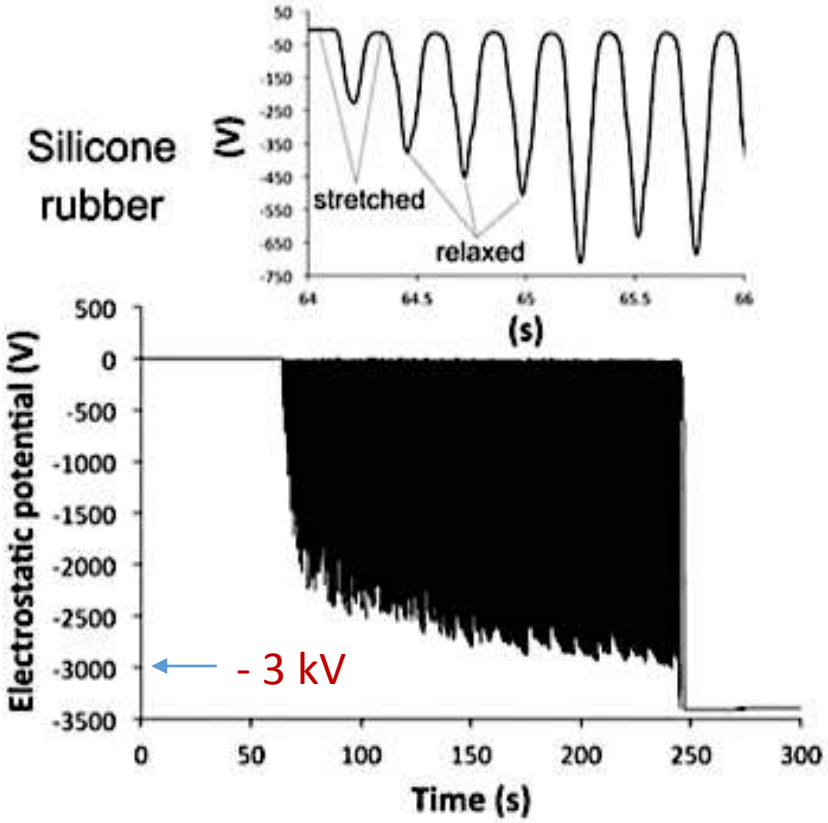


"Charge Partitioning at Gas-Solid Interfaces: Humidity Causes Electricity Buildup on Metals" Telma R. D. Ducati, Luís H. Simões, Fernando Galembeck. *Langmuir*, **2010**, *26*, 13763-13766.

Elastoelectricity

Periodically stretched rubber tubing shows potential variation in phase with length.



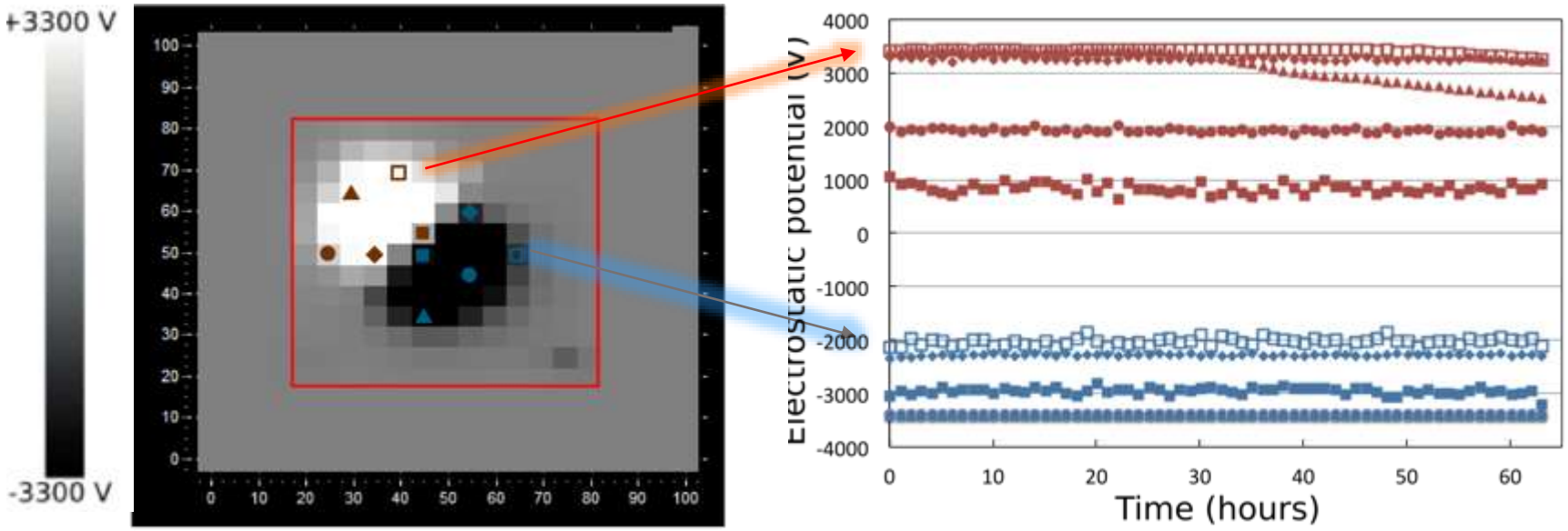


Stretching rubber exposes and hides sub-surface groups that adsorb water acquiring excess charge.

A capacitor is charged.

Burgo, Batista, Galembeck, ACS Omega (2018).

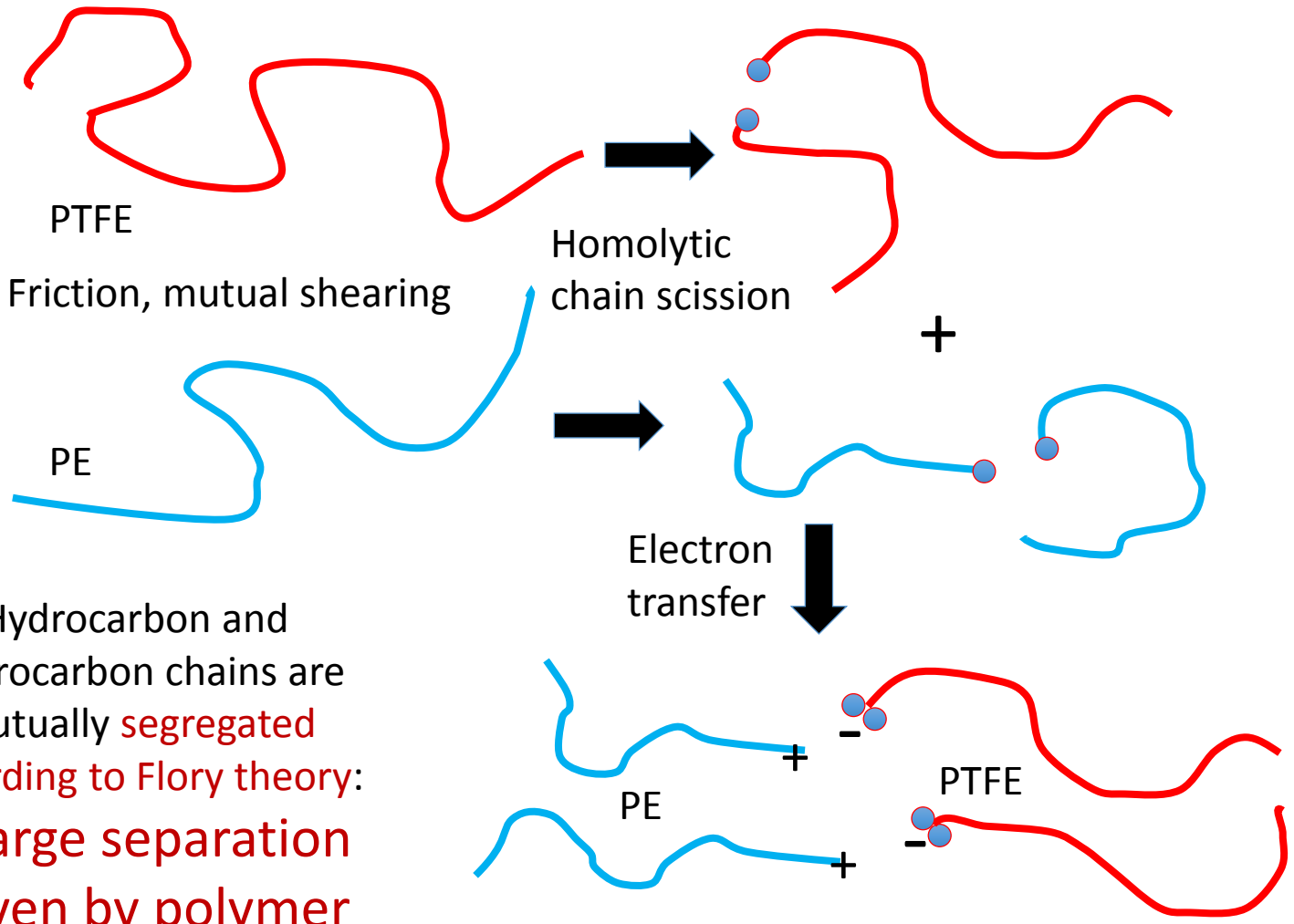
Charge produced by friction: PTFE rubbed with LDPE foam



Formation of positive AND negative charges on the same surface.

Chalenges the paradigm of unidirectional charge transfer in contacting solids.

How? mechanochemical mechanism for triboelectricity

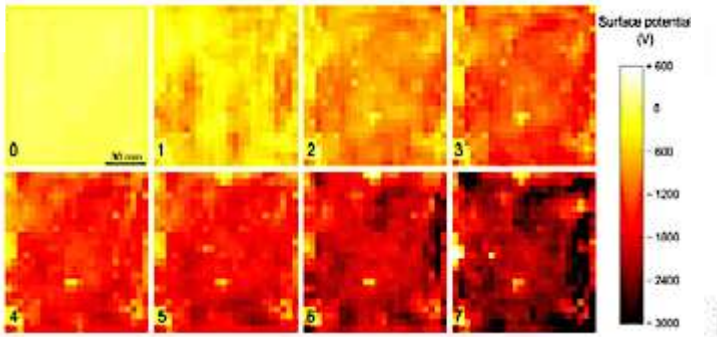


Hydrocarbon and fluorocarbon chains are mutually segregated according to Flory theory:

charge separation driven by polymer immiscibility

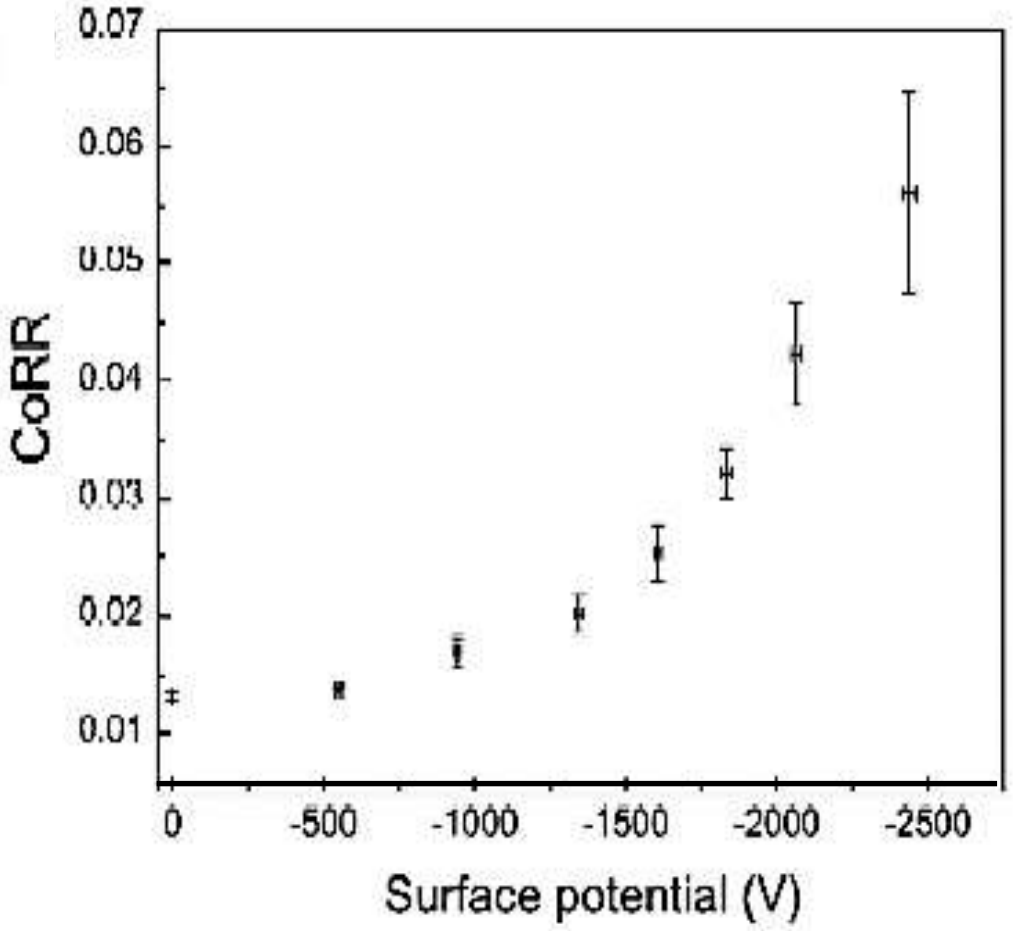
Burgo et al., *Langmuir* 28, (2012) 7407-7416

Feeding back: friction creates charge that increases friction coefficients

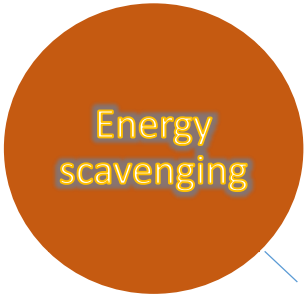


T. A. L. Burgo, C. A. Silva, L. B. S. Balestrin & F. Galembeck

Scientific Reports 3 (2013) 2384



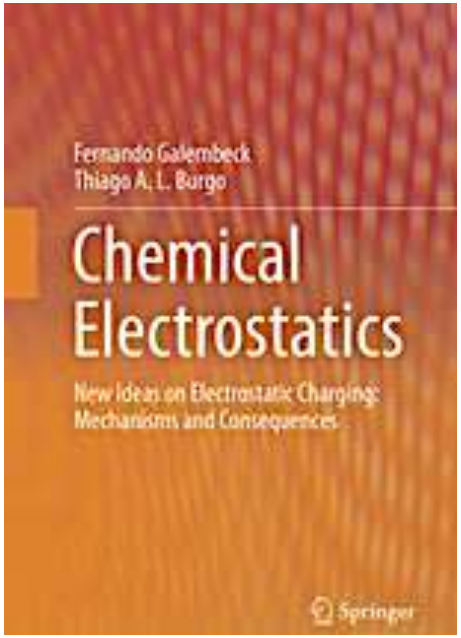
Outlook



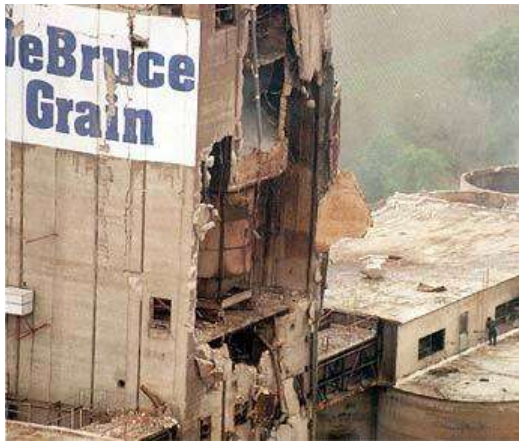
New,
understanding of
the mechanisms for
electrostatic
charging

Electrostatics is Alive, Again

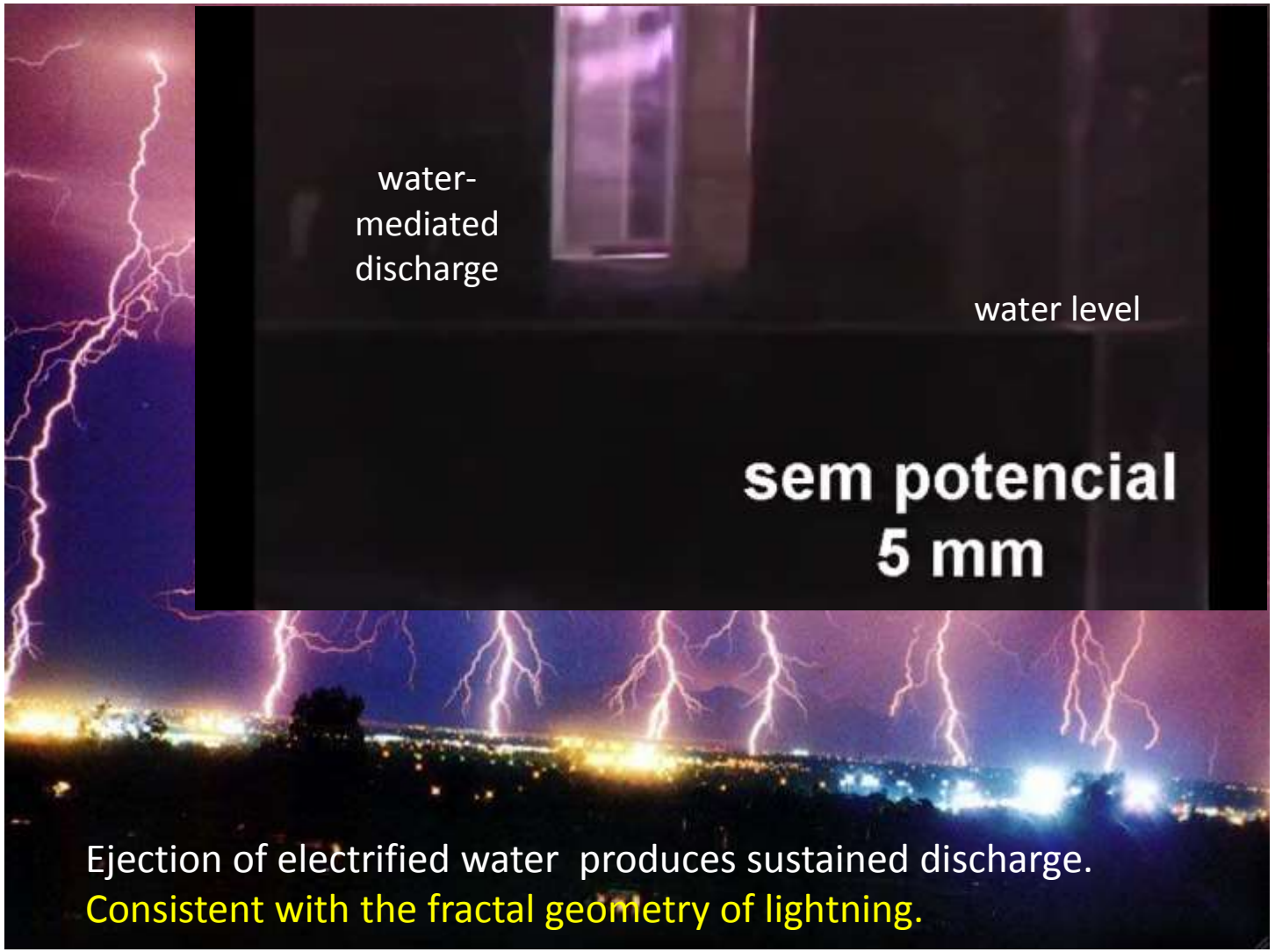
- We live in an electrified environment
- Electricity is produced within the Earth capacitor
- Electroneutrality is the exception, anywhere
- The charge carriers
- Chemical electrostatics
- The atmosphere is a charge reservoir
- Fires, explosions, safety
- Outlook: new science, new technology



Explosions triggered by electrostatic discharge



The first dust explosion that was outlined in a world literature occurred in 14 December 1785 in Italy.
Turin Science Academy noticed that it was an explosion of flour dust in the centre of Turin.
According to literature all building was destroyed.
Reported by Rafal Porowski from HQ of SFS. http://www.ppoz.pl/wwwold/current.htm



Ejection of electrified water produces sustained discharge.
Consistent with the fractal geometry of lightning.

Acknowledgements

André Herzog
André Galembeck
Bruno Batista
Carlos Alberto Costa
Camila Resende
Carlos Alberto Leite
Douglas Soares
Elisa Ferreira
Fabio Bragança
Jeferson Santos
João Paulo Bertacchi
Juliana Bernardes
Juliane Santos
Leandra Santos
Leonardo Valadares
Lia Beraldo Balestrin
Lucimara Lopes
Lucas Soares
Márcia Rippel
Melissa Braga
Pompeu Abreu Filho
Rubia Gouveia
Telma Doi Ducati
Thiago Burgo
Victor Chida
Maria do Carmo da Silva

Aldo Zarbin (UFPr), Steven Armes (Sussex), Gerd Kaupp (Oldenburg), P. Somasundaran (Columbia), K. Kurihara (Tohoku), Lay-Theng Lee (Gif), B. Vincent (Bristol)

INCT Program grant to **Inomat (Institute for Functional Complex Materials)**
Grants and fellowships from **Fapesp, CNPq, Finep and Capes**

Bunge, Cameron, Odebrecht Agro, Orbys, Oxiteno, Pirelli, Unilever.

SBQ, SBPMat/BMRS, ABPol, IACIS, ABC, ESA, RSC, ACS, IOP

A note on policy (II)

- Is money being spent where it should?
  - Little, poor diagnosis. Poor decisions on project implementation.
- Lack of assessment.
  - Results of the largest funding body in the country (FNDCT) do not even have a definite assessment methodology.
  - Poor planning
- Result: huge sums spent in facilities and equipment that do not provide the basis for the introduction of much-needed public policies.