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Quantum Field Coherences

Quantum Electro- and Quantum Chromo- Dynamic String Excitations

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Coherent Fields and QCD Strings

- The Insoluble Problem of Pure Glue
- The Growth of a Length Scale from Nothing at all
- Color Ferromagnetic and Color Diaelectric Effects
- The Unstable QCD Perturbative Vacuum
- String Excitations

Coherent Fields and Polar Liquids (Water)

- Mean Field Theory of Ferroelectric Liquids
- Domains and Ferroelectric Ordering
- Dynamical Field Equations

Pure Glue in the Vacuum I

Color matrices $\{T_a\}$ obey a Lie group algebra. The glue is then described by electric ***E*** and magnetic ***B*** fields.

$$\mathbf{E} = \sum_a \mathbf{E}^a T_a$$

$$\mathbf{B} = \sum_a \mathbf{B}^a T_a$$

$$[T_a, T_b] = i \sum_c f^c{}_{ab} T_c$$

$$Div\, \mathbf{B} = 0$$

$$Div\, \mathbf{E} = 0$$

$$D_t \mathbf{B} = -c\, Curl\, \mathbf{E}$$

$$D_t \mathbf{E} = c\, Curl\, \mathbf{B}$$

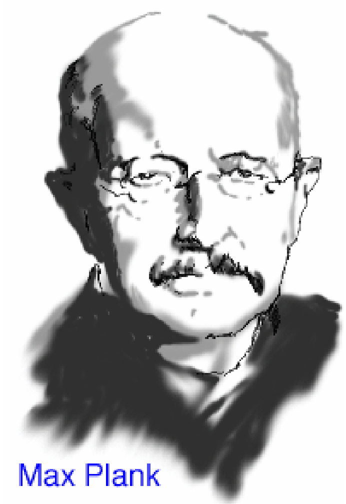
The vector operations "*Div*" and "*Curl*" and the time derivative D_t are nonlinear in the vacuum glue field equations.

Pure Glue in the Vacuum II

$$u = \frac{1}{2}\sum_a \left(\mathbf{E}^a \cdot \mathbf{E}_a + \mathbf{B}^a \cdot \mathbf{B}_a\right)$$

$$\mathbf{P} = \frac{1}{2}\sum_a \left(\mathbf{1}(\mathbf{E}^a \cdot \mathbf{E}_a + \mathbf{B}^a \cdot \mathbf{B}_a) - 2\mathbf{E}^a\mathbf{E}_a - 2\mathbf{B}^a\mathbf{B}_a\right)$$

$$u = tr\mathbf{P} = 3P$$



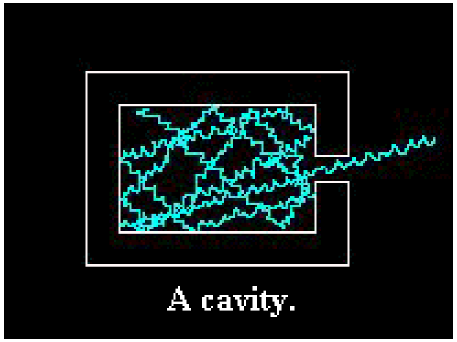
Max Plank

The energy density u and pressure P formally obey u=3P which is sufficient for obeying a Planck law for “Black Body” gluons.

$$u \propto \frac{(k_B T)^4}{(\hbar c)^3}$$

Such thermal activation of glue implies that when you cook food in an oven using (say) microwave photons, you should also be cooking the food partly in glue. This fact would rule out QCD experimentally. You cannot experimentally cook food with glue in known laboratory ovens!

Pure Glue in the Vacuum III



There must be a gap in energy (i.e. energy cost) before one can form glue in a black body oven (cavity) with walls at earthly temperatures.

A mathematical proof of an energy (i.e. mass) gap required to form glue yields a millennium mathematics prize of one million dollars collectable from the Clay Mathematics Institute (http://www.claymath.org/millennium/)

The details of the mathematical QCD conjecture are discussed in the Clay Mathematics Institute report on Yang Mills theory.

Pure Glue in the Vacuum IV

The energy gap Δ or mass gap μ or spontaneous length Λ scale are all equivalent.

$$\Delta = \mu c^2 = \frac{\hbar c}{\Lambda}$$

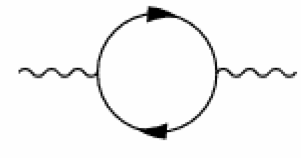
Giuliano Preparata

The spontaneously grown length scale is related to a spontaneously grown color "ferromagnetic" field B.

$$B \sim \frac{\sqrt{\hbar c}}{\Lambda^2}$$

Running Coupling Strength I

Quantum Electrodynamic Vacuum Screening



$\varepsilon(Q^2)$ = dielectric response function

$\mu(Q^2)$ = magnetic permeability function

$$\alpha(Q^2) = \frac{e^2}{4\pi\hbar c\,\varepsilon(Q^2)} = \frac{e^2\mu(Q^2)}{4\pi\hbar c}$$

Quantum Electrodynamic Spectral Representation

$$\varepsilon(Q^2) = 1 - \frac{Q^2}{\pi}\int_0^\infty \frac{\rho(s)ds}{s(s+Q^2)}$$

Coulomb Vacuum Screened Potential $\chi(r\to\infty)=1$

$$V(r) = \frac{e^2 Z_1 Z_2}{4\pi r}\chi(r)$$

$$\chi(r) = \frac{2}{\pi}\int_0^\infty \left[\frac{\sin(Qr)}{\varepsilon(Q^2)}\right]\frac{dQ}{Q}$$

The spectral function $\rho(s)$ is non-negative and has non-trivial positive features for a minimum mass squared values $s > s_0$.

Running Coupling Strength II

Quantum Chromodynamic Vacuum Screening

$\varepsilon_s(Q^2)$ = color dielectric response function

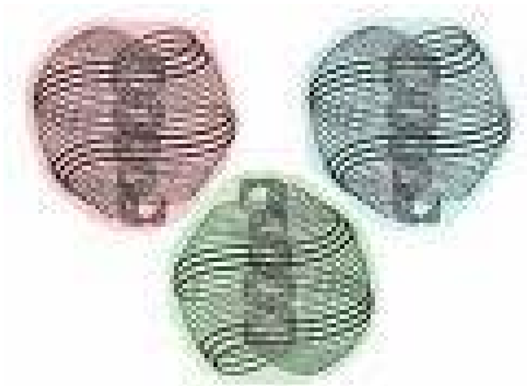
$\mu_s(Q^2)$ = color magnetic permeability function

$$\alpha_s(Q^2) = \frac{g^2}{4\pi\hbar c\,\varepsilon_s(Q^2)} = \frac{g^2\mu_s(Q^2)}{4\pi\hbar c}$$

$$\varepsilon_s(Q^2) = -\frac{Q^2}{\pi}\int_0^\infty \frac{\rho_s(s)ds}{s(s+Q^2)}$$

The perturbation theory QCD spectral function $\rho_s(s)$ has negative values above minimum mass squared values s > s_0. The perturbation theory QCD vacuum is unstable.

Quark Potential



$$V_s(r) = \frac{g^2\eta^{ab}t_{1a}t_{2b}}{4\pi r}\chi_s(r)$$

$$\chi_s(r) = \frac{2}{\pi}\int_0^\infty \left[\frac{\sin(Qr)}{\varepsilon_s(Q^2)}\right]\frac{dQ}{Q}$$

$$\chi_s(r\to\infty) = -\frac{r^2}{L^2}$$

Running Coupling Strength III

The length scale *L* is related to the quark-quark potential QCD "string tension" σ.

$$V_s(r) \approx -\eta^{ab} t_{1a} t_{2b} \left(\sigma r - \frac{g^2}{4\pi r} \right)$$

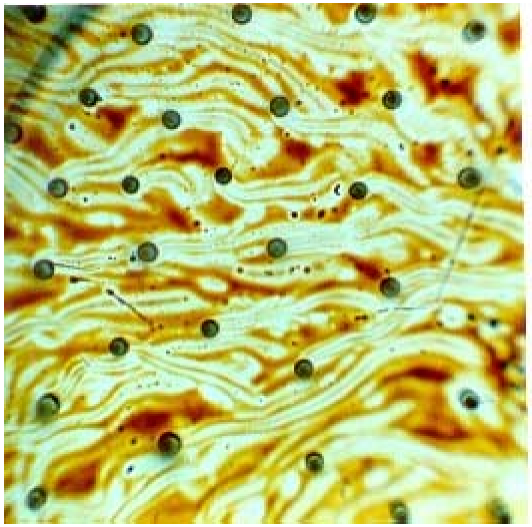
$$\sigma = \frac{g^2}{4\pi L^2}$$

Color Electric Field Viewpoint: Diaelectric Response

$$L^2 = \lim_{Q^2 \to 0} \left(\frac{2\varepsilon_s(Q^2)}{Q^2} \right)$$

Color Magnetic Field Viewpoint: Ferromagnetic Response

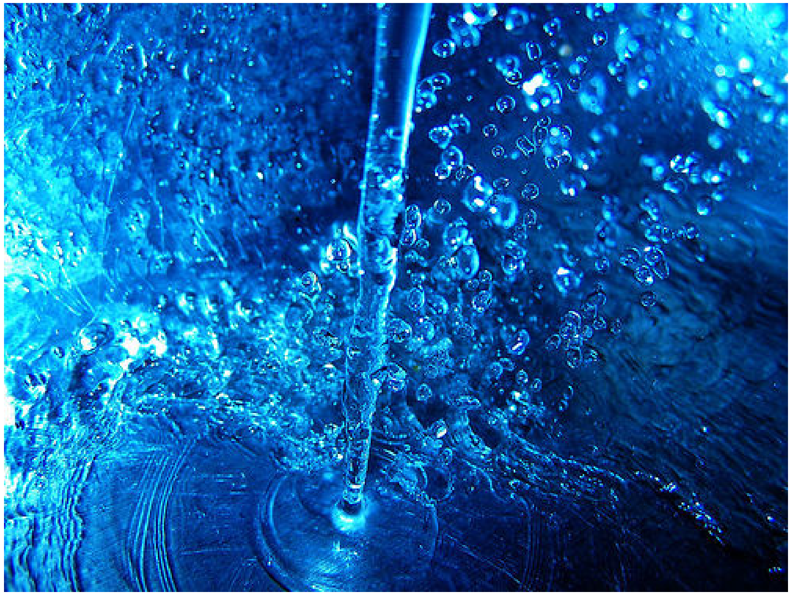
$$\frac{1}{L^2} = \lim_{Q^2 \to 0} \left(\frac{Q^2 \mu_s(Q^2)}{2} \right)$$

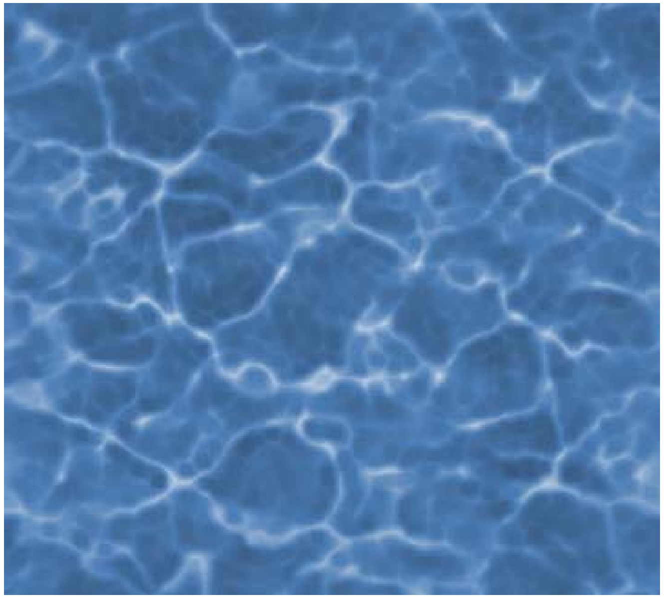


Nuclear Matter as Quarks and QCD Strings

The magnetic and electric views are equivalent: $\varepsilon_s \mu_s = 1$

QED Ordered Domains in Water





Mean Field Theory I: Static

liquid ferroelectric: free energy per unit volume $f(\mathbf{P},T)$

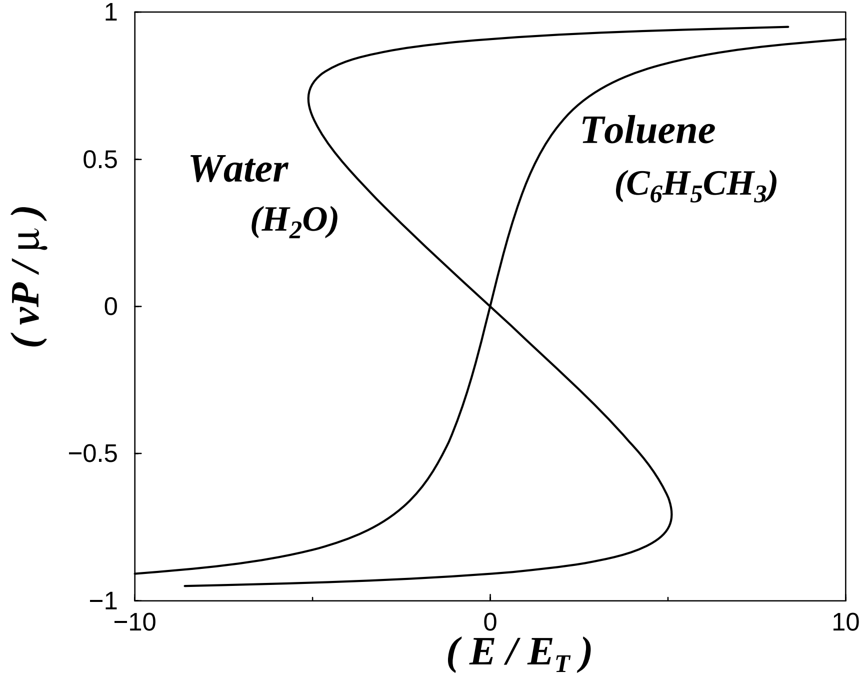
$$df = -sdT + \mathbf{E}\cdot d\mathbf{P}$$

I: Local Electric Field

$$\mathbf{F} = \mathbf{E} + \frac{4\pi}{3}\mathbf{P}$$

II: Molecular Dipole Moment $\mathbf{p}$

$$\mathbf{P} = \mathbf{p}(\mathbf{F},T)/v$$



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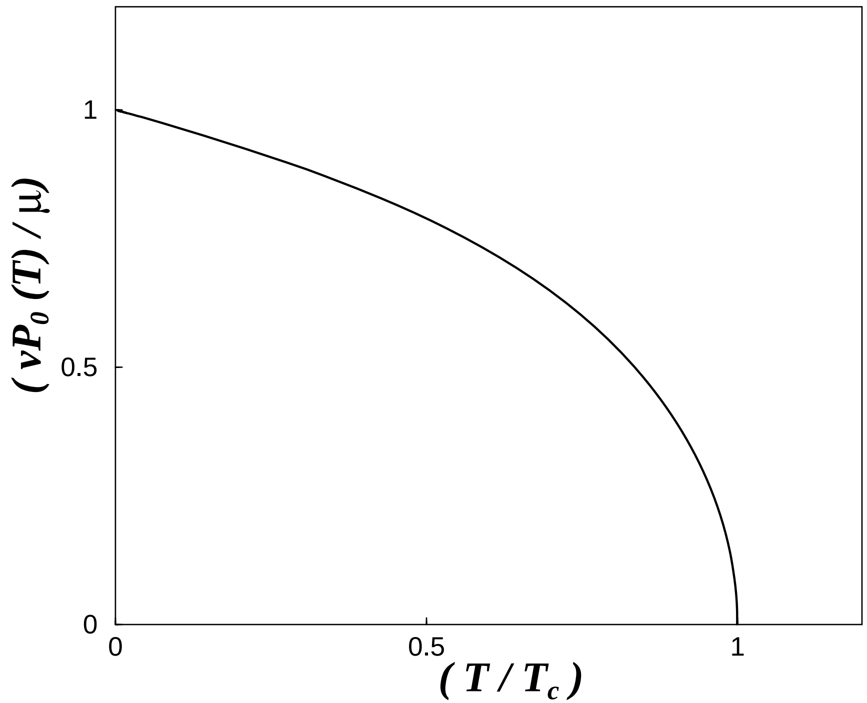
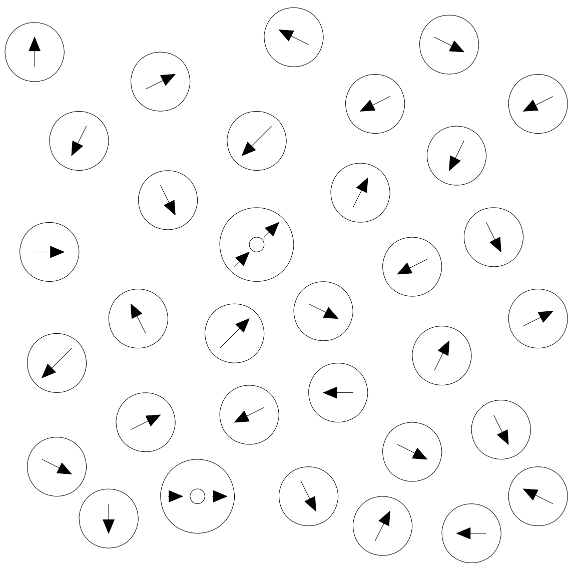
Mean Field Theory II: Static





Net Polarization

Domains

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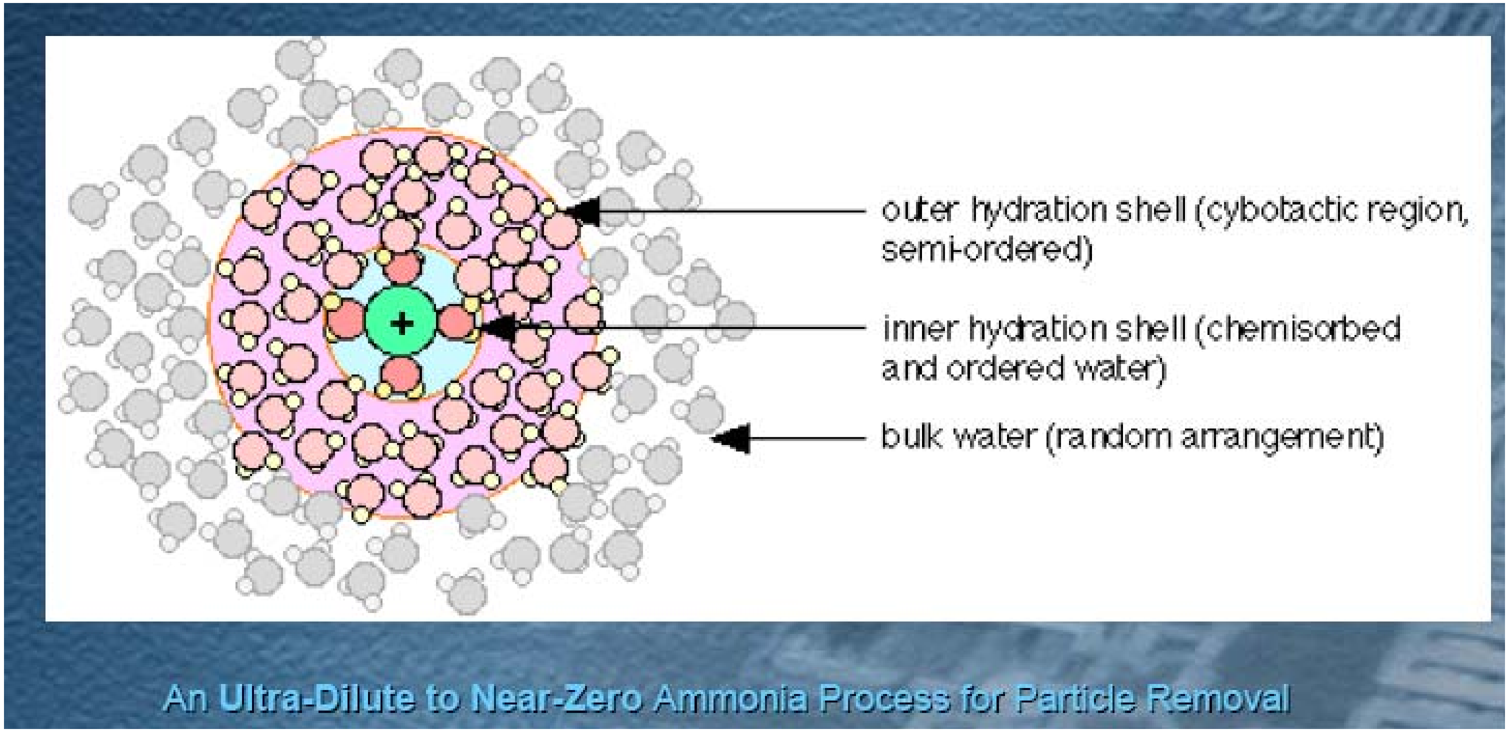
Mean Field Theory III: Static

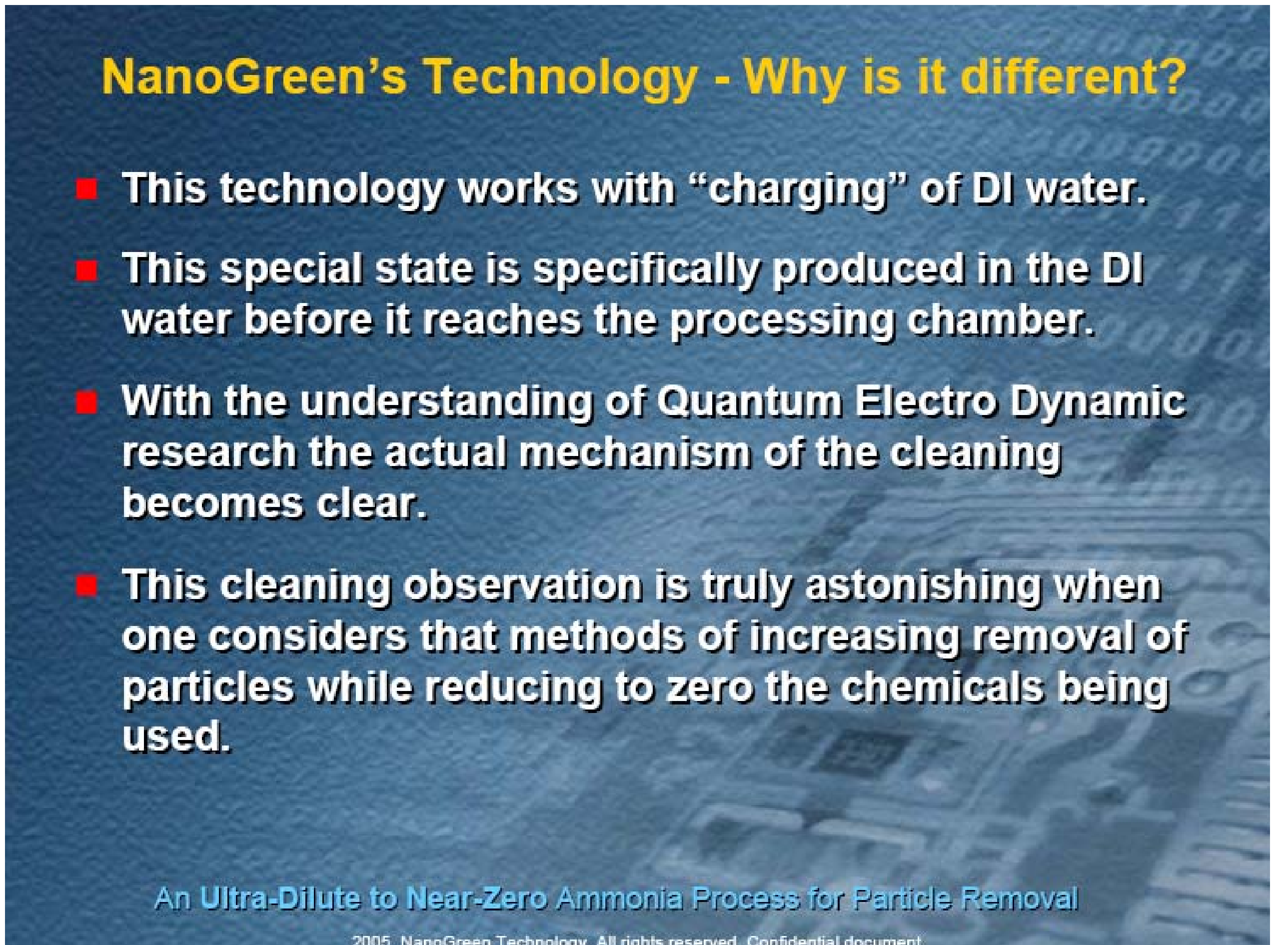
Nano Green Technology (Livermore California)

Patent Claim to NH_3 insertion into water domains which are then used to clean microelectronic circuit wafer substrates.



Mean Field Theory IV: Static

Shown are Claims of Nano Green Technology (Livermore California)



Dynamic Equations I:

Dynamical field coherence in water was introduced by G. Vitiello, E. Del Guidice and G. Preparata and the dynamical coherence equation implications are still being worked out by G. Vitiello and E. Del Guidice. What follows is a perhaps simplified treatment.

Consider a domain of volume V containing charged particles $\{q_a = Z_a e\}$.

$$\mathbf{P} = \frac{e}{V}\sum_a Z_a \mathbf{r}_a$$

Polarization

$$\mathbf{J} = \frac{\partial \mathbf{P}}{\partial t} = \frac{e}{V}\sum_a Z_a \mathbf{v}_a$$

Current Density

Dynamic Equations II:

$$\frac{\partial \mathbf{J}}{\partial t} = \frac{\partial^2 \mathbf{P}}{\partial t^2} = \frac{e}{V} \sum_a Z_a \frac{d\mathbf{v}_a}{dt}$$

$$M_a \frac{d\mathbf{v}_a}{dt} = Z_a e \mathbf{E}_a$$

$$\frac{\partial^2 \mathbf{P}}{\partial t^2} = \frac{e^2}{V} \sum_a \frac{Z_a^{\ 2}}{M_a} \mathbf{E}_a$$

$$\Omega^2 = \frac{4\pi e^2}{V} \sum_a \frac{Z_a^{\ 2}}{M_a}$$

Plasma frequency Ω dominated by electrons with M=m and Z=-1.

Polarization Dynamics

$$\frac{\partial^2 \mathbf{P}}{\partial t^2} = \frac{\Omega^2}{4\pi} \overline{\mathbf{E}}$$

$$\overline{\mathbf{E}} = \mathbf{E} - \frac{\partial f(\mathbf{P}, T)}{\partial \mathbf{P}} - \rho \mathbf{J}$$

The mean electric field is made up of an applied electric field E, a resistivity ρ term and a nonlinear thermal electric field obtained from domain free energy per unit volume term *f(P,T)*.

Dynamic Equations III:

$$\frac{4\pi}{\Omega^2}\frac{\partial^2 \mathbf{P}}{\partial t^2} + \rho \frac{\partial \mathbf{P}}{\partial t} + \frac{\partial f(\mathbf{P},T)}{\partial \mathbf{P}} = \mathbf{E}$$

This is the Khalatnikov dynamical equation of motion applied to water domains driven by an electric field. It is physically equivalent to the Vitiello - Del Guidice field coherent dynamic equations of motion.

$$\mathbf{E} = \frac{\partial f(\mathbf{P},T)}{\partial \mathbf{P}}$$

Thermal Equilibrium

$$df = -s dT + \mathbf{E} \cdot d\mathbf{P}$$

Employing the full nonlinear free energy *f(*P*,T)* allows for stable solutions of the dynamics. There are no “runaway” solutions.

Conclusions

Coherent Fields and QCD Strings

- The Problem of Pure Glue and the Color Magnetic Field is unsolved.
- The Growth of a QCD Length Scale from Nothing at all is also unsolved.
- The QCD perturbative vacuum is unstable.
- The QCD string is useful for describing quark-quark interactions.

Coherent Fields and Polar Liquids

- There are coherent domains in water.
- Mean Field Theory shows that the domains are ferroelectric.
- The domains are of use for applications in nano technology.
- The full dynamical equations will soon have engineering applications.