Ultrafast Conversion of Graphite to Diamond in Gravitational Pressure Apparatus

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Currently the artificial production of diamond is very expensive because it consumes large amounts of energy in order to produce a single diamond. Here, we propose a new type of press based on the *intensification of the gravitational acceleration*. This Gravitational Press can generate pressures several times more intense than the *80GPa* required for *ultrafast transformation of graphite into diamond*. In addition, due to the enormous pressure that the Gravitational Press can produce, the "synthesis capsule" may be very large (up to about 1000 cm^3 in size). This is sufficient to produce diamonds with up to 100 carats (20g) or more. On the other hand, besides the ultrafast conversion, the energy required for the Gravitational Presses is very low, in such a way that the production cost of the diamonds becomes very low, what means that they could be produced on a large scale.

Key words: Modified theories of gravity, High-pressure apparatus, Graphite, Diamond.
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1. Introduction

After the discovery that diamond was pure carbon, many attempts were made to convert various carbon forms into diamond. Converting graphite into diamond has been a long held dream of alchemists. The artificial production of diamond was first achieved by H.T Hall in 1955. He used a press capable of producing pressures above 10 GPa and temperatures above 2,000 °C [1].

Today, there are several methods to produce synthetic diamond. The more widely utilized method uses high pressure and high temperature (HPHT) of the order of 10 GPa and 2500°C *during many hours* in order to produce a single diamond. The fact that this process requires high pressure and high temperatures *during a long time* means that it consumes large amounts of energy, and this is the reason why the production cost of artificial diamond is so expensive. The second method, using chemical vapor deposition (CVD), creates a carbon plasma over a substrate onto which the carbon atoms deposit to form diamond. Other methods include explosive formation and sonication of graphite solutions [2,3,4].

In the HPHT method, there are three main press designs used to supply the pressure and temperature necessary to produce synthetic diamond: the *Belt press*, the *Cubic press* and the split-sphere (*BARS*) press. Typical pressures and temperatures achievable are of the order of 10 GPa and 2500°C [5].

Diamonds may be formed in the Earth's mantle mainly by direct transition, graphite to diamond or by systems involving carbon dissolved in molten metals. The classic high-pressure, high-temperature synthesis of diamond utilizes molten transition metals as solvent/catalysts. *Converting diamond from graphite in the absence of a catalyst requires pressures that are significantly higher than those at equilibrium coexistence* [6-12]. At lower temperatures, the formation of the metastable hexagonal polymorph of diamond is favored instead of the more stable cubic diamond [7, 10-12]. These phenomena cannot be explained by the concerted mechanism suggested in previous theoretical studies [13-17]. However, recently Michele Parrinello, Professor of Computational Science at ETH Zurich, and his team have developed a method by which they have successfully simulated this phase transition accurately and adequately using computer models [18]. Instead of happening concerted, all at once, the conversion evidently takes place in a step by step process involving the formation of a

diamond seed in the graphite, *which is then transformed completely at high pressure*. In quantitative agreement with the *ab initio* calculations of Tateyama at al. [19], the stability of diamond relative to graphite increases with pressure whereas the barrier separating two phases decreases. Parrinello's work shows that *at a pressure of 80 GPa and temperature between* 0 *and* 1,000*K graphite* reaches a lattice instability point and *undergoes an ultrafast transformation to diamond* as was previously observed in *ab initio* simulations by Scandolo et al [20].

Here, we propose a new type of press based on the *intensification of the gravitational acceleration*[*]. This press can generate pressures several times more intense[†] than the *80GPa* required for the *ultrafast transformation of graphite to diamond*. In addition, due to the enormous pressure that the Gravitational Press can produce (*>>80GPa*), the ceramic cube ("synthesis capsule") can be very large (up to about 1000 cm^3 in size). This is sufficient to produce diamonds up to 100 carats (20g) or more. On the other hand, besides the ultrafast conversion, the energy required for the Gravitational Presses is very low, in such a way that the production cost of the diamonds becomes very low, what means that they could be produced on a large scale.

2. Theory

From the quantization of gravity it follows that the *gravitational mass* m_g and the *inertial mass* m_i are correlated by means of the following factor [21]:

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1+\left(\frac{\Delta p}{m_{i0}c}\right)^2} - 1\right]\right\} \qquad (1)$$

where m_{i0} is the *rest* inertial mass of the particle and Δp is the variation in the particle's *kinetic momentum*; c is the speed of light.

When Δp is produced by the absorption of a photon with wavelength λ, it is expressed by $\Delta p = h/\lambda$. In this case, Eq. (1) becomes

$$\frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1+\left(\frac{h/m_{i0}c}{\lambda}\right)^2} - 1\right]\right\} = \left\{1 - 2\left[\sqrt{1+\left(\frac{\lambda_0}{\lambda}\right)^2} - 1\right]\right\} \qquad (2)$$

where $\lambda_0 = h/m_{i0}c$ is the *De Broglie wavelength* for the particle with *rest* inertial mass m_{i0}.

It has been shown that there is an additional effect - *Gravitational Shielding* effect - produced by a substance whose gravitational mass was reduced or made negative [22]. This effect is that just *beyond* the substance the gravity acceleration g_1 is reduced at the same proportion $\chi_1 = m_g/m_{i0}$, i.e., $g_1 = \chi_1 g$, (g is the gravity acceleration *before* the substance). Consequently, *after a second gravitational shielding*, the gravity will be given by $g_2 = \chi_2 g_1 = \chi_1 \chi_2 g$, where χ_2 is the value of the ratio m_g/m_{i0} for the *second* gravitational shielding. In a generalized way, we can write that after the *nth* gravitational shielding the gravity, g_n, will be given by

$$g_n = \chi_1 \chi_2 \chi_3 \cdots \chi_n g \qquad (3)$$

This possibility shows that, by means of a battery of gravitational shieldings, we can make particles acquire enormous accelerations. In practice, this is the basis to the conception of the *Gravitational Press*.

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[*] De Aquino, F. (2008) *Process and Device for* Controlling the Locally the Gravitational Mass and the Gravity Acceleration, BR Patent Number: PI0805046-5, July 31, 2008.

[†] The limit is basically determined by the compression resistance of the material of the piston and anvils of the Gravitational Press since it can produce pressures far beyond 1000 GPa.

From Electrodynamics we know that when an electromagnetic wave with frequency f and velocity c incides on a material with relative permittivity ε_r, relative magnetic permeability μ_r and electrical conductivity σ, its *velocity is reduced* to $v = c/n_r$ where n_r is the index of refraction of the material, given by [23]

$$n_r = \frac{c}{v} = \sqrt{\frac{\varepsilon_r \mu_r}{2}\left(\sqrt{1+(\sigma/\omega\varepsilon)^2}+1\right)} \qquad (4)$$

If $\sigma >> \omega\varepsilon$, $\omega = 2\pi f$, Eq. (4) reduces to

$$n_r = \sqrt{\frac{\mu_r \sigma}{4\pi\varepsilon_0 f}} \qquad (5)$$

Thus, the wavelength of the incident radiation (See Fig. 1) becomes

$$\lambda_{\text{mod}} = \frac{v}{f} = \frac{c/f}{n_r} = \frac{\lambda}{n_r} = \sqrt{\frac{4\pi}{\mu f \sigma}} \qquad (6)$$

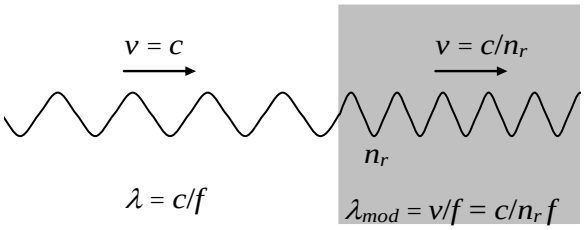

Fig. 1 – *Modified Electromagnetic Wave*. The wavelength of the electromagnetic wave can be strongly reduced, but its frequency remains the same.

If a lamina with thickness equal to ξ contains n atoms/m^3, then the number of atoms per area unit is $n\xi$. Thus, if the electromagnetic radiation with frequency f incides on an area S of the lamina it reaches $nS\xi$ atoms. If it incides on the *total area of the lamina*, S_f, then the total number of atoms reached by the radiation is $N = nS_f\xi$. The number of atoms per unit of volume, n, is given by

$$n = \frac{N_0 \rho}{A} \qquad (7)$$

where $N_0 = 6.02\times10^{26}\, atoms/kmole$ is the Avogadro's number; ρ is the matter density of the lamina (in kg/m^3) and A is the molar mass($kg/kmole$).

When an electromagnetic wave incides on the lamina, it strikes N_f front atoms, where $N_f \cong (nS_f)\phi_m$, ϕ_m is the "diameter" of the atom. Thus, the electromagnetic wave incides effectively on an area $S = N_f S_m$, where $S_m = \frac{1}{4}\pi\phi_m^2$ is the cross section area of one atom. After these collisions, it carries out $n_{collisions}$ with the other atoms (See Fig.2).

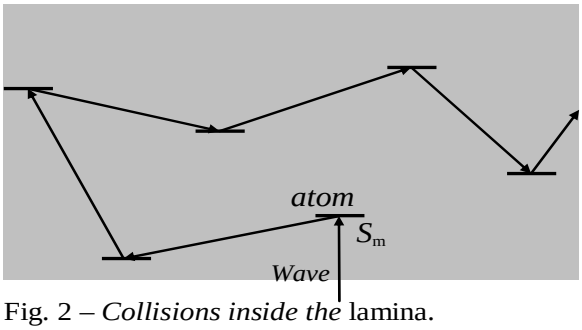

Fig. 2 – *Collisions inside the* lamina.

Thus, the total number of collisions in the volume $S\xi$ is

$$N_{collisions} = N_f + n_{collisions} = n_1 S\phi_m + (n_1 S\xi - n_m S\phi_m) = n_m S\xi \qquad (8)$$

The power density, D, of the radiation on the lamina can be expressed by

$$D = \frac{P}{S} = \frac{P}{N_f S_m} \qquad (9)$$

We can express the *total mean number of collisions in each atom*, n_1, by means of the following equation

$$n_1 = \frac{n_{total\ \ photons}\, N_{collisions}}{N} \qquad (10)$$

Since in each collision a *momentum* h/λ is transferred to the atom, then the *total momentum* transferred to the lamina will be

$\Delta p = (n_1 N)h/\lambda$. Therefore, in accordance with Eq. (1), we can write that

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1-2\left[\sqrt{1+\left[(n_1 N)\frac{\lambda_0}{\lambda}\right]^2}-1\right]\right\} =$$

$$= \left\{1-2\left[\sqrt{1+\left[n_{total\ photons} N_{collisions}\frac{\lambda_0}{\lambda}\right]^2}-1\right]\right\} \quad (11)$$

Since Eq. (8) gives $N_{collisions} = n_l S\xi$, we get

$$n_{total\ \ photons} N_{collisions} = \left(\frac{P}{hf^2}\right)(n_l S\xi) \quad (12)$$

Substitution of Eq. (12) into Eq. (11) yields

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1-2\left[\sqrt{1+\left[\left(\frac{P}{hf^2}\right)(n_l S\xi)\frac{\lambda_0}{\lambda}\right]^2}-1\right]\right\} \quad (13)$$

Substitution of P given by Eq. (9) into Eq. (13) gives

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1-2\left[\sqrt{1+\left[\left(\frac{N_f S_m D}{f^2}\right)\left(\frac{n_l S\xi}{m_{i0(l)}c}\right)\frac{1}{\lambda}\right]^2}-1\right]\right\} \quad (14)$$

Substitution of $N_f \cong (n_l S_f)\phi_m$ and $S = N_f S_m$ into Eq. (14) results

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1-2\left[\sqrt{1+\left[\left(\frac{n_l^3 S_f^2 S_m^2 \phi_m^2 \xi D}{m_{i0(l)}cf^2}\right)\frac{1}{\lambda}\right]^2}-1\right]\right\} \quad (15)$$

where $m_{i0(l)} = \rho_{(l)} V_{(l)}$.

Now, considering that the lamina is inside an ELF electromagnetic field with E and B, then we can write that [24]

$$D = \frac{n_{r(l)} E^2}{2\mu_0 c} \quad (16)$$

Substitution of Eq. (16) into Eq. (15) gives

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1-2\left[\sqrt{1+\left[\left(\frac{n_{r(l)} n_l^3 S_f^2 S_m^2 \phi_m^2 \xi E^2}{2\mu_0 m_{i0(l)} c^2 f^2}\right)\frac{1}{\lambda}\right]^2}-1\right]\right\} \quad (17)$$

In the case in which the area S_f is just the *area of the cross-section of the lamina* (S_α), we obtain from Eq. (17), considering that $m_{i0(l)} = \rho_{(l)} S_\alpha \xi$, the following expression

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1-2\left[\sqrt{1+\left[\left(\frac{n_{r(l)} n_l^3 S_\alpha S_m^2 \phi_m^2 E^2}{2\mu_0 \rho_{(l)} c^2 f^2}\right)\frac{1}{\lambda}\right]^2}-1\right]\right\} \quad (18)$$

If the electrical conductivity of the lamina, $\sigma_{(l)}$, is such that $\sigma_{(l)} >> \omega\varepsilon$, then the value of λ is given by Eq. (6), i.e.,

$$\lambda = \lambda_{\mathrm{mod}} = \sqrt{\frac{4\pi}{\mu f \sigma}} \quad (19)$$

Substitution of Eq. (19) into Eq. (18) gives

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1-2\left[\sqrt{1+\frac{n_{r(l)}^2 n_l^6 S_\alpha^2 S_m^4 \phi_m^4 \sigma_{(l)} E^4}{16\pi\mu_0 \rho_{(l)}^2 c^4 f^3}}-1\right]\right\} \quad (20)$$

Note that $E = E_m \sin\omega t$. The average value for E^2 is equal to $\frac{1}{2} E_m^2$ because E varies sinusoidaly (E_m is the maximum value for E). On the other hand, $E_{rms} = E_m/\sqrt{2}$. Consequently we can change E^4 by E_{rms}^4, and the equation above can be rewritten as follows

$$\chi = \frac{m_{g(l)}}{m_{i0(l)}} =$$

$$= \left\{1-2\left[\sqrt{1+\frac{n_{r(l)}^2 n_l^6 S_\alpha^2 S_m^4 \phi_m^4 \sigma_{(l)} E_{rms}^4}{16\pi\mu_0 \rho_{(l)}^2 c^4 f^3}}-1\right]\right\} \quad (21)$$

Now consider the system (*Gravitational Press*) shown in Fig.3.

Inside the system there is a *dielectric tube* ($\varepsilon_r \cong 1$) with the following characteristics: $\alpha = 60mm$, $S_\alpha = \pi\alpha^2/4 = 2.83\times10^{-3}m^2$. Inside the tube there is an *Aluminum sphere* with 30mm radius and mass $M_{gs} = 0.30536kg$. The tube is filled with *air* at ambient temperature and 1atm. Thus, inside the tube, the air density is

$$\rho_{air} = 1.2 \quad kg.m^{-3} \qquad (22)$$

The number of atoms of air (Nitrogen) per unit of volume, n_{air}, according to Eq.(7), is given by

$$n_{air} = \frac{N_0\rho_{air}}{A_N} = 5.16\times10^{25} atoms/m^3 \qquad (23)$$

The *parallel metallic plates* (p), shown in Fig.3 are subjected to different drop voltages. The two sets of plates (*D*), placed on the extremes of the tube, are subjected to $V_{(D)rms} = 10.28V$ at $f = 60Hz$, while the central set of plates (*A*) is subjected to $V_{(A)rms} = 121.69V$ at $f = 60Hz$. Since $d = 98mm$, then the intensity of the electric field, which passes through the 36 *cylindrical air laminas* (each one with 5mm thickness) of the *two* sets (*D*), is

$$E_{(D)rms} = V_{(D)rms}/d = 104.898V/m$$

and the intensity of the electric field, which passes through the 7 *cylindrical air laminas* of the central set (*A*), is given by

$$E_{(A)rms} = V_{(A)rms}/d = 1.2418\times10^3 V/m$$

Note that the *metallic rings* (5*mm* thickness) are positioned in such way to block the electric field out of the cylindrical air laminas. The objective is to turn each one of these laminas into a *Gravity Control Cell* (GCC) [22]. Thus, the system shown in Fig. 3 has 3 sets of GCC. Two with 18 GCC each and one with 7 GCC. The two sets with 18 GCC each are positioned at the extremes of the tube (*D*). They work as gravitational *decelerator* while the other set with 7 GCC (*A*) works as a gravitational *accelerator*, intensifying the gravity acceleration produced by the mass M_{gs} of the Aluminum sphere. According to Eq. (3), this gravity, after the 7^{th} GCC becomes $g_7 = \chi^7 GM_{gs}/r_0^2$, where $\chi = m_{g(l)}/m_{i(l)}$ given by Eq. (21) and $r_0 = 92.53mm$ is the distance between the center of the Aluminum sphere and the surface of the first GCC of the set (A).

The objective of the sets (*D*), with 18 GCC each, is to reduce strongly the value of the external gravity along the axis of the tube. In this case, the value of the external gravity, g_{ext}, is reduced by the factor $\chi_d^{18}g_{ext}$, where $\chi_d = 10^{-2}$. For example, if the base BS of the system is positioned on the Earth surface, then $g_{ext} = 9.81m/s^2$ is reduced to $\chi_d^{18}g_{ext}$ and, after the set A, it is increased by χ^7. Since the system is designed for $\chi = -308.5$, then the gravity acceleration on the sphere becomes $\chi^7\chi_d^{18}g_{ext} = 2.6\times10^{-18}m/s^2$, this value is much smaller than $g_{sphere} = GM_{gs}/r_s^2 = 2.26\times10^{-8}m/s^2$.

Note that *Americium* 241‡ droplets are conveniently placed along the dielectric tube *in order to increase the electrical conductivity of the air*. The objective is to increase the conductivity of the air, inside the dielectric tube, up to $\sigma_{air} = 1\times10^{-6}S/m$. This value is of fundamental importance in

‡ The radioactive element *Americium* (Am-241) is widely used in *ionization smoke detectors*. This type of smoke detector is more common because it is inexpensive and better at detecting the smaller amounts of smoke produced by flaming fires. Inside an ionization detector there is a small amount (perhaps 1/5000th of a gram) of americium-241. The Americium is present in oxide form (AmO_2) in the detector. The cost of the AmO_2 is US$ 1,500 per gram. The amount of radiation in a smoke detector is extremely small. It is also predominantly alpha radiation. Alpha radiation cannot penetrate a sheet of paper, and it is blocked by several centimeters of air. The americium in the smoke detector could only pose a danger if inhaled.

order to obtain the convenient values of χ and χ_d, which are given by Eq. (21), i.e.,

$$\chi = \left\{1-2\left[\sqrt{1+\frac{n_{r(air)}^2 n_{air}^6 S_\alpha^2 S_m^4 \phi_m^4 \sigma_{air} E_{(A)rms}^4}{16\pi\mu_0 \rho_{air}^2 c^4 f^3}}-1\right]\right\} = \left\{1-2\left[\sqrt{1+1.02\times10^{-8} E_{(A)rms}^4}-1\right]\right\} \quad (24)$$

$$\chi_d = \left\{1-2\left[\sqrt{1+\frac{n_{r(air)}^2 n_{air}^6 S_\alpha^2 S_m^4 \phi_m^4 \sigma_{air} E_{(D)rms}^4}{16\pi\mu_0 \rho_{air}^2 c^4 f^3}}-1\right]\right\} = \left\{1-2\left[\sqrt{1+1.02\times10^{-8} E_{(D)rms}^4}-1\right]\right\} \quad (25)$$

where $n_{r(air)} = \sqrt{\mu_{r(air)}\sigma_{air}/4\pi\varepsilon_0 f} = 12.24$, $n_{air} = 5.16\times10^{25} atoms/m^3$, $\phi_m = 1.55\times10^{-10} m$, $S_m = \pi\phi_m^2/4 = 1.88\times10^{-20} m^2$ and $f = 60Hz$. Since $E_{(A)rms} = 1.2418 \times 10^3 V/m$ and $E_{(D)rms} = 104.898 V/m$, we get

$$\chi = -308.5 \quad (26)$$

and

$$\chi_d \cong 10^{-2} \quad (27)$$

Then, the gravitational acceleration upon the piston of the Gravitational Press shown in Fig. 3 is equal to the value of the gravitational acceleration *after the 7th gravitational shielding*, i.e.,

$$g_7 = \chi^7 g = -\chi^7 \frac{GM_{gs}}{r_0^2} \cong 6.3\times10^8 m/s^2 \quad (28)$$

If the mass of the piston is $m_{piston} = 15kg$ with 20cm diameter then the *pressure* upon the *cubic-anvil apparatus* (Fig. 4) is

$$p = \frac{F}{S} = \frac{m_{piston} g_7}{\pi(0.1)^2} = 3\times10^{11} N/m^2 = 300GPa$$

It is important to note that the pressure can be easily increased by increasing the value of χ. However, the pressure limit is basically determined by the compression resistance of the material of the piston and anvils of the Gravitational Press since it can produce pressures far beyond 1000 GPa.

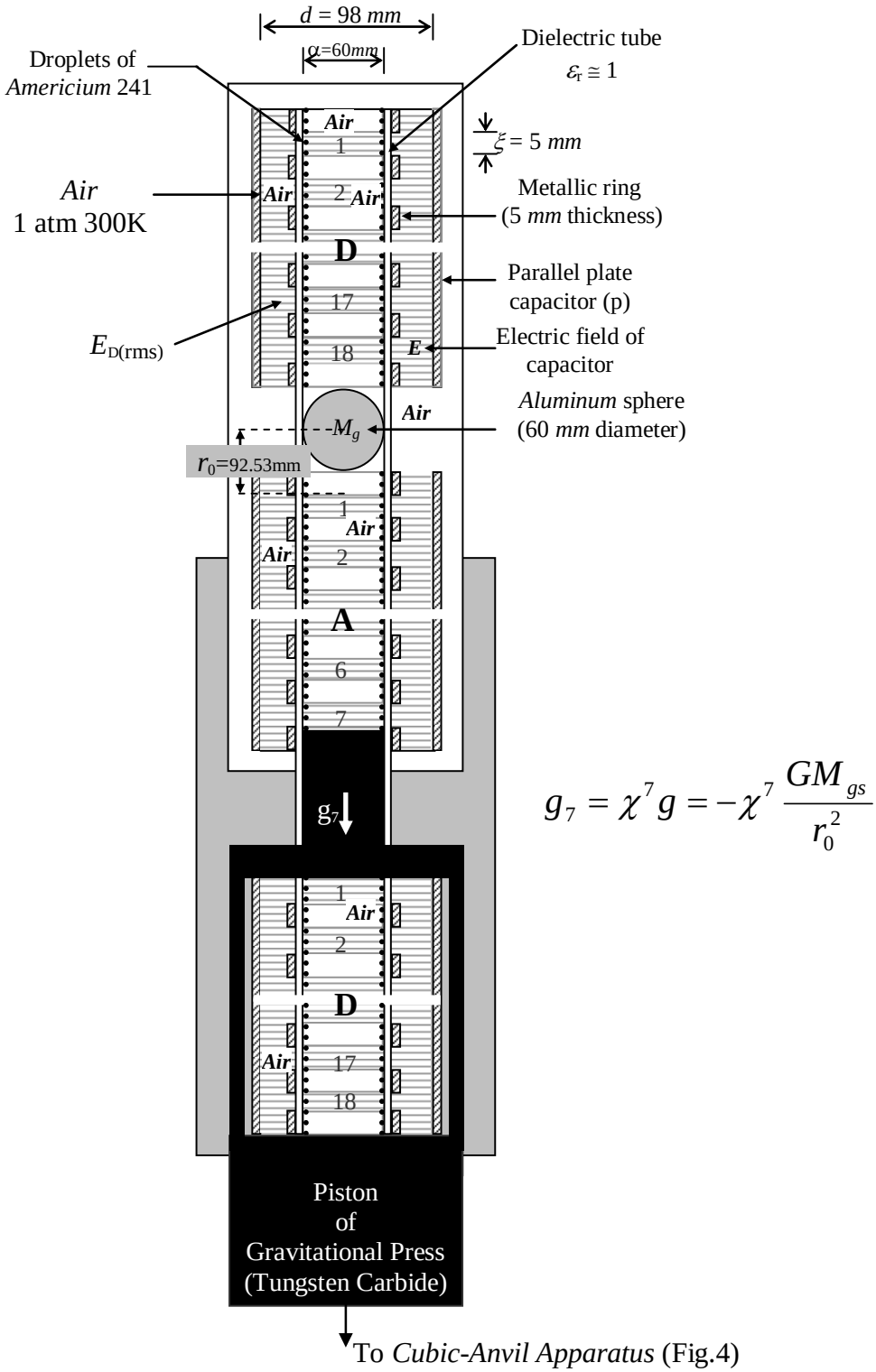

Fig. 3 – *Gravitational Press* (Developed from a process *patented* in July, 31 2008, PI0805046-5)

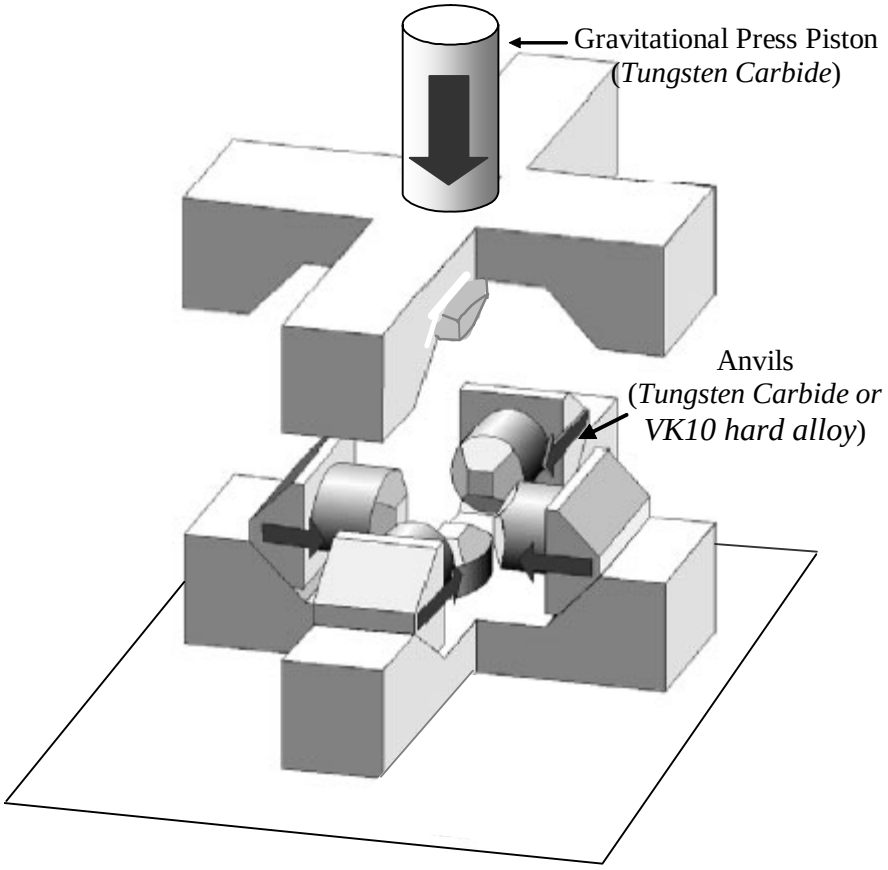

Fig.4 - *Diagram of Cubic-Anvil Apparatus for the Gravitational Press*. – In the center of the apparatus, is placed a ceramic cube ("synthesis capsule") of pyrophyllite ceramics, which contains graphite and is pressed by the anvils made from cemented carbide (e.g., tungsten carbide or VK10 hard alloy). Note that, due to the enormous pressure that the Gravitational Press can produce (*>>80GPa*), the "synthesis capsule" can be very large (up to about 1000 cm^3 in size). This is sufficient to produce diamonds with up to 100 carats (20g) or more.

References

[1] Hall, H. T. (1960). "Ultra-high pressure apparatus". *Rev. Sci. Instr.* **31** (2): 125.

[2] Werner, M; Locher, R (1998). "Growth and application of undoped and doped diamond films". *Rep. Prog. Phys.* **61** (12): 1665.

[3] Osawa, E (2007). "Recent progress and perspectives in single-digit nanodiamond". *Diamond and Related Materials* **16** (12): 2018.

[4] Galimov, É. M.; Kudin, A. M.; Skorobogatskii, V. N.; Plotnichenko, V. G.; Bondarev, O. L.; Zarubin, B. G.; Strazdovskii, V. V.; Aronin, A. S. et al. (2004). "Experimental Corroboration of the Synthesis of Diamond in the Cavitation Process". *Doklady Physics* **49** (3): 150.

[5] N. Pal'yanov *et al.* (2002). "*Fluid-bearing alkaline carbonate melts as the medium for the formation of diamonds in the Earth's mantle: an experimental study*". *Lithos* **60**: 145.

[6] F. P. Bundy(1963) J. Chem. Phys. 38, 631.

[7] F. P. Bundy and J. S. Kasper(1967) J. Chem. Phys. 46, 3437
.

[8] F. P. Bundy,W. A. Bassett, M. S.Weathers, R. J. Hemley, H. K. Mao, and A. F. Goncharov (1996) Carbon 34, 141.

[9] T. Irifune, A. Kurio, S. Sakamoto, T. Inoue, and H. Sumiya(2003) Nature 421, 806.

[10] V. F. Britun, A. V. Kurdyumov, and I. A. Petrusha (2004) Powder Metall. Met. Ceram. 43, 87.

[11] H. Sumiya, H. Yusa, T. Inoue, H. Ofuji, and T. Irifune (2006) High Pressure Res. 26, 63.

[12] H. Ohfuji and K. Kuroki(2009) J. Mineral. Petrol. Sci. 104, 307.

[13] S. Fahy, S. G. Louie, and M. L. Cohen (1986) Phys. Rev. B 34, 1191.

[14] S. Fahy, S. G. Louie, and M. L. Cohen (1987) Phys. Rev. B 35, 7623.

[15]Y. Tateyama, T. Ogitsu, K. Kusakabe, and S. Tsuneyuki (1996) Phys. Rev. B 54, 14994.

[16] S. Scandolo, M. Bernasconi, G. L. Chiarotti, P. Focher, and E. Tosatti (1995) Phys. Rev. Lett. 74, 4015.

[17] F. Zipoli, M. Bernasconi, and R. Martonak (2004) Eur. Phys. J. B 39, 41.

[18] Khaliullin, RZ, Eshet, H, Kühne, TD, Jörg Behler, J & Parrinello, M. (2011) *Nucleation mechanism for the direct graphite-to-diamond phase transition*, Nature Materials, 10, 693–697.

[19] Y. Tateyama, T. Ogitsu, K. Kusakabe, and S. Tsuneyuki (1996) Phys. Rev. B 54, 14994.

[20] S. Scandolo, M. Bernasconi, G. L. Chiarotti, P. Focher and E. Tosatti (1995) Phys. Rev. Lett. 74, 4015.

[21] De Aquino, F. (2010) Mathematical Foundations of *the Relativistic Theory of Quantum Gravity*, Pacific Journal of Science and Technology, **11** (1), pp. 173-232.

[22] De Aquino, F. (2010) *Gravity Control by means of Electromagnetic Field through Gas at Ultra-Low Pressure*, Pacific Journal of Science and Technology, **11**(2) November 2010, pp.178-247, Physics/0701091.

[23] Quevedo, C. P. (1977) *Eletromagnetismo*, McGraw-Hill, p. 270.

[24] Halliday, D. and Resnick, R. (1968) *Physics*, J. Willey & Sons, Portuguese Version, Ed. USP, p.1124.