# Project Lucy

## Radio Transmitter to decompose methane

Extended Version 4

# The technology

Methane in the air is decomposed in between radio transmitters that each use slightly different radio frequencies.
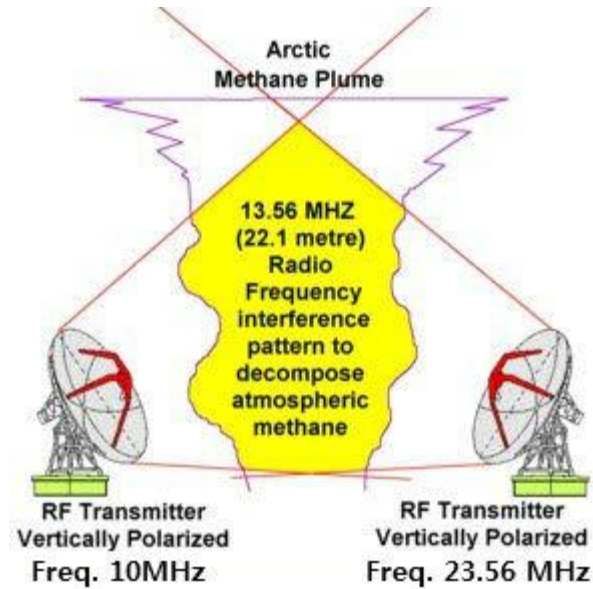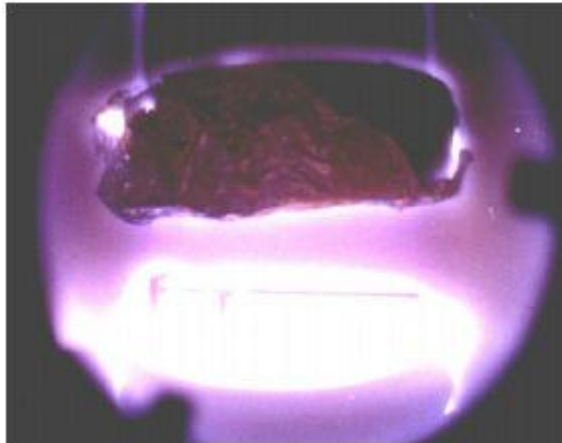


Figure 1. Schematic representation of two beamed parabolic radio transmitters using slightly different frequencies, the radio interference pattern of which is designed to decompose methane in a plume rising into the Arctic atmosphere from unstable surface and submarine methane hydrates

# Existing technology - example

Nanocrystalline diamond can be formed from methane with radio frequencies in a reactor chamber.

The images left date back to 2005 and show a reactor chamber with an orthopedic bold placed on a radio frequency-driven electrode and a discharge initiated in a radio frequency electrical field.

Testing is necessary to find out what can best make such a process operate under Arctic conditions, in terms of:

- pressure (from slide 10)
- scale (from slide 15)
- configurations (from slide 18)
- frequencies (from slide 25)
- energy (from slide 30)
- temperature (from slide 34)

images and description from:
journalamme.org/papers_cams05/1244.pdf

# Why start now?

Project Lucy is part of a range of geo-engineering efforts to reduce warming in the Arctic. Other methods include:
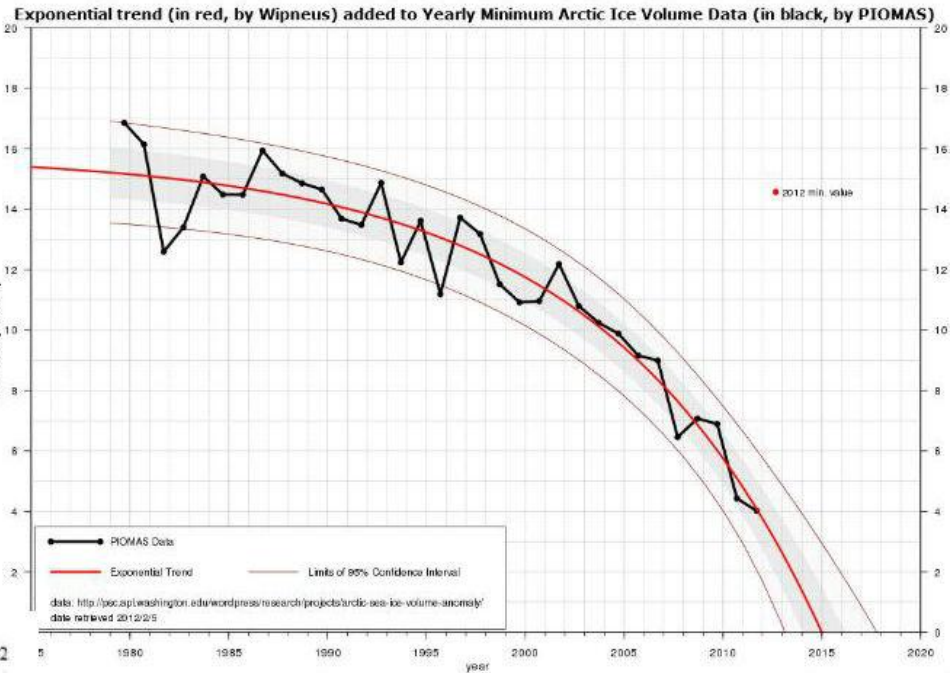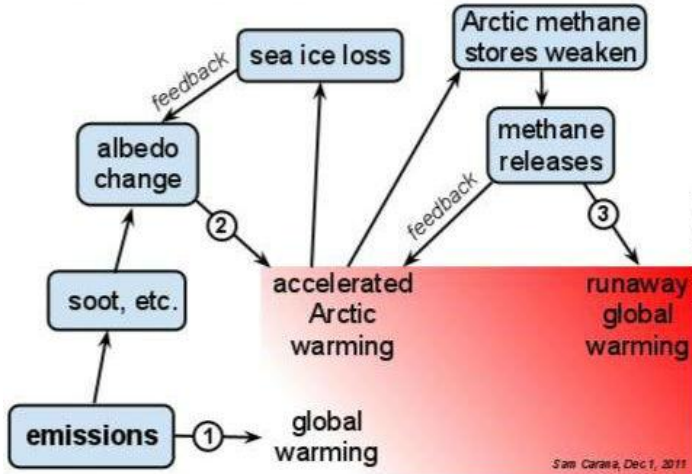  - Methane capture in the Arctic
  - Spraying particles in the atmosphere to reflect sunlight back into space
  - Pyrolysis of organic waste and carbon burial, to reduce atmospheric CO2 and soot

The need to act on methane in the Arctic is such that, most likely, a range of methods will need to be deployed in parallel. Lucy has the potential to be very effective, as it can decompose methane while any resulting nano diamond powder could also reflect sunlight back into space.
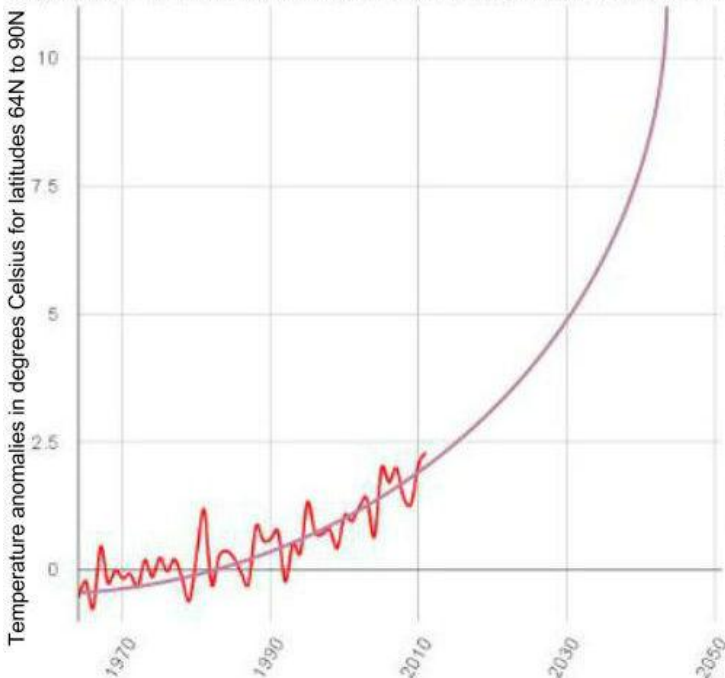
It will take time to build and test Lucy. International negotiations to agree to deploy Lucy will take time.

The longer action on warming in the Arctic is delayed, the greater the risks of famine, war and loss of biodiversity, at global scale and at incalculable cost.

# What's the danger?



feedback

sea ice loss

Arctic methane stores weaken

albedo change

methane releases

②

③

soot, etc.

feedback

accelerated Arctic warming

runaway global warming

emissions ① → global warming

Sam Carana, Dec 1, 2011

Exponential trend (in red, by Wipneus) added to Yearly Minimum Arctic Ice Volume Data (in black, by PIOMAS)



● 2012 min. value

PIOMAS Data

Exponential Trend

Limits of 95% Confidence Interval

data: http://psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/
date retrieved 2012/2/5

Projection 1964 - 2050, based on NASA GHCN-v3 1880-12/2011, by Sam Carana, March 21, 2012



Selected images from AMEG poster displayed at AGU 2011: Global warming heats up the Arctic, soot contributes to albedo change, while methane threatens to be released - 1700 Gt of methane is located in the squared area alone, of which 50 Gt is ready for abrupt release at any time. This would dwarf warming by $CO_2$ from fossil fuel (~ 33 Gt/y), as methane's immediate global warming potential is over 100x that of $CO_2$.

$CH_4$ (ppb), S. C. Wofsy et al.
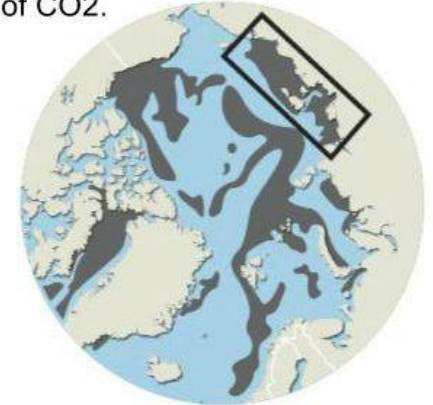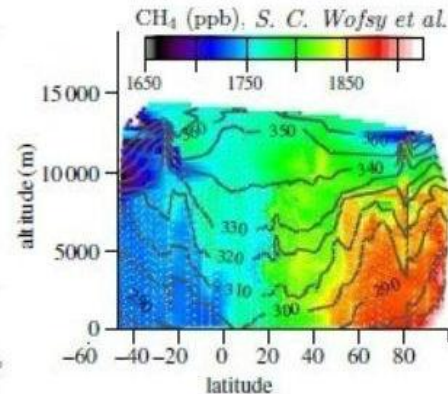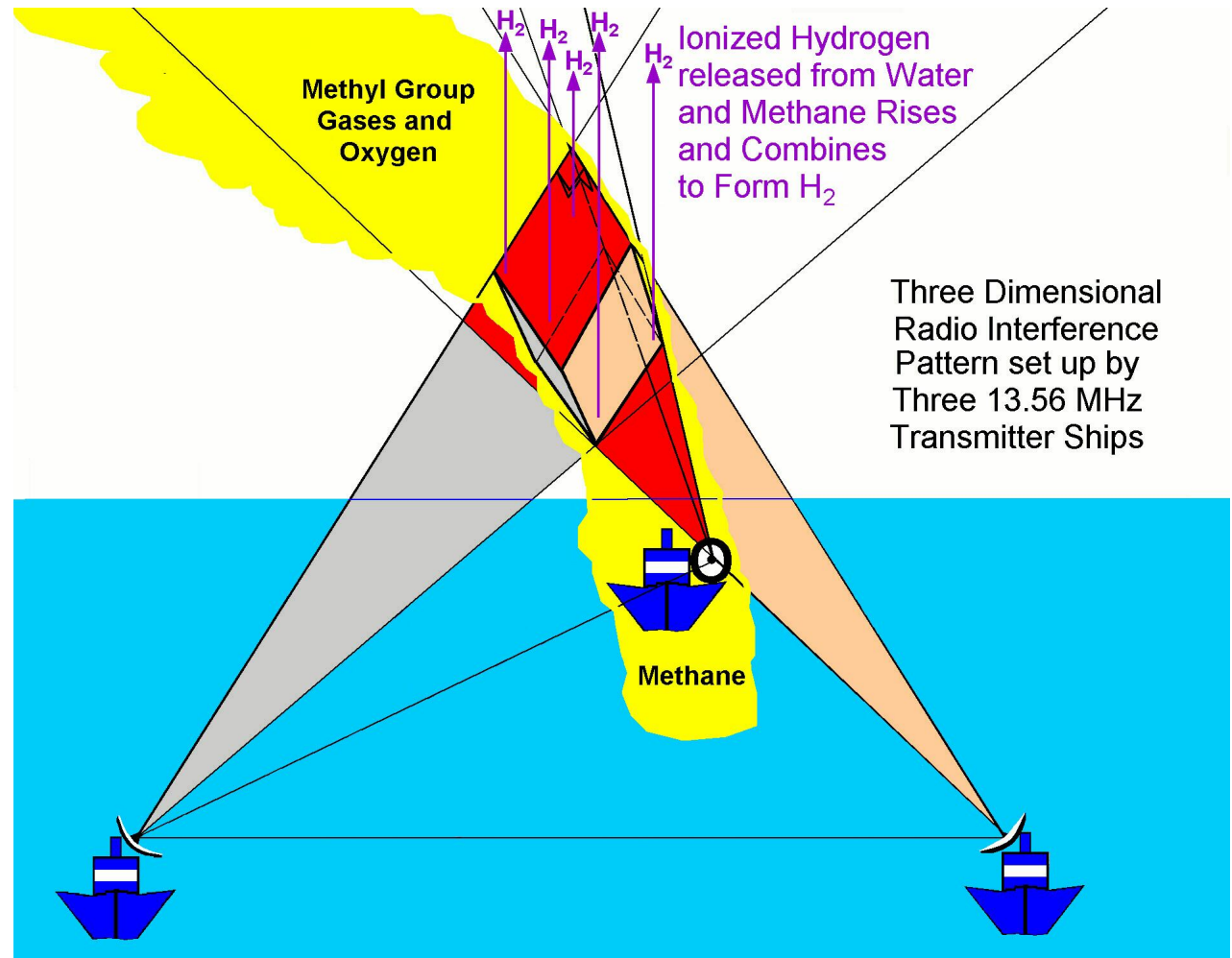


predicted methane hydrates, Soloviev et al.

## Arctic methane releases threaten to trigger runaway global warming soon

# What does Project Lucy envisage?

Project Lucy therefore aims to design, build and test a microwave transmission system targeting low-altitude methane clouds with the aim of breaking the first C-H bond as soon as the methane erupts into the atmosphere from the Arctic Ocean.

The transmitters can be mounted on submarines, planes and after 2015 on boats and drilling rigs when the Arctic ice cap has melted (Arctic News, 2012).

**Methyl Group Gases and Oxygen**

**H$_2$ H$_2$ H$_2$ H$_2$ H$_2$**

Ionized Hydrogen released from Water and Methane Rises and Combines to Form H$_2$

Three Dimensional Radio Interference Pattern set up by Three 13.56 MHz Transmitter Ships

**Methane**

*Cubic radio interference pattern*

# Cost Elements

1. R&D and testing (this proposal)

2. Political negotiations (could be covered under existing diplomacy financial budgets)

3. Transport and installation (could be covered under existing military budgets)

4. Energy supply (could be provided by nuclear submarines)

5. Operational cost (could be part of military budgets)

# Thank you

Presentation prepared with content supplied by:

- Malcolm Light, PhD (Univ. of London), consultant with many years of experience in methane, diamonds and numerous related topics

- Sam Carana, creator of AMEG poster, AGU 2011, and editor of geo-engineering.blogspot.com

- Brion Hurley, Rockwell Collins

*For further details on Project Lucy, continue reading the supplementary part of this presentation*

# Supplement - Index

Testing is necessary to find out what can best make Project Lucy work under Arctic conditions. Further details are provided in chapters (see headers below, followed by slide number).

# Supplement - Introduction

Project Lucy was conceived by Malcolm Light in response to the growing danger posed by large amounts of methane escaping into the atmosphere in the Arctic, threatening to trigger runaway global warming, famine, war and loss of biodiversity, at unprecedented scale and at incalculable cost.

Project Lucy aims to target growing methane clouds in the Arctic atmosphere in a "non–evasive" manner,  without generating any further serious pollution to the atmosphere. The subsea Arctic methane is now erupting at a fast increasing rate on the East Siberian Arctic Shelf and Beaufort Sea off Alaska and Canada (Shakova and Semiletov, 2012; Polar View, 2012). Atmospheric methane, because of its high global warming potential (more than 100 over 5 years) will cause runaway global warming and widespread extinction within one human lifetime (i.e. by the middle of this century) if it is not dealt with effectively.

Preparations therefore have to commence immediately, starting with testing of pressure, configurations, scale, frequencies, power and temperature. For example, decomposition of methane into less threatening daughter components requires only enough energy to break one of the four C-H bonds in methane molecule. This makes the process much less energy demanding than commercial applications that convert the carbon in methane to diamonds. Lucy only needs to break one out of four C-H bonds in methane; one would therefore expect that only about a quarter of the energy is needed per molecule, but testing is required to verify such expectations.
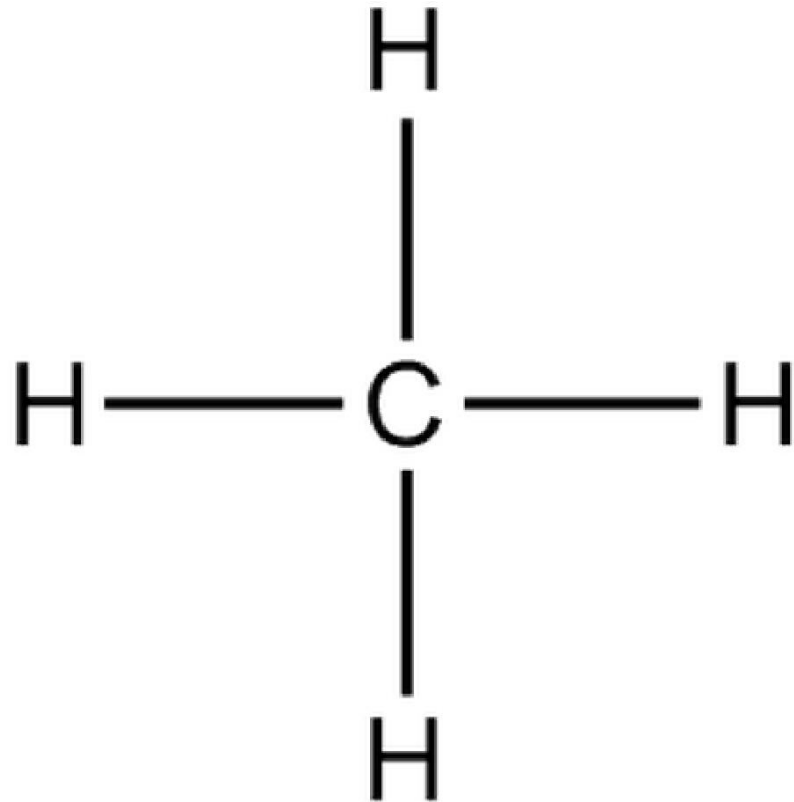
Methane Molecule viewed down
Axis of Two - Fold Symmetry.
Length C-H bond = 1.087 ^ 10-10 m
Angle between C-H bonds =109.5°
(Hurlbut, 1959, Wikipedia, 2001a)
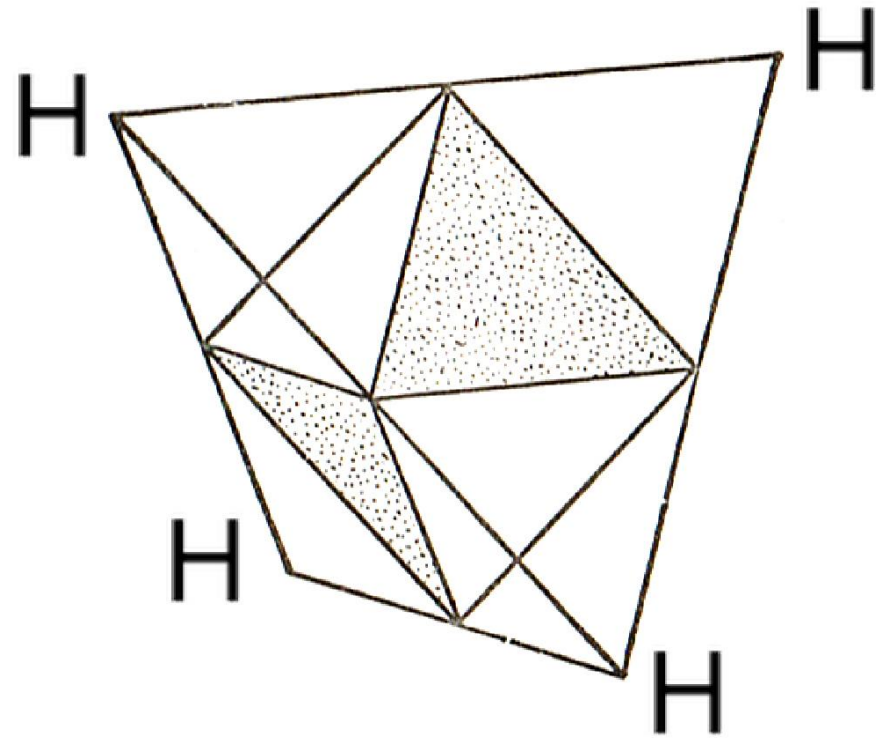
Relation between Diamond
Octahedron and Methane
Tetrahedron (Hurlbut, 1959)

Because of the direct relationship between the methane CH4 tetrahedron and an enclosed (diamond) octahedron, methane can be looked at as representing a hydrated diamond at its smallest state.

# Pressure - Decomposition at ambient atmosphere

Chemical vapour deposition (CVD) of diamond by the destruction of methane can take place at atmospheric pressure (APCVD) or at subatmospheric pressure (LPCVD) which removes unwanted gas phase reactions. Diamonds can also be generated in an ultra-high vacuum (UHVCVD) with pressures between 10-6 to 10-7 pascals (Wikipedia, 2012b).

The method chosen depends on the specific (commercial) purpose, ranging from deposition of a thin layer of nano-diamonds onto medical equipment to the production of custom-made diamonds.

In such commercial applications, varying amounts of gases (which include a carbon source such as methane) are typically fed into a reactor chamber, and are energised using microwave power, laser, hot filament, arc discharges, welding torch or other energy sources (Wikipedia 2012c).

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Note: Pressure can be given in many different units depending on the particular field of science:-

100 KPa (Kilo pascals) = 100,000 pascals = 100,000 newtons*m-2 = 1 bar = 1000 mb

(millibars) = 0.98692 atmospheres = 750.06 Torr = 14.50377 psi (pounds per sq. inch)

(Lide and Frederickse, 1994).

_____

CVD pressure for methane destruction and diamond formation in Hirakuri et al's (2001) experiments ranged from 5 KPa to 200 KPa., equivalent to pressure ranges from the surface of the Earth to just over 20 km altitude and at higher pressures of about two atmospheres (Lide and Frederickse, 1994).

# Influence of the methane concentration on HF–CVD diamond under atmospheric pressure

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**Abstract**

The most common approach for chemical vapor deposition (CVD) of diamond is the utilization of hydrocarbon gases highly diluted in hydrogen at low pressure (e.g. several thousands of Pascals (Pa)). The quality and growth rate of diamond strongly depends on the methane gas concentration, especially at high pressure, because the generation of atomic hydrogen sharply decreases with increasing pressure. In order to increase the growth rate, we have carried out CVD diamond growth under atmospheric pressure. A dramatic increase of the growth rate could be achieved when using the hot-filament (HF)–CVD technique at atmospheric pressure. Such an increase could already be observed in a previous experiment, however, under varying pressure and at a constant methane concentration of 0.5%. Furthermore, the crystalline quality of the diamond grains could be improved by hydrogen etching at atmospheric pressure.

In the current study, the methane volume concentration was varied from 0.03% to 2.0% in order to estimate its effect on diamond growth. The relationship between the quality of the deposited diamond and the methane concentration has been investigated by Raman spectroscopy. The amount of activated hydrogen was estimated from the etching rate of non-diamond components. At high atmospheric pressure, high growth rates could be achieved up to a methane concentration of 0.3%. Moreover, the growth rate has also been shown to depend on the residence time of the precursor in the reactor. Finally, Raman analysis revealed an increasing quality of diamond with decreasing methane concentration. © 2001 Elsevier Science Ltd. All rights reserved.

*Keywords:* Diamond growth and characterization; Hot filament; Grain size; Morphology

## 1. Introduction

Chemical vapor deposition (CVD) of diamond films has received considerable attention due to their attractive film properties such as high thermal conductivity, mechanical hardness, wide band gap, and chemical inertness [1–3]. If rapid growth and improved quality of CVD diamonds can be realized then they are expected to be utilized widely industrially in the fields of electro-

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atomic hydrogen and methyl radical enhanced the crystalline property in the diamond grains.

In order to compare the quality of the diamonds grown at different conditions, micro Raman spectroscopy was applied. Fig. 4 shows the Raman spectra of diamond grains produced at methane concentrations between 0.1% and 1.0%. In each case the grains were identified as diamond due to the sharp peak at $1332\,cm^{-1}$. Significant peaks at $1350\,cm^{-1}$ (D band) and $1530\,cm^{-1}$ (G band) originating from disordered and glassy amorphous carbon around the grains cannot be observed in the Raman spectra. The full width at half maximum (FWHM) of the peaks was used to characterize the quality of the diamond grains. Typical FWHMs of the diamond peak at $1332\,cm^{-1}$ are listed in Table 2. A significant increase of the FWHM with increasing methane concentration can be observed. In particular, a strong decrease of the FWHM can be found for a methane concentration of 0.5%.

Table 1
Growth conditions for CVD diamond deposition under atmospheric pressure

| Parameters | Range |
| --- | --- |
| Substrate material | Si (100) |
| Pressure (kPa) | 5~200 |
| Residence time (s) | 0.02~5 |
| Methane concentration (%) | 0.03, 0.1, 0.3, 0.5, 1.0, 1.5, 2.0 |
| Deposition time (h) | 3 |
| Substrate temperature (K) | 1120 |



(a)  Methane concentration 0.1%
     Deposition time 3 hours

(c)  Methane concentration 0.3%
     Deposition time 3 hours

(b)  Methane concentration 0.5%
     Deposition time 3 hours

(d)  Methane concentration 1.0%
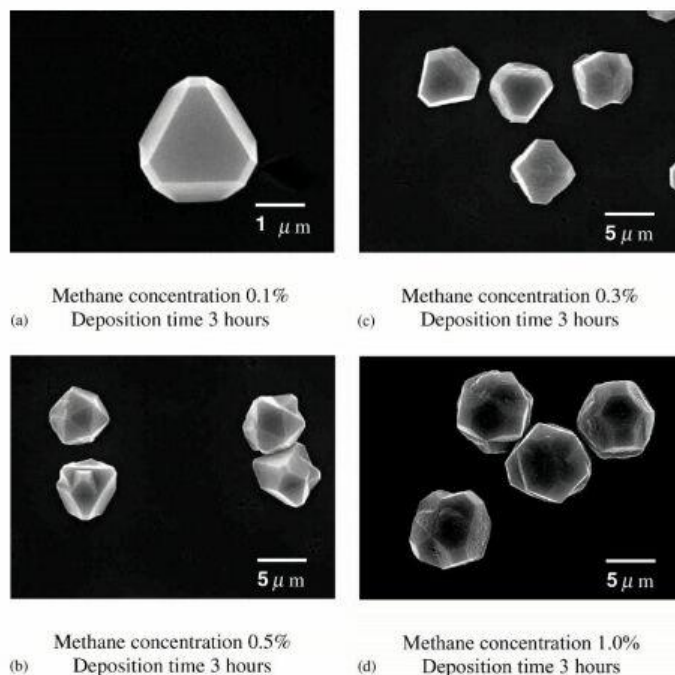     Deposition time 3 hours

Fig. 3. SEM images showing the morphology of diamond grains grown on a silicon substrate. Methane concentration: (a) 0.1%, (b) 0.3%, (c) 0.5%, and (d) 1.0%. The total deposition time was 3 h in all the cases.

concentrations, the comparative ratio between atomic hydrogen and methyl radical increases with decreasing methane concentration. Thus, non-diamond species can be etched off, which is also supported by the SEM micrographs in Fig. 3.

Next, the quality of diamond grains before and after etching was investigated by Raman spectroscopy since non-diamond components can be identified by this technique. All the spectra have been recorded on the same individual diamond grain by focussing the laser beam at the center of the grain (Fig. 5). In the spectrum of the as-deposited sample (at a methane concentration of 0.5%), besides the dominant diamond peak at $1332\,cm^{-1}$, a weak peak around $1450\,cm^{-1}$ can be observed, which indicates the existence of amorphous carbon [7,8]. After the etching treatment the amorphous carbon peak is strongly

were determined as well (Table 3). A reduction of the FWHM by the etching treatment from 11.28 to $6.58\,cm^{-1}$ can be observed. Furthermore, the residence time of the etching gas also influences the FWHM of the etched samples. While an FWHM of $6.58\,cm^{-1}$ is observed for the sample etched with a residence time of 0.5 s (denoted as etching I in Fig. 5), the respective value for a residence time of 1.5 s (etching II in Fig. 5) is $5.76\,cm^{-1}$. This can be explained by the increased generation of atomic hydrogen through extension of the residence time, enhancing the removal of non-diamond components [3].

## 4. Conclusions

Using the HF–CVD technique, the influence of the methane concentration on diamond growth

was investigated under atmospheric pressure. A decreasing growth rate of the diamond could be observed with decreasing methane concentration. A variation of the $CH_4$ concentration from 0.03% to 1.0% leads to an increase in growth rate by a factor of about 10. On the other hand, the quality of the diamond decreases at the same time. However, the significant enhancement of the growth rate at atmospheric pressure allows production of high quality diamond at low $CH_4$ concentration and still with reasonable deposition rates, making the technique useful for industrial applications.

## References

[1] Rye RR. J Appl Phys 1994;76:1220–7.
[2] Connell LL, Fleming JW, Chu H-N, Vestyck Jr DJ, Jansen E, Butler JE. J Appl Phys 1995;78:3622–30.
[3] Kobayashi T, Hirakuri KK, Mutsukura N, Machi Y. Diamond Related Mater 1999;8:1057–60.
[4] Takeuchi D, Yamanaka S, Watanabe H, Sawada S, Ichinose H, Okushi H, Kajimura K. Diamond Related Mater 1999;8:1046–9.
[5] Takeuchi D, Watanabe H, Yamanaka S, Okushi H, Kajimura K. Phys Stat Sol 1999;174:101–15.
[6] Hayashi K, Yamanaka S, Watanabe H, Sekiguchi T, Okushi H, Kajimura K. J Cryst Growth 1998;183:338–46.
[7] Hirakuri KK, Yoshii M, Friedbacher G, Grasserbauer M. Diamond Related Mater 1997;6:1031–5.
[8] Leeds SM, Davis TJ, May PW, Pickard CDO, Ashfold MNR. Diamond Related Mater 1998;7:233–7.

en.wikipedia.org/wiki/Chemical_vapor_deposition

**Chemical vapor deposition (CVD)** is a chemical process used to produce high-purity, high-performance solid materials. The process is often used in the semiconductor industry to produce thin films. In a typical CVD process, the wafer (substrate) is exposed to one or more volatile precursors, which react and/or decompose on the substrate surface to produce the desired deposit. Frequently, volatile by-products are also produced, which are removed by gas flow through the reaction chamber.

Microfabrication processes widely use CVD to deposit materials in various forms, including: monocrystalline, polycrystalline, amorphous, and epitaxial. These materials include: silicon, carbon fiber, carbon nanofibers, filaments, carbon nanotubes, $SiO_2$, silicon-germanium, tungsten, silicon carbide, silicon nitride, silicon oxynitride, titanium nitride, and various high-k dielectrics. The CVD process is also used to produce synthetic diamonds.



DC plasma (violet) enhances the growth of carbon nanotubes in this laboratory-scale PECVD apparatus.

### Contents [hide]

## Types of chemical vapor deposition [edit]

A number of forms of CVD are in wide use and are frequently referenced in the literature. These processes differ in the means by which chemical reactions are initiated (e.g., activation process) and process conditions.

- Classified by operating pressure
  - *Atmospheric pressure CVD* (APCVD) – CVD processes at atmospheric pressure.
  - *Low-pressure CVD* (LPCVD) – CVD processes at subatmospheric pressures.[1] Reduced pressures tend to reduce unwanted gas-phase reactions and improve film uniformity across the wafer. Most modern CVD processes are either LPCVD or UHVCVD.
  - *Ultrahigh vacuum CVD* (UHVCVD) – CVD processes at a very low pressure, typically below $10^{-6}$ Pa ($\sim 10^{-8}$ torr). Note that in other fields, a lower division between high and ultra-high vacuum is common, often $10^{-7}$ Pa.
- Classified by physical characteristics of vapor
  - *Aerosol assisted CVD* (AACVD) – A CVD process in which the precursors are transported to the substrate by means of a liquid/gas aerosol, which can be generated ultrasonically. This technique is suitable for use with non-volatile precursors.
  - *Direct liquid injection CVD* (DLICVD) – A CVD process in which the precursors are in liquid form (liquid or solid dissolved in a convenient solvent). Liquid solutions are injected in a vaporization chamber towards injectors (typically car injectors). Then the precursor vapors are transported to the substrate as in classical CVD process. This technique is suitable for use on liquid or solid precursors. High growth rates can be reached using this technique.



Hot-wall thermal CVD (batch operation type)



Plasma assisted CVD
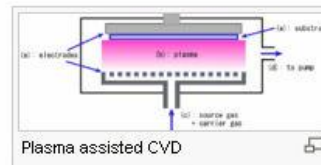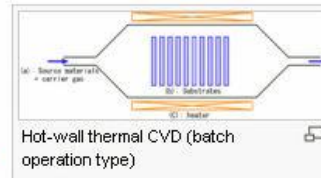
# Upscaling the technology for use in the Arctic

The main Arctic methane clouds occur within the Troposphere at altitudes of less than 10 km as recognised on Hippo, Airs and stratospheric data (Wolfsy, 2009; Polar View, 2012; Nassar et al., 2005) well within the pressure range tested by Hirakuri et al. 2001.

Hirakuri et al. 2001 found that diamond growth rate was significantly advanced when chemical vapour deposition was carried out at atmospheric pressure and this diamond was of very high quality at low methane pressures. This implies that the methane destruction reactions at atmospheric pressure are simple C-H bond breaking generating a nearly pure diamond.

Project Lucy therefore aims to design, build and test a microwave transmission system targeting low-altitude methane clouds with the aim of breaking the first C-H bond as soon as the methane erupts into the atmosphere from the Arctic Ocean. The transmitters can be mounted on submarines, planes and after 2015 on boats and drilling rigs when the Arctic ice cap has melted (Arctic News, 2012).

In the methane molecule, opposite tetrahedral sides with hydrogen on the corners are at right angles to one another while the radiating C-H bonds are at an angle of 109.5 degrees to one another (see slide 9 or thumbnail on the right).
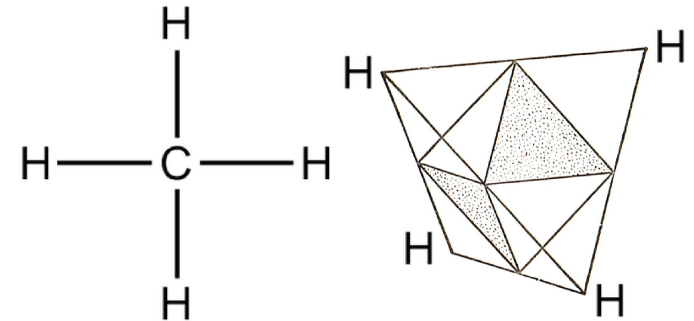


Methane Molecule viewed down Axis of Two - Fold Symmetry. Length C-H bond = 1.087 ^ 10-10 m Angle between C-H bonds =109.5° (Hurlbut, 1959, Wikipedia, 2001a)

Relation between Diamond Octahedron and Methane Tetrahedron (Hurlbut, 1959)

By using two separate radio transmitters whose beams that cross one another within the Methane cloud at variable angles but close to 90 degrees, it should be possible (by changing the intersection angles, phase shift and frequencies) to set up a lateral fifth harmonic (3:2) or the second overtone (3:1) standing or rotating interference pattern (see thumbnail right; Ashton, 2005) whose peaks and troughs trace out the cross-shaped bond structure of the methane molecules we are trying to decompose.



The Lateral Fifth harmonic 3:2 between transmitters at right angles to one another

The Fifth harmonic is also seen as the second overtone (3:1) and the phase shifted pair below are stereographic if viewed cross-eyed (Ashton, 2005)

This will be a way of enhancing the radio frequency energy input in the methane and confining it to particular methane clouds we are trying to decompose and disperse. $H_2$, $O_2$, $CO_2$ and $N_2$ are all linearly shaped molecules (Lide and Frederickse, 1994) and should also be subjected to increased energetic stress by the radio transmission harmonic pattern increasing the likelihood of the oxidation of the methane.

# References

Sam Carana. Arctic News, 2012. AMEG at Planet under Pressure Conference.

http://arctic-news.blogspot.com/2012/03/ameg-at-planet-under-pressure.html

Ashton A. 2005. A Visual Guide to the Mathematics of Music. Wooden Books Ltd. Glastonbury, U.K.  58 pp.

Heicklen,  J. 1976. Atmospheric Chemistry. Academic Press, New York. 406 pp.

Hurlbut, C.S. Jr. 1959.Dana's Manual of Mineralogy. 17th Edition., John Wiley, New York. 609 pp.

Lide D. R. and Frederikse, H.P.R., 1995. Handbook of Chemistry and Physics. 75th Ed. CRC Press, Ann Arbor, pp. 1-1 to 1 -33.

Nassar R., Bernath P.F., Boone C.D., Manney G.L., McLeod S.D., Rinsland C.P., Skelton R., Walker K.A., 2005. Stratospheric abundances of water and methane based on ACE-FTS measurements. Geophysical Research Letters, Vol. 32, LI5504, 5 pp.

http://www.atmosp.physics.utoronto.ca/~rnassar/Publications_pdfs/Nassar_water_methane_2005GL022383.pdf

Polar View. 2012. Earth Observation for Polar  Monitoring (AIRS data) - DTU Space, Technical University of Denmark -   http://www.seaice.dk,

Shakhova, N. and I. Semiletov (2012). Methane release from the East-Siberian Arctic Shelf and its connection with permafrost and hydrate destabilization: First results and potential future development. Geophys. Res., Vol. 14, EGU2012-3877-1.

Wikipedia, 2012a. Methane -   http://en.wikipedia.org/wiki/Methane

Wikipedia, 2012b. Chemical vapor deposition -   http://en.wikipedia.org/wiki/Chemical_vapor_deposition

Wikipedia, 2012c. Chemical vapour deposition of diamond -   http://en.wikipedia.org/wiki/Chemical_vapor_deposition_of_diamond

Wofsy, S.C. (image: HIPPO-1 flight along the date line, January 2009)

HIAPER Pole-to-Pole Observations (HIPPO): fine-grained, global-scale measurements of climatically important atmospheric gases and aerosols

Phil. Trans. R. Soc. A (2011) 369, 2073–2086 doi:10.1098/rsta.2010.0313

http://rsta.royalsocietypublishing.org/content/369/1943/2073.full.html

# Configurations to decompose methane under atmospheric pressure

In the atmosphere under natural conditions the first C-H bond in the methane molecule is broken by photodissociation or other chemical means (Heicklen, 1976).

Project Lucy proposes to achieve the same result in outdoor conditions using microwaves or laser, as is now commonly used in synthetic diamond production in the laboratory (Wikipedia 2012 a,b,c).

The daughter products produced by the break of the first C-H bond of the methane molecule do not have the extreme global warming potential shown by methane and are likely to oxidize with oxygen at low altitudes, so the methane threat will have been eliminated.

In nature, it is hard for oxygen to break the C-H bond. It can takes a decade for methane to become fully oxidized, which requires reactions with hydroxyl. Lack of hydroxyl can further extend methane's lifetime to decades, which is specifically problematic in the Arctic.

The natural process starts when one hydroxyl ion (OH) attaches itself to a methane molecule, loosening one of the four hydrogen (H) bonds within the methane molecule, yielding methyl ($CH_3$) and water vapor ($H_2O$).

In the natural oxidation process, methyl is then further oxidized by hydroxyl, and the carbon in methyl will eventually become oxidized to carbon dioxide.

Chemical vapour deposition (CVD) processes are used commercially by decomposing methane in a reactor chamber with radio frequencies at 13.56 MHz, resulting in the carbon from methane to be deposited in the form of a thin layer of diamonds onto objects in the chamber. Diamond has a deep ultraviolet bandgap at 225 nanometers which is almost a harmonic of the 22.1 meter (13.56 MHz) methane decomposition frequency.
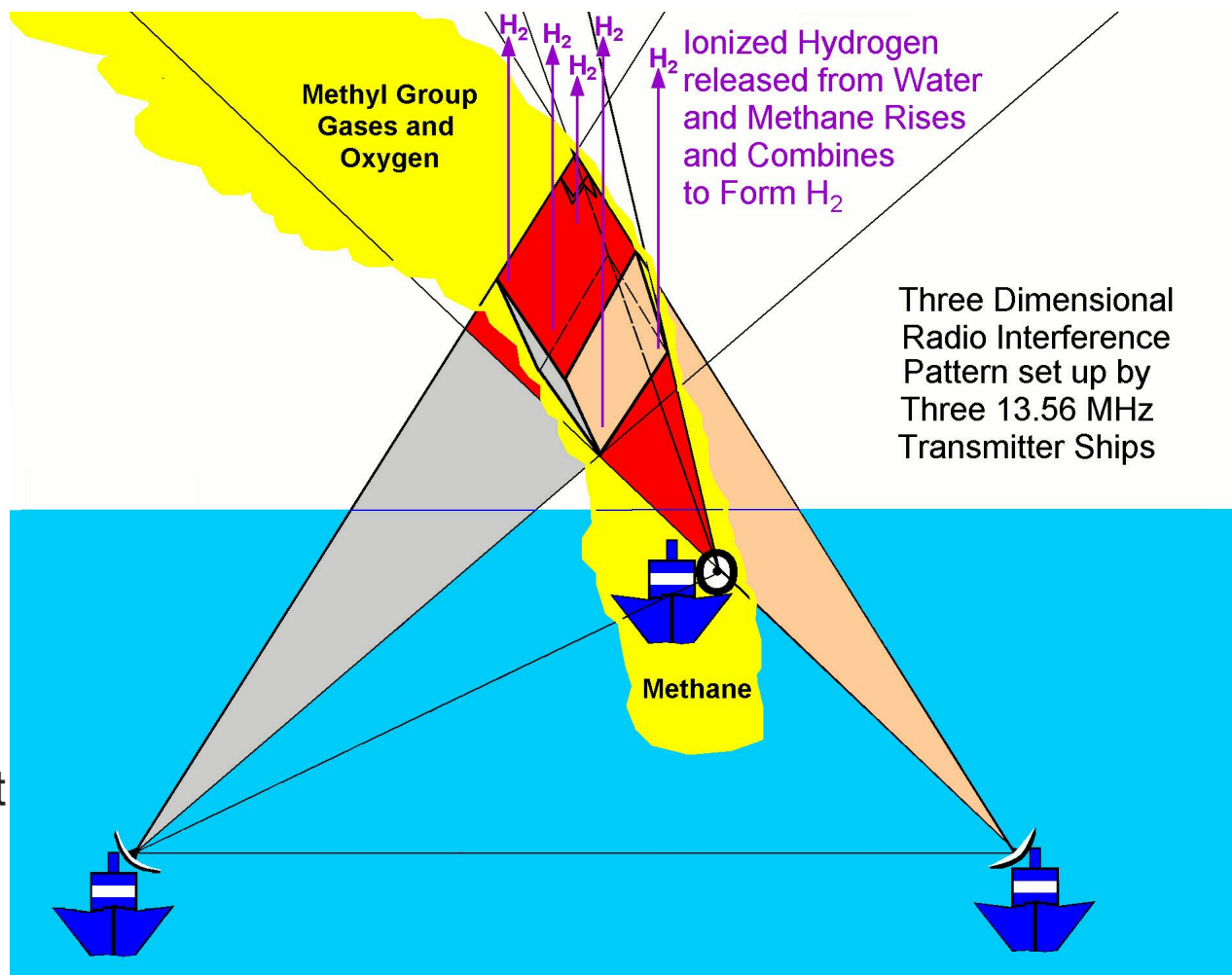
Thus, the CVD process does not require hydroxyl. Furthermore, the CVD process can take place at pressures that include the entire atmospheric pressure range up to 100 km altitude (Wikipedia CVD).

While it is unlikely that diamonds will be generated in the troposphere (due to the high oxygen content, which will oxidize carbon into carbon dioxide), it is nonetheless possible that, high in the stratosphere or mesosphere (80 km) where the methane, hydrogen and oxygen contents are similar (Heicklen, 1976), some nanodiamonds may form, with the additional benefits of reflecting some sunlight back into space.

As discussed, the radio transmitters only need to break the first C-H bond in the methane molecule. The moment this occurs, the daughter products do not have the massively high global warming potential of the methane and the threat is sharply diminished.

Thus, no further loosening of the bonds of the remaining methyl is necessary.

Instead of two transmitters, three transmitters could be used, mounted on vessels, to target a methane cloud, with three transmission beams intersecting at the point where methane is abundantly present.

Methyl Group Gases and Oxygen

$H_2$ $H_2$ $H_2$ $H_2$ $H_2$ $H_2$ Ionized Hydrogen released from Water and Methane Rises and Combines to Form $H_2$

Three Dimensional Radio Interference Pattern set up by Three 13.56 MHz Transmitter Ships
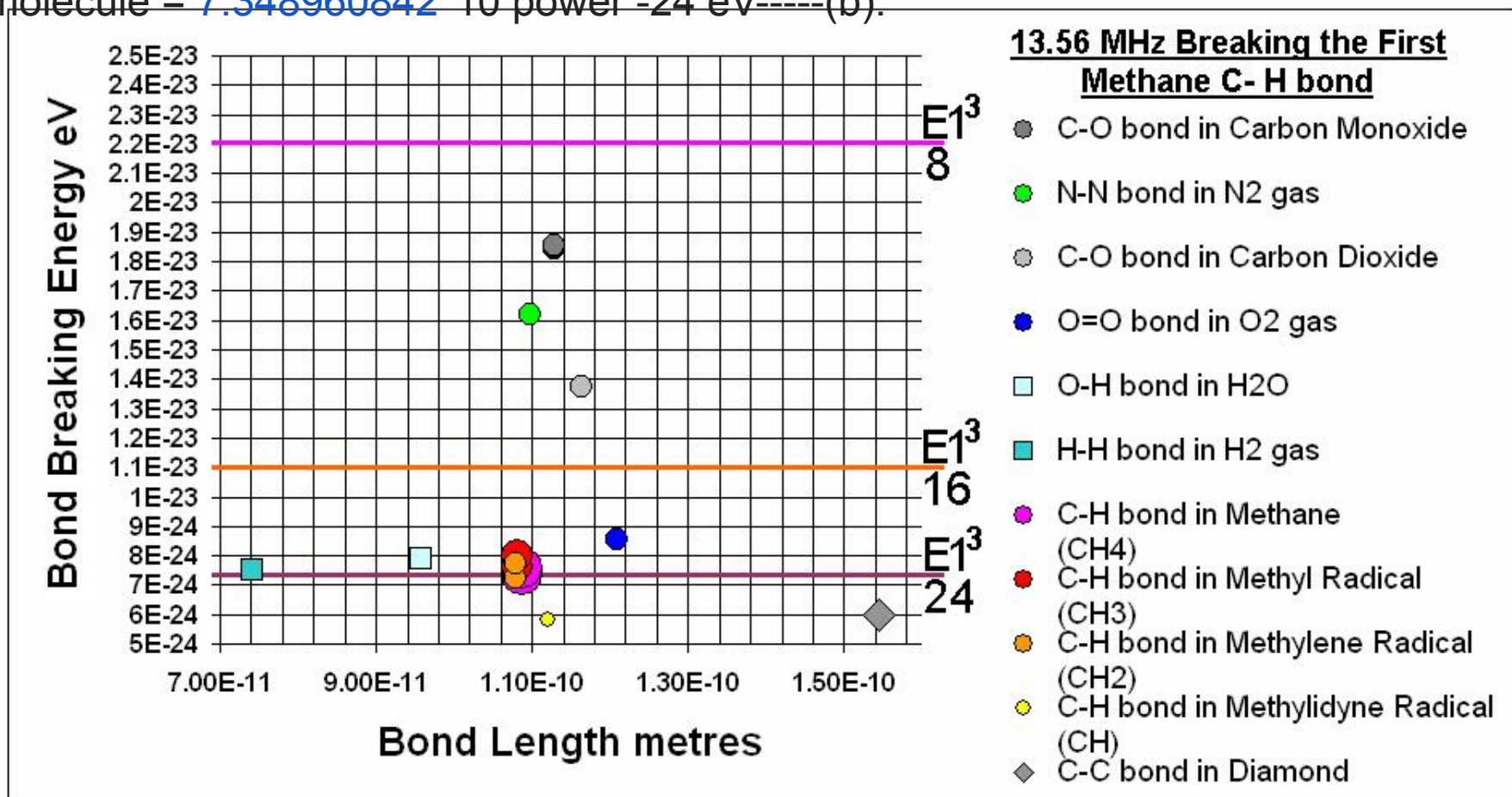
Methane

*Cubic radio interference pattern*

# Breaking the first C-H bond

The calculated energy (E1) of the 13.56 MHz beam is $5.607967164*10$ power -8 eV.

13.56 MHz = a wavelength of 22.10858835 metres (=RFT).

Now (E1)cubed/(3* octave) = (E1) cubed/24 = $7.348609071*10$ power -24 eV---(a).

This is almost exactly the energy required to break the first C-H bond in the methane molecule = $7.348960842*10$ power -24 eV-----(b).



Figure: Plot of Bond Breaking Energy eV (y-axis, 5E-24 to 2.5E-23) vs Bond Length metres (x-axis, 7.00E-11 to 1.50E-10).

Legend — **13.56 MHz Breaking the First Methane C- H bond**:
- C-O bond in Carbon Monoxide
- N-N bond in N2 gas
- C-O bond in Carbon Dioxide
- O=O bond in O2 gas
- O-H bond in H2O
- H-H bond in H2 gas
- C-H bond in Methane (CH4)
- C-H bond in Methyl Radical (CH3)
- C-H bond in Methylene Radical (CH2)
- C-H bond in Methylidyne Radical (CH)
- C-C bond in Diamond

Horizontal lines labelled $E1^3/8$, $E1^3/16$, $E1^3/24$.

When the cubic radio interference pattern is set up in the cloud, the radio band width can be exactly designed to only ionize the initial C-H bonds on the methane molecule, the oxygen, water and small amount of hydrogen in the air.
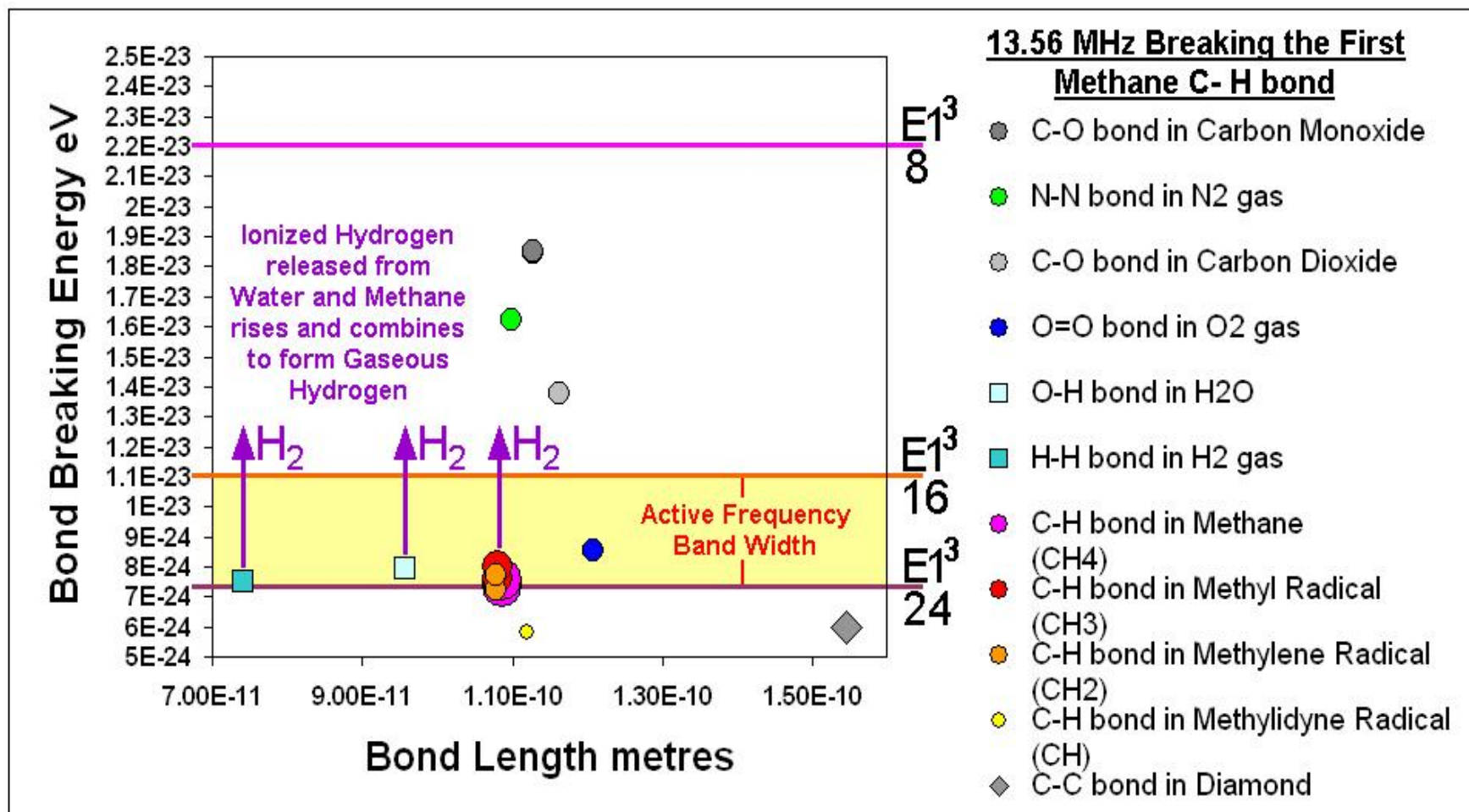
Once these molecules are ionized, the hydrogen will quickly rise up because of its low density out of the interference zone and recombine back into H2 above and away from the methane cloud. The loosened hydrogen may continue rising in the atmosphere, or may combine into water vapor, through oxidation with oxygen. Apart from hydrogen, the other ionized reactants in the methane cloud are mostly oxygen and methyl group gases which will be carried laterally by winds out of the radio interference pattern. Effectively, the gravity field of the Earth and the Arctic wind systems act as a giant atmospheric ion separator.

The reactions of Methyl Group gases depend on what other gases are present and the abundance of ionized oxygen suggests that CH2OH, CO2H or CHO will probably form. Methyl Group gases can be quite nonreactive and resist strong acid attack in some organic compounds (Wikipedia, 2012). As said, methyl gases do not have the high global warming potential that methane has, so there's no need to complete the full decomposition process that takes place in a reactor chamber to deposit carbon onto an object.

The mean C-H bond length of the methane molecule (CH4) is 1.087 *10 power -10 metres and the C-H bonds are at angle of 109.5 degrees to one another. The methyl radical CH3 has a C-H bond length of  1.08*10 power -10 metres and is planar. The methylene molecule CH2 has a C-H bond length of 1.078*10 power -10 metres and the C-H bonds are at an angle of 130 degrees.  The C-H molecule has a bond length of 1.1199*10 power-10 metres and is linear (Lide and Frederickse, 1995).

# References

Heicklen, J. 1976. Atmospheric Chemistry. Academic Press, New York, 405 pp.

Lide, D. R. and Frederikse, H.P.R., 1995. Handbook of Chemistry and Physics. 75th Ed. CRC Press, Ann Arbor, pp. 1-1 to 1 -33.

Wikipedia, 2012. Methyl Group.

en.wikipedia.org/wiki/methyl_group

Wikipedia, 2012. CVD

http://en.wikipedia.org/wiki/Chemical_vapor_deposition_of_diamond

http://en.wikipedia.org/wiki/Chemical_vapor_deposition

# Radio frequencies in the decomposition process

A radio frequency of 13.56 MHz is equivalent to a wavelength of 22.10858835 metres (= RFT).

Now:- RFT/(3*2 power 36) = RFT/(3*8 power 12) = RFT/(3*(8*8) power (3*2) = 1.072407678*10 power -10 metres = 0.986575601 of the methane C-H bond length of 1.087*10 power-10 metres. Note that the harmonic wave of wavelength = 1.072407678*10 power -10 metres is an exact number of octaves of the 13.56 MHz transmission frequency, i.e. it is exactly in tune with it, while it also contains the numbers 3 and 2 in its formulation, which are the harmonic numbers needed in the interference pattern we wish to generate within the methane cloud to break it down.

The 13.56 MHz frequency has an octave harmonic wavelength that is 1.3424398 % shorter than the C-H bond length on the methane molecule. Because the radio frequency harmonic wavelength is shorter, it will set up a natural vibration of the C-H bond by trying to compress it and the C-H bond will then extend as the zero energy point part of the radio wave passes through it to greater than its normal length. Enhancing this natural vibration is only necessary to the point of sufficient waves passing through the methane molecule to make one of the four C-H bonds in the methane loosen enough for hydrogen to break free.

If we consider the methane CH4 tetrahedron as enclosed in a cube of side 1 then the cube face diagonal (square root 2) is equivalent to the spacing of the hydrogen atoms and half the cube diagonal ((square root 3)/2) is equivalent to the C-H bond spacing. We can use this to calculate the H-H spacing in the methane molecule as 1.775063867*10 power -10 metres from the C-H bond length of 1.087*10 power -10 metres.

The radio frequency harmonic of the H-H spacing in the methane molecule

= ((2* square root 2)/(square root 3))* (RFT/(3*(8*8) power (3*2))

= ((2* square root 2)/(3*square root 3))*(RFT/((8*8) power (3*2))

= ((2 power (3/2)/(3 power (3/2))* (RFT/((8*8) power (3*2))

= 1.751234406*10 power -10 metres which is 0.986575434 of the actual H-H spacing calculated from the methane C-H spacing of 1.087*10 power -10 metres.

This means the RFT harmonic is shorter than the methane H-H spacing by 1.34 % and will undergo the same compression and expansion stresses as the methane C - H bonds when the 13.56 MHz radio frequency is imposed on it. It should be noted again that the H- H harmonic is exactly in tune with the 13.56 MHz transmission and it contains the numbers 3, 2 and 3/2 in its formulation which are the same as the harmonic numbers needed in the interference pattern we wish to generate within the methane cloud to break it down.

There are four fundamental vibration frequencies of the methane molecule (classified as a Tetrahedral XY4 molecule with a point group Td) which are tabulated below with their wavelengths (Lide and Frederickse, 1995).

**Symmetrical Stretching**

Wavenumber 2917 cm-1 = Wavelength 3.428179637*10 power -6 metres

Frequency = 8.744945999*10 power 13 Hertz     (micrometer/infrared)

**Degenerate Deformation (e)**

Wavenumber 1534 cm-1 = Wavelength 6.518904824*10 power -6 metres

Frequency = 4.598816306*10 power 13 Hertz     (micrometer/infrared)

**Degenerate Stretching (f)**

Wavenumber 3019 cm-1 = Wavelength 3.312355084*10 power -6 metres

Frequency = 9.050734308*10 power 13 Hertz     (micrometer/infrared)

**Degenerate Deformation (f)**

Wavenumber 1306 cm-1 = Wavelength 7.656967841*10 power -6 metres

Frequency = 3.915289501*10 power 13 Hertz     (micrometer/infrared)

The fundamental **Degenerate Deformation (e)** vibration with a wavelength of 6.518904824*10 power -6 metres when divided by 3 power 10 ( = 1.103982256*10 power -10) gives the closest match to the measured C-H bond length of 1.087*10 power -10 metres.

The Degenerate Deformation (e) wavelength/(3 power 10) is 1.16 % longer than the measured C-H bond length and 2.9 % longer than the RFT harmonic of 1.072407678*10 power -10 metres.  The RFT harmonic will be trying to compress the measured methane C-H bond by 1.34 % and then as the C-H bond rebounds  when the zero energy level of the RFT wave passes through it, it should cause the fundamental Degenerate Deformation (e) vibration to resonate and become enhanced because it is only 1.16 % longer than the measured methane C-H bond length(1.087*10 power -10 metres).

A good match is found between the estimated methane H-H  separation (1.775063867*10 power -10 metres) and the fundamental **Symmetrical Stretching** vibration with a wavelength of 3.428179637*10 power -6 metres when it is divided by 3 power (3*3) giving a wavelength of 1.741695695*10 power -10. The wavelength of the Symmetrical Stretching/(3 power 9) is some 1.9 % shorter than the estimated methane H-H separation.

An almost perfect match is found between the RFT harmonic of 1.751234406*10 power-10 and the fundamental **Symmetrical Stretching** vibration with a wavelength of 3.428179637*10 power -6 metres when it is divided by 3 power (3*3) giving a wavelength of 1.741695695*10 power -10. The fundamental Symmetrical Stretching vibration/(3 power 9) is some 0.55 % shorter than the RFT harmonic and should resonate and amplify the H-H spacing as the 13.56 MHz wave passes through.

It should be noted that the Degenerate Deformation (e) and Synthetic Stretching harmonics contain the number 3 in their formulation which is one of the harmonic numbers needed in the interference pattern we wish to generate within the methane cloud to break it down.

I believe that the resonance of the fundamental **Degenerate Deformation (e)/(**3 power 10) vibration on the methane C-H bond with the 13.56 MHz harmonic in concert with the compression and extension of the methane H -H separation by the fundamental **Synthetic Stretching** resonance/(3 power 9) will grow until one of the methane C-H bonds breaks eliminating the methane molecule from the global warming equation. This process should be enhanced by the generation of a three dimensional radio frequency 3:2 or 3:1 harmonic interference pattern in the methane clouds.

Reference: http://icb.u-bourgogne.fr/omr/SMA/methane/vib.html
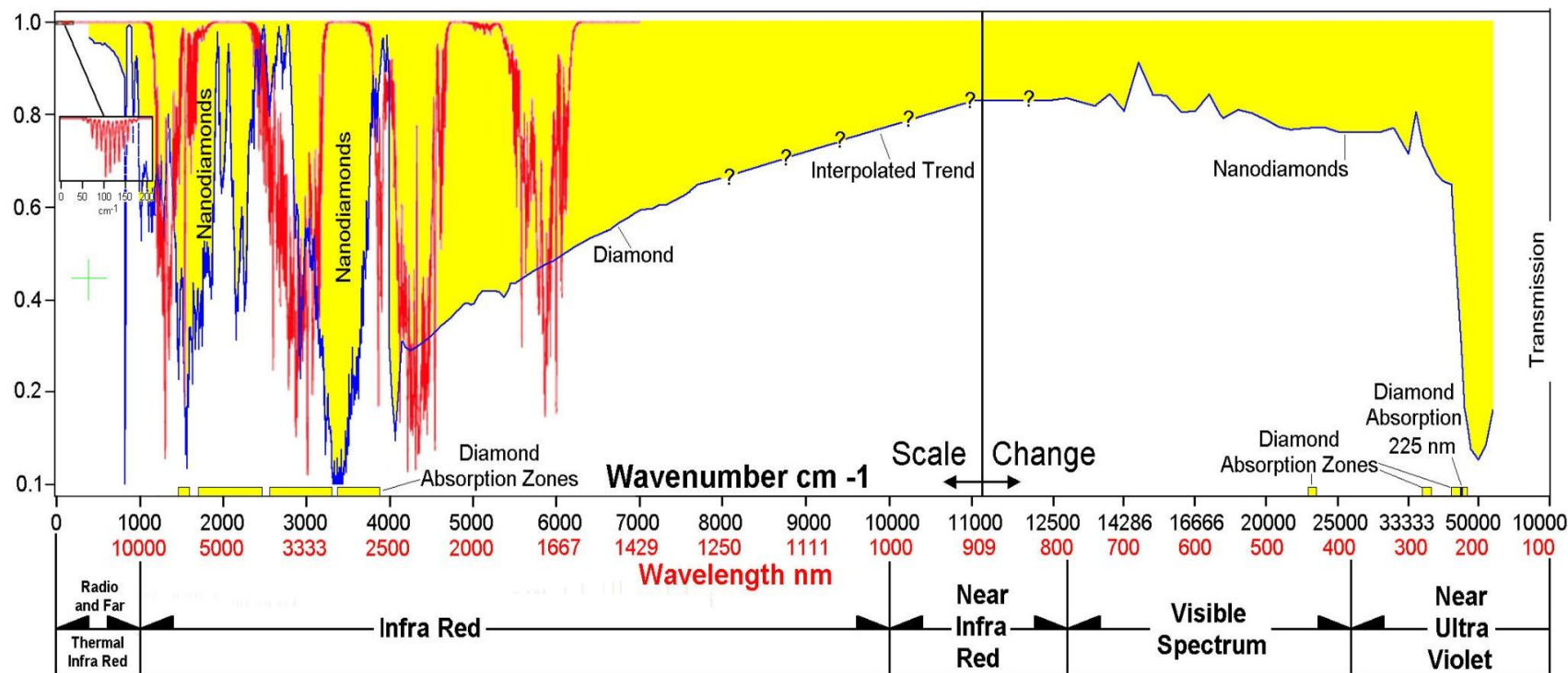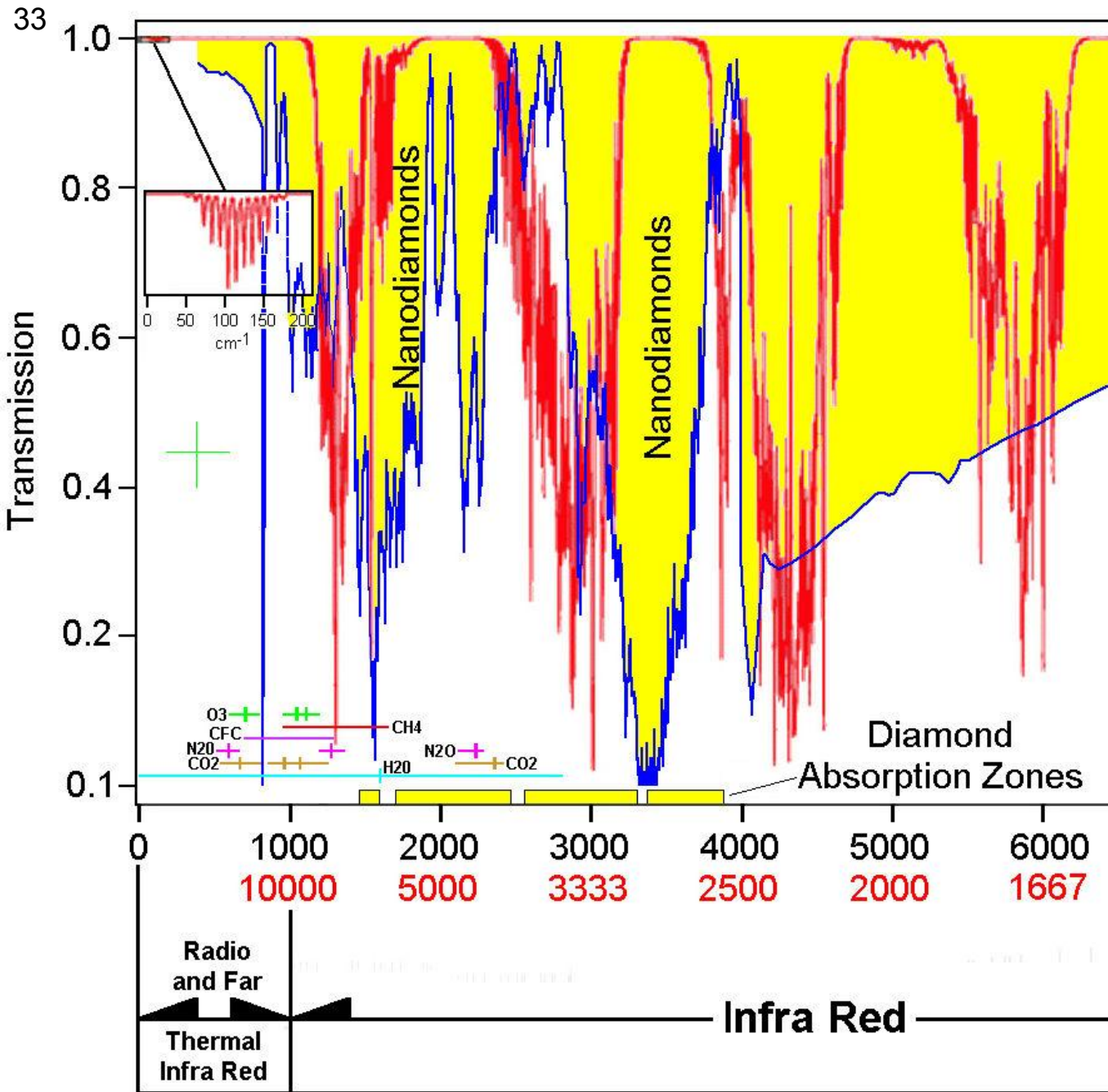
# Absorption spectrum



Figure 1. The absorption spectra of methane, nanodiamond and diamond in the infra-red, visible and ultraviolet frequency range. Red methane curve from ICB, 2012. Blue nanodiamond curves from Shiryaev et al. 2006 and Lansley et al. 2002. Diamond absorption trend from the Smithsonian (2012). Diamond absorption zones from Lide and Frederickse, 1995. Diamond absorption peak at 225 nm (5.5 eV) from Lansley et al. 2002.

From the previous image, this time with a focus on the lower end of the spectrum.

Infra-red absorption peaks and ranges are added for various gases, including methane (CH4), carbon dioxide (CO2), nitrous oxide (N2O), water vapor (H2O), ozone (O3) and chlorofluorocarbon (CFC).

From: Sternowski, 2012 and

# References

ICB 2012. Spectroscopy of Methane. Molecular Spectroscopy and Applications. Department of Optics and Matter-Radiation Interaction. Institut Carnat de Bourgogne. UMR5209 CNRS-Universite de Bourgogne, Dijon. France. http://icb.u-bourgogne.fr/omr/SMA/Methane

Lansley S.P., Gaudin, O., Ye, H., Rizvi N., Whitfield, M.D., Mc Keag, R.D., Jackman R.B., 2002. Imaging deep UV light with diamond-based systems. Diamond and Related Materials, 11, pp 433 – 436.

Lide D.R. and Frederickse H.P.R., 1995. CRC Handbook of Chemistry and Physics. CRC Press. Boca Raton. pp. 1-1 to I-1.

McCartney E.J. 1983. Absorption and Emission by Atmospheric Gases. John Wiley and Sons.

Shiryaev , A.A., Lakoubovskii, N., Grambole D. and Dubrovinskaia, N., 2006. Spectroscopic study of defects and inclusions in bulk poly-and nanocrystalline diamond aggregates. Journal of Physics. Condensed Matter 18, No. 40, L493 – L501.

Smithsonian, 2012. Infrared Spectroscopy Laboratory. Smithsonian Museum of Natural History. Washington. Mineral Sciences. si.edu/facilities/ftir.htm

Sternowski, R.H., 2012. Lecture 7. Softronics Ltd. http://www.softronicsltd.com

# Energy Requirements

In this method of destruction of atmospheric methane, three transmitters are situated at the correct distance apart so that their three transmission beams intersect exactly at right angles in space within the methane cloud we are wanting to decompose and they set up an interference pattern which is a cube of the original linear transmission beams. Accordingly, the three transmitter and the intersection point form a three dimensional interference figure.

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Note:-  A frequency of 1 MHz = a wavenumber of $3.33564*10$ power -5 cm-1

= a wavelength of $2.997925436*10$ power 4 cm = $2.997925436*10$ power 2 metres

= $3.990313*10$ power -7 kJ/mol (kilo joules per mole) = $4.135669*10$ power -9 eV

= $4.79922*10$ power-5 Kelvin.

Lide and Frederickse, 1995.

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The radio frequency of 13.56 MHz which is used to decompose methane and form diamonds in the lab. is equivalent to a wavelength of 22.10858835 metres (=RFT). The energy of the 13.56 MHz beam is $5.607967164*10$ power -8 eV.

It requires 427 kJ/mol to break the first C-H bond on the methane molecule in one mole of methane which is equivalent to 16.04276 grams methane (6.022*10 power 23 methane molecules). Therefore the energy per unit mole to break the first C-H bond in the methane is 4.425544219 eV. This makes the energy required to break the first C-H bond in a single methane molecule equal to 7.348960842*10 power -24 eV.

The calculated energy (E1) of the 13.56 MHz beam is 5.607967164*10 power -8 eV. 13.56 MHz  = a wavelength of 22.10858835 metres (=RFT).

Now (E1)cubed/(3* octave) = (E1) cubed/24 = 7.348609071*10 power -24 eV---(a). This is almost exactly the energy required to break the first C-H bond in the methane molecule = 7.348960842*10 power -24 eV-----(b).

The ratio (a)/(b) = 0.999952133.

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Note:- (E1) cubed/(3*octave)=(E1) cubed/(3*(2 cubed))=(1/3*((E1/2) cubed))

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However  each 13.56 MHz beam has an energy which is the cube root of 24 greater than the energy required to break the first C-H bond in the methane molecule equal to 2.884499141 times the amount of energy and thus this radio signal should easily destroy the methane molecule

We can however try transmitting at twice the 13.56 MHz frequency = 27.12 MHz = 27.12*10 power 6 Hertz. A frequency of 27.12 MHz = a wavelength of 11.05429417 metres. The 27.12 MHz frequency has an energy (E2) of 1.121593433*10 power -7 eV.

Now (E2)cubed/(3*(square octave)) = 7.348609071*10 power -24 eV---(c).

This is the same energy as calculated in (a) and is almost identical to the energy required to break the first C-H bond in the methane molecule =7.348960842*10 power -24 eV-----(b). The ratio of (c)/(b) = 0.999952133.

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Note:- (E2) cubed/(3*square octave)=(E2) cubed/(3*8*8)=

(E2) cubed/(3*(2 cubed)*(2 cubed)) = (E2) cubed/(3*(4 cubed)) =(1/3*((E2/4) cubed))

_____

However  each 27.12 MHz beam has an energy which is the cube root of 192 greater than the energy required to break the first C-H bond in the methane molecule equal to 5.768998281 times the amount of energy and thus this radio signal should even more easily destroy the methane molecule.

We can also transmit at four times the 13.56 MHz frequency = 54.24 MHz = 54.24*10 power 6 Hertz  = wavelength of 5.527147087 metres, which is equivalent

Now (E3)cubed/(3*(cubic octave)) = 7.348609071*10 power -24 eV---(d). This is the same energy as calculated in (a) and is almost identical to the energy required to break the first C-H bond in the methane molecule =7.348960842*10 power -24 eV-----(b). The ratio of (d)/(b) = 0.999952133.

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Note:- (E3) cubed/(3*cubic octave)=(E3) cubed/(3*8 cubed) =(1/3*((E3/8) cubed))

_____

However each 54.24 MHz beam has an energy which is the cube root of 1536 greater than the energy required to break the first C-H bond in the methane molecule equal to 11.53799656 times the amount of energy and thus this radio signal should even more easily destroy the methane molecule.

As I stated before, I believe that the resonance of the fundamental **Degenerate Deformation (e)/(**3 power 10) vibration on the methane C-H bond with the 13.56 MHz harmonic in concert with the compression and extension of the methane H - H separation by the fundamental **Synthetic Stretching** resonance/(3 power 9) will grow until one of the methane C-H bonds breaks eliminating the methane molecule from the global warming equation. This process will be enhanced by the generation of a three dimensional radio frequency 3:2 or 3:1 harmonic interference pattern in the methane clouds by using three transmitters separated such that the three radio beams intersect one another almost exactly at right angles .

# Temperature and further variables

To change the temperature at the point where radio beams intersect, their wattage could be varied, while the impact of using long periods of exposure versus short strong pulses could also be tested. Varying energy, frequency and further variables should be tested further, e.g. beams with slightly different frequencies could be used to produce an amplifying effect that could, apart from increasing signal strength, could also raise temperature levels.

Temperature could also be manipulated by temporarily creating hotspots in the area focused on, by using two laser beams from small airplanes, heating up the area where the radio beams intersect, synced with radiofrequency pulses.

To further assist the process, hydroxyl and oxygen could be added to the atmosphere to speed up oxidation (see: oxygenating the Arctic).

Further methods, in addition to radio transmitters, could be used in complementary ways to reduce the risk and impact of large releases of methane in the Arctic.

# References

Sam Carana - Oxygenating the Arctic

http://arctic-news.blogspot.com/p/oxygenating-arctic.html

How would you allocate US$10 million per year to most reduce climate risk?

http://geoengineering.gather.com/viewArticle.action?articleId=281474979240772



Sam Carana, April 2011