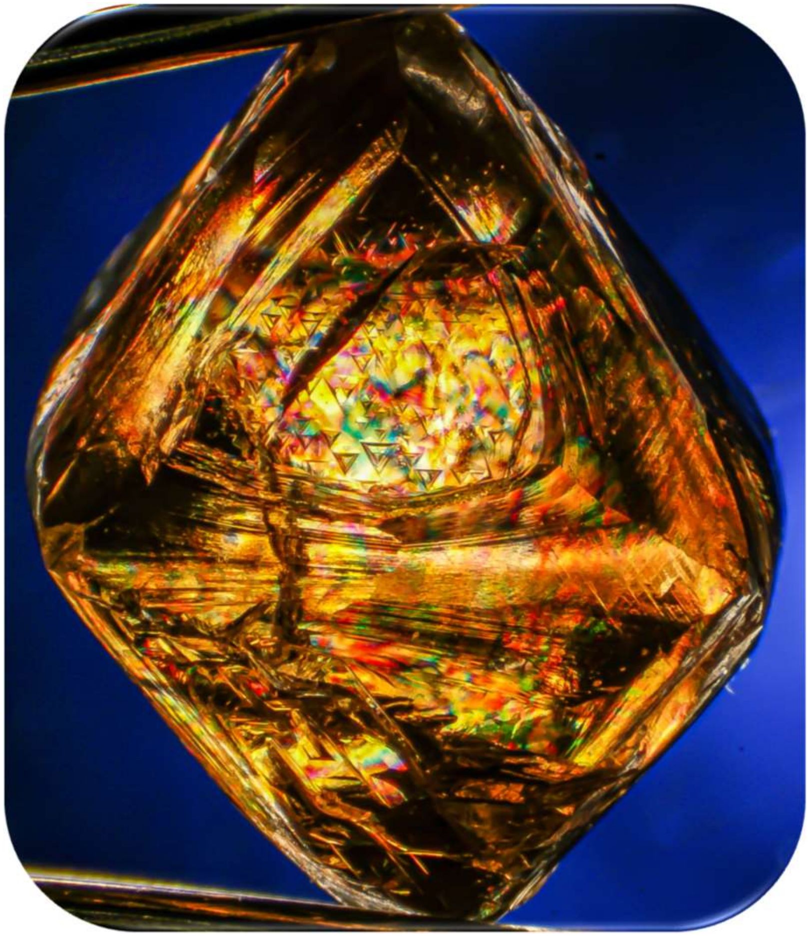


Photo by R. Lightfoot

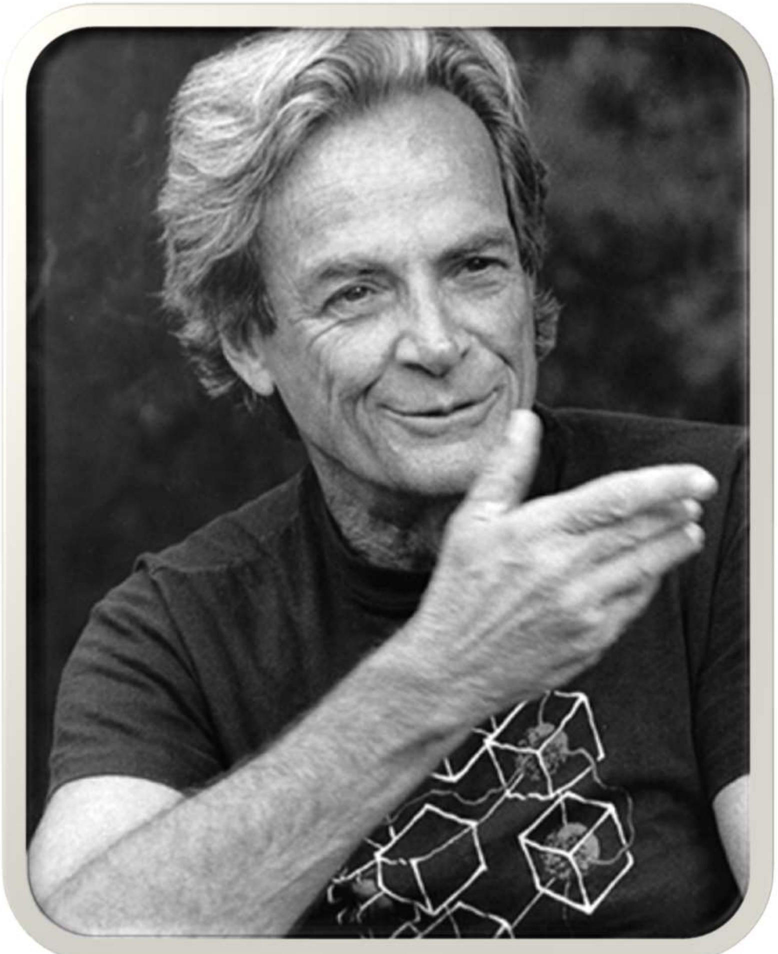
Screening Challenges: A Discussion of Standard Methods for Diamond

Randy Lightfoot

GG, CG, CM (NAJA), RGA (ISG)

MAYFLOWER
Estate Buying & Consulting

Email: randy@mayflowerestatebuyers.com
Instagram: gemguy_13



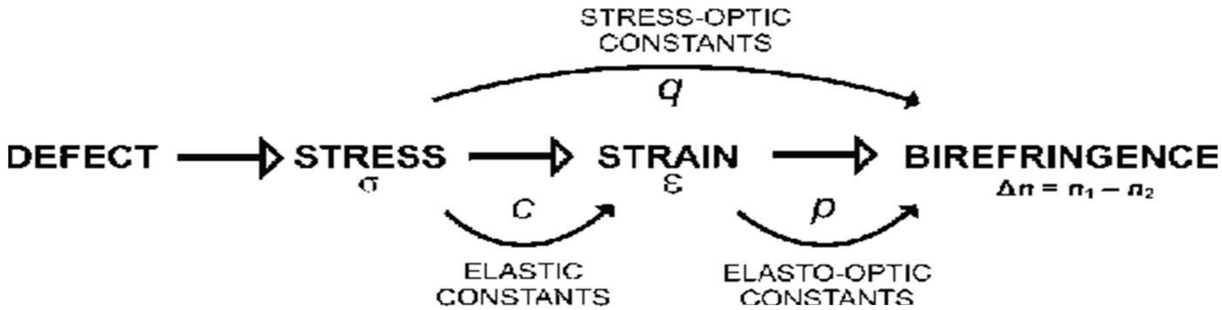
"I learned very early on the difference between knowing the name of something and knowing something."
– Dr. Richard P. Feynman

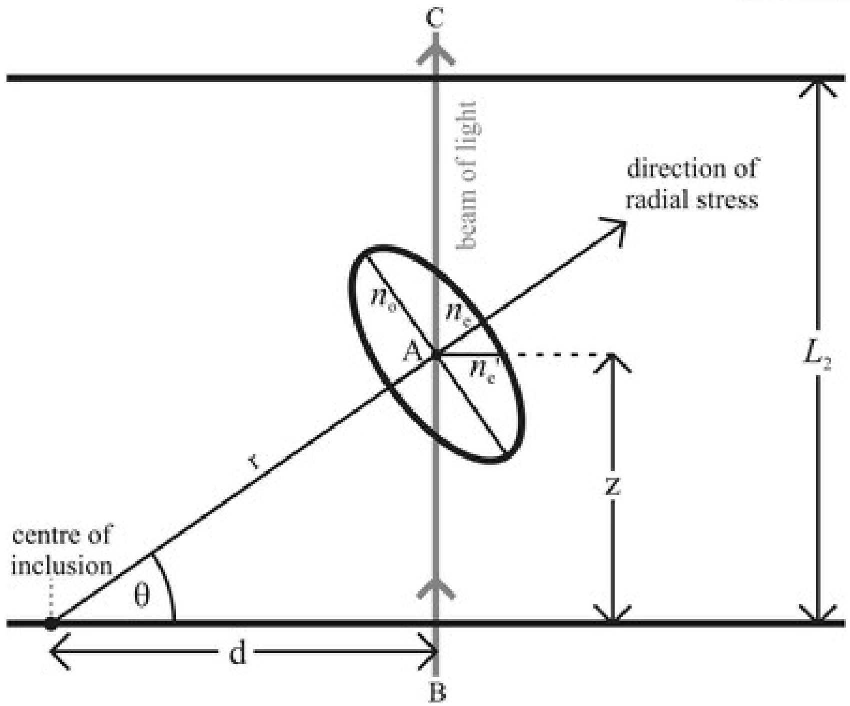
How does learning about standard screening methods benefit you practically? Why should you care about diamond science?....

Disclaimers

- ***Goal***: reinforce the importance of understanding and using standard screening methods in your daily work, and the current challenges involved in using certain standard screening methods.
- As industry professionals, we are responsible for achieving continued education, investing in appropriate equipment, and adhering to updated industry standards/best practices no matter your level of expertise or established years in the industry.
- Standard screening methods do not replace advanced testing techniques – FTIR, UV-Vis-NIR, PL spectroscopy etc.
- I am not an experimental gemologist. I am a gemologist-appraiser using standard screening methods to observe diamond for clues to origin and possible treatment for color.
- “Origin” refers to the growth environment (i.e., natural or lab-grown), not geographic provenance

Quantifying Anomalous Birefringence in Singly Refractive Crystalline Materials





$$U = \frac{1}{2} F \Delta L = \frac{1}{2}(200\ N)(0.05\ m)$$

$$\boxed{U = 5\ J}$$

$I(r)=\sum_g H_g \exp(2\pi i g\cdot r)=\sum_g A_g \exp\{2\pi i g\cdot r+iP_g\}$

Illustrations Courtesy of Dr. Daniel Howell & Shizhe Feng and Zhiping Xu

Cross section illustration of kimberlite eruption by De Beers

Understanding Diamond Geology

Mother nature is quite the bully to diamonds…

“Mother nature cooks in a very dirty kitchen.” J. Koivula

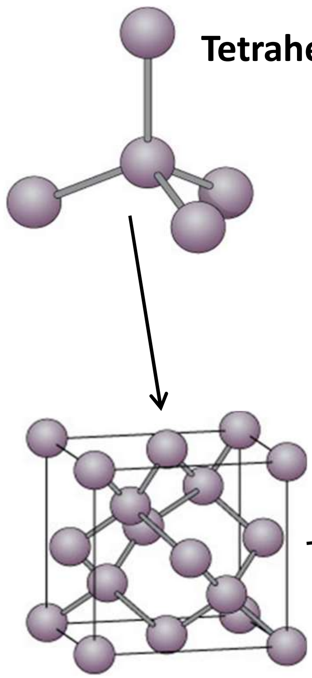
Photo by GIA

Specimen of the Australian Museum, Sydney, Australia

Photo by GIA

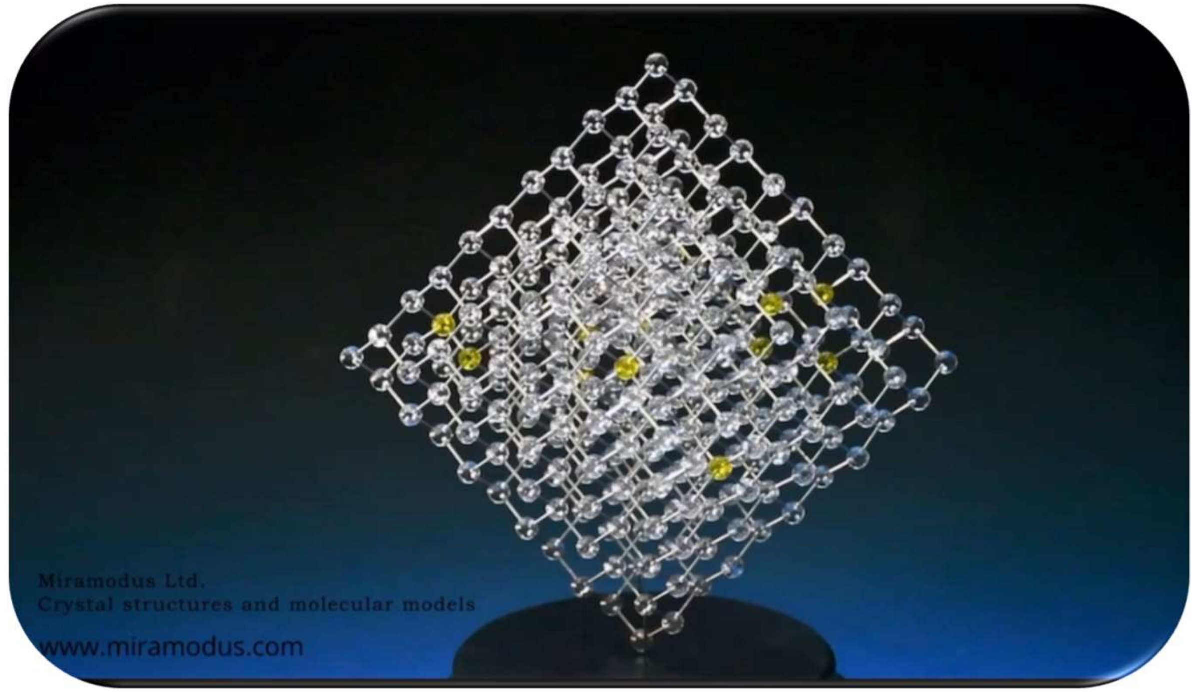
The Diamond Crystal Lattice

Tetrahedron



Unit Cell

One C atom bonded to four neighboring C atoms by covalent bonds in a tetrahedral coordination



Defect: anything other than pure carbon and where there is no strain imposed on the crystal lattice

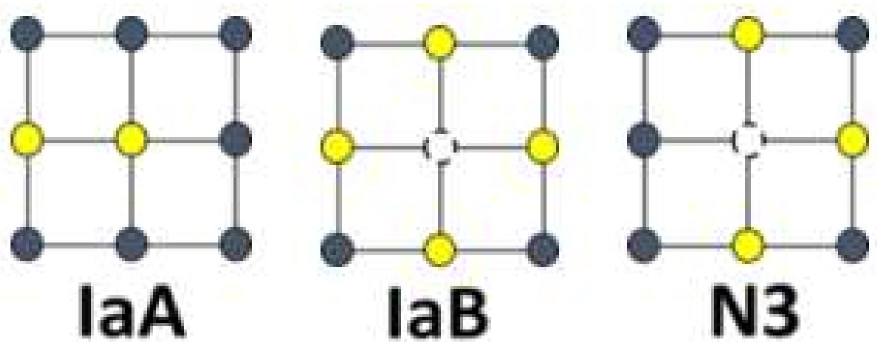
No Defects = Perfect Diamond → **We would see nothing inside of the diamond**

Crystal Lattice Defects

Defect: anything other than pure carbon and where there is no strain imposed on the crystal lattice

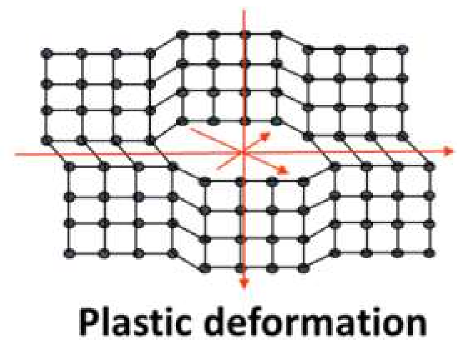
Point Defects

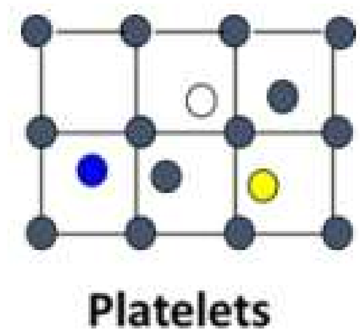
Trace elements (N, B, Si, H, Ni etc.,) & vacancies (isolated or N-V) (*defects that require optical spectroscopy to identify)*



Extended Defects

Plastic and elastic deformation of the crystal lattice, slip traces, dislocations, vacancy clusters/complexes (*defects generally large enough to see under magnification and predominantly caused by geologic forces*)





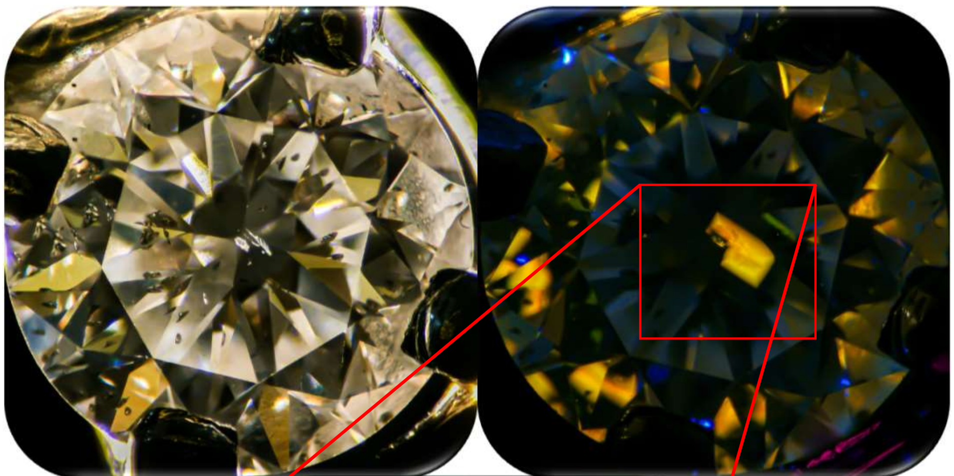
These defects cause variations in the RI of diamond that we can then observe in the form of color (i.e., strain/anomalous birefringence)

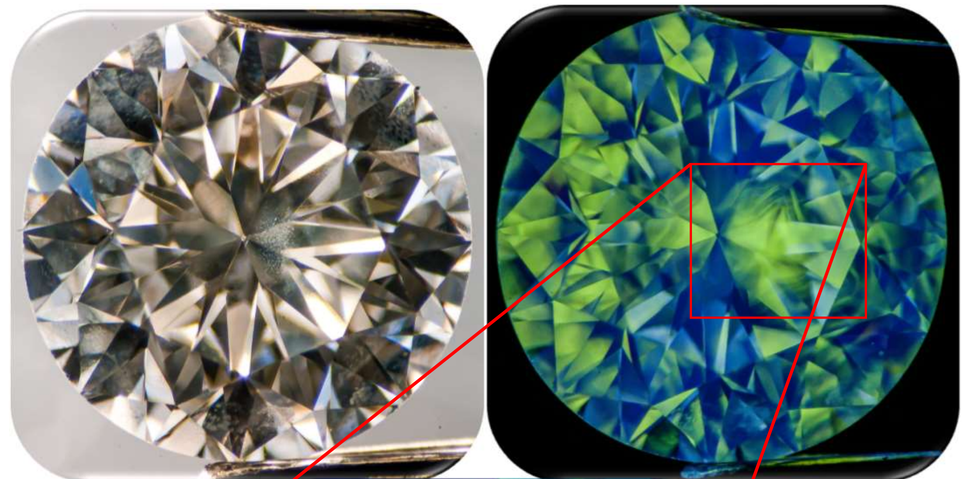
YouTube: APHT and HPHT treatments of natural and of Laboratory-grown Diamonds - Dusan Simic (@Branko Gems)

Illustrations courtesy of Dusan Simic

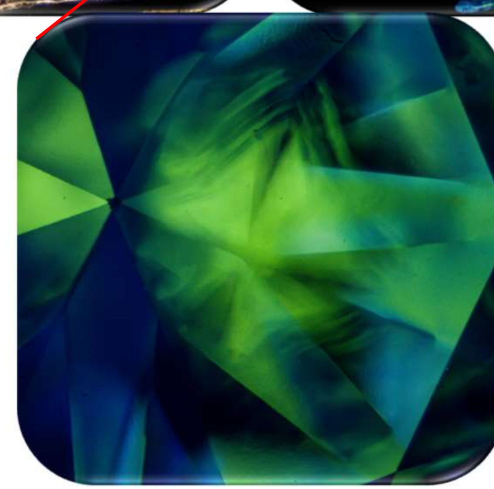
Crystal Lattice Defects

Keep in mind that defect distribution in natural diamond is very often highly heterogeneous





Both natural diamonds photographed in 365nm [longwave] UV



Photos by R. Lightfoot

Standard Screening Methods

I. Microscopy – Internal Graining & Inclusions
- Can help to determine origin & treatments for clarity -

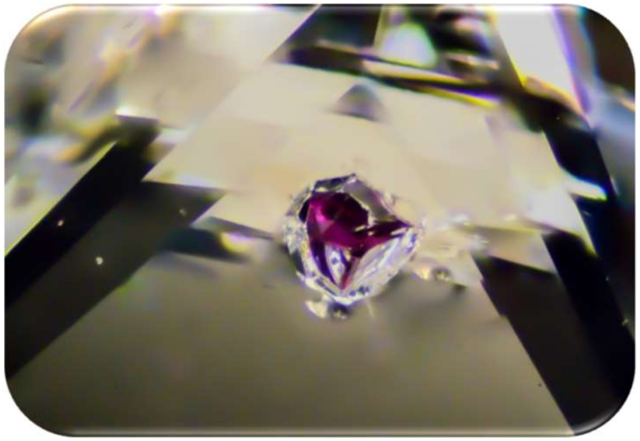
II. Cross-Polarized Filters (CPF) & 1st Order Red Compensator (1ORC)
- Helps to identify clues to diamond type & origin by observing strain patterns -

III. UV Illumination – LW, SW, Phosphorescence
- Helps to identify clues to origin and possible treatment for color -

IV. Diamond verification instruments (DVI)
- Helps to screen for natural and lab-grown diamond using certain UV technology

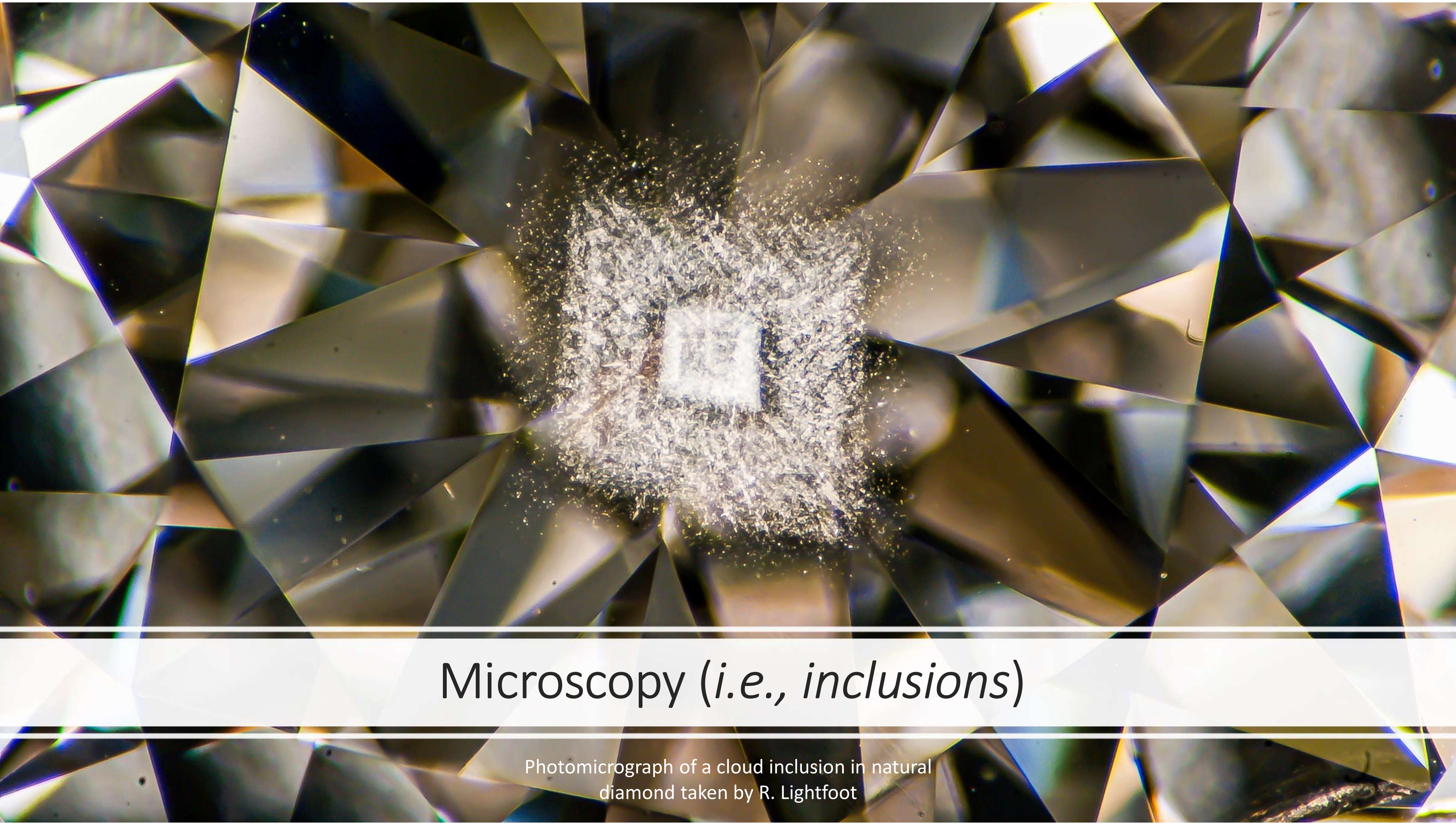
Treated natural diamond under 365nm UV illumination

Pyrope garnet inclusion in natural diamond



Strain in a natural diamond

Photos by R. Lightfoot

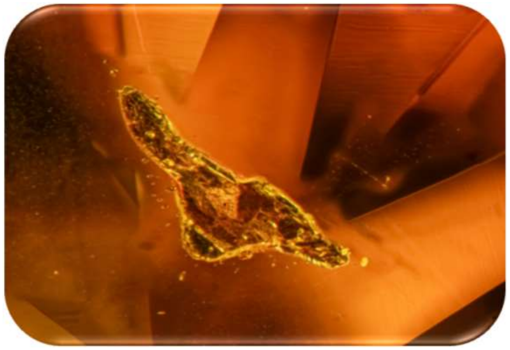


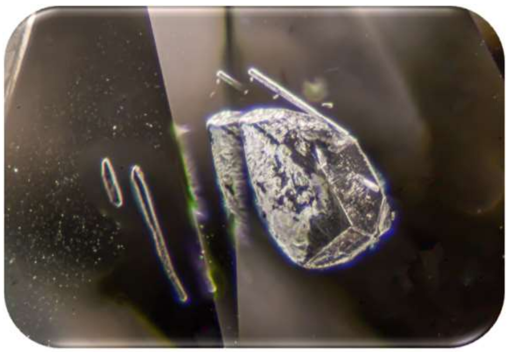
Microscopy (*i.e., inclusions*)

Photomicrograph of a cloud inclusion in natural diamond taken by R. Lightfoot

HPHT-Grown Diamond Inclusions

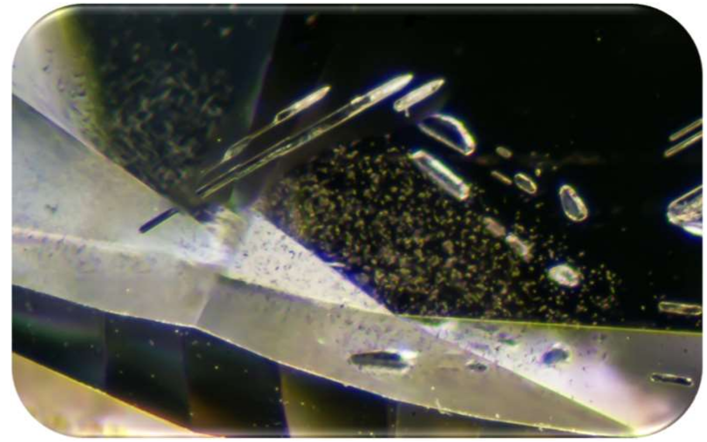
Only metallic flux can be relied upon for positive inclusion ID

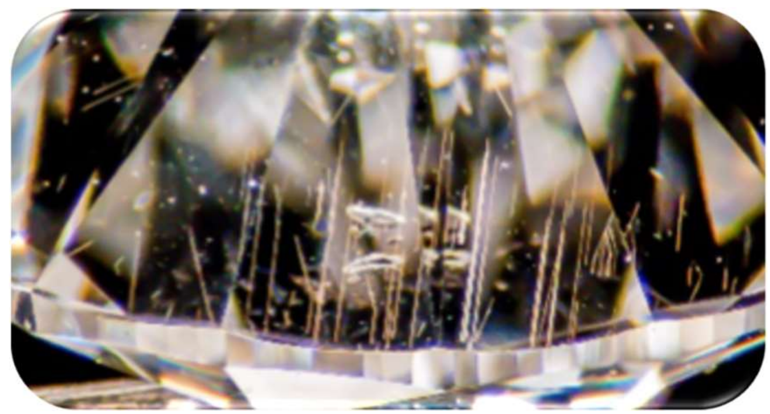




Metallic flux (***magnetic***)

Isolated or clusters of pinpoint inclusions



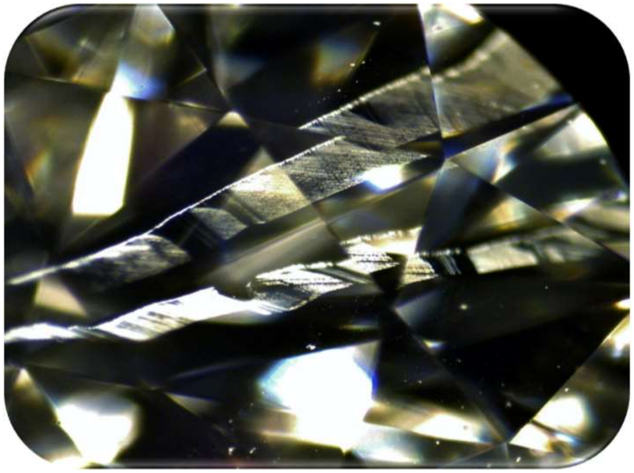


Linear or string-like inclusions

Photos by R. Lightfoot

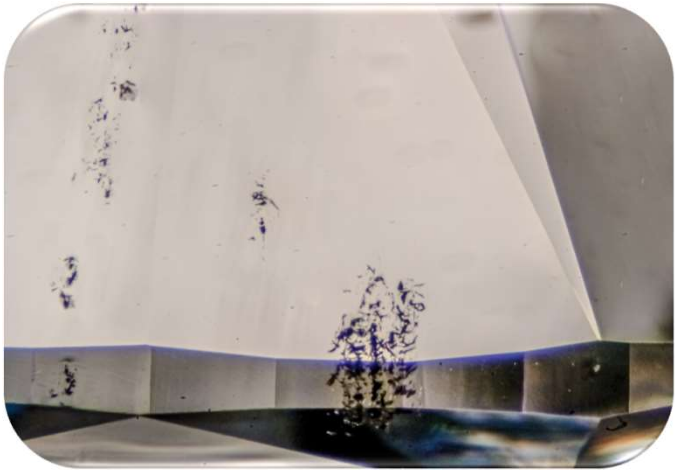
CVD-Grown Diamond Inclusions

No CVD inclusions can be relied upon for positive ID



Twinning wisps in natural diamond

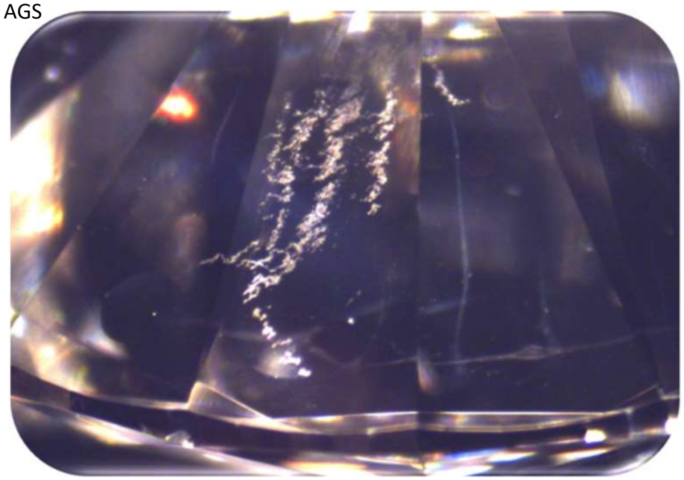
Non-diamond carbon inclusions either mimicking isolated pinpoints or in cloudlike arrangements (most common)

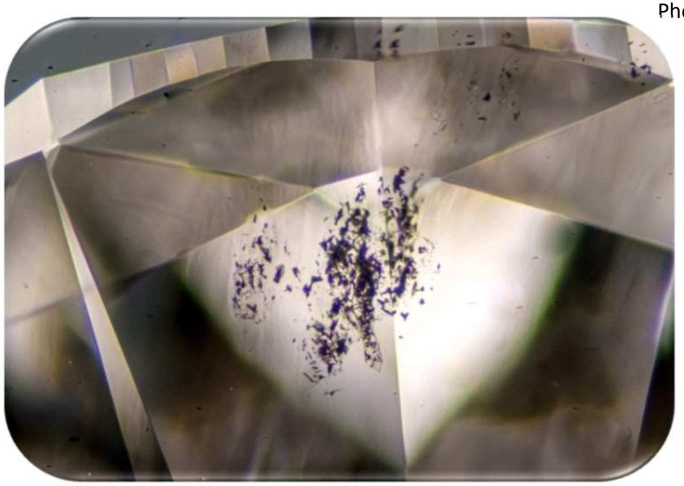


Photos by Wade Abel of AGS

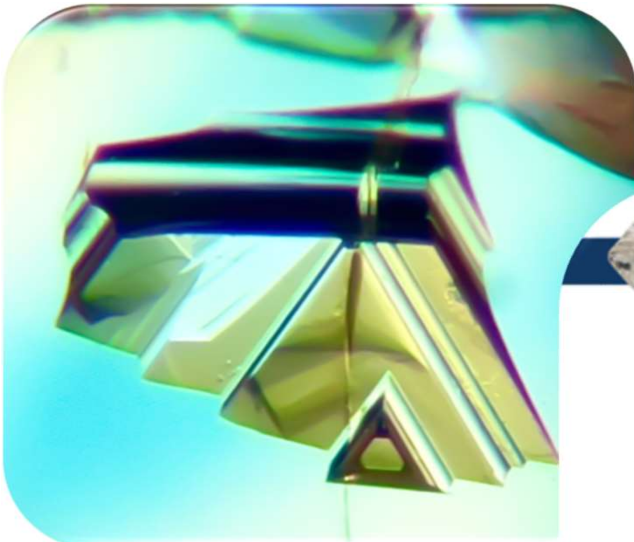
Photos by R. Lightfoot

Less common, irregular inclusions that resemble twinning wisps to the untrained eye

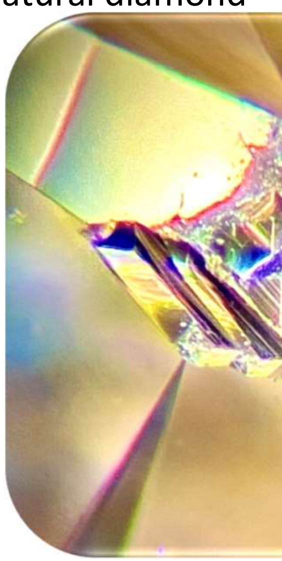




Surface Features Of Diamond



Resorption of natural diamond



DIAMONDS FROM THE DEEP
WINDOWS INTO SCIENTIFIC RESEARCH

Karen V. Smit and Steven B. Shirey

Diamonds Are Not Forever! Diamond Dissolution

Before cutting and polishing, diamonds have highly variable surface features rarely, if ever, seen by the jewelry wearer. These features can tell an interesting story of diamond's geological history deep within Earth—both in the mantle rocks where diamonds grew and during their subsequent volcanic transport. Our previous column showed that volcanic eruptions of kimberlite are how diamonds make their way from depth in the mantle to Earth's surface. But this violent process does not leave the rough diamond unscathed.

These early histories are rarely considered once the diamond has been faceted and set into jewelry, but they raise interesting and geologically important questions:

- Why do rough diamonds look so different from each other, and what might this tell us about their geological history?
- What effect does the kimberlite magma have on the diamond cargo?
- How can we see through this later stage of the diamond's history to its millions and billions of years of mantle storage?

Features on Natural Rough Diamonds

There is so much variety in natural diamond surfaces that, like snowflakes, no two diamonds are exactly alike. These differences can give us useful information about how diamonds react with fluids in the mantle after crystallization and also reveal the dissolving properties of the kimberlite magma that brought them to Earth's surface.

External surface and internal features are related to the internal crystallographic structure of the diamond. Deformation lamellae (also known as "graining" to gemologists) can be subtle and evenly distributed. Other features relating to diamond structure, such as trigons, are only skin deep, microscopic, and can seem randomly distributed. The external form of a diamond crystal can be dissolved to form secondary shapes by the partial removal of crystalline diamond in a geological process known as dissolution or resorption. Left alone without dissolution, diamond will form a perfect octahedron or a cube. But with dissolution, diamond can change from an octahedron to other forms such as dodecahedron or tetrahexahedron, and even form "irregular" diamonds with no discernible shape.

These transformations to the rough diamond's exterior surface can be distinguished from one another. Complex shapes can form in the mantle prior to being picked up by the kimberlite. Resorption to secondary shapes and trigon formation can occur during kimberlite eruption. Surface features like hillocks and frosting are also regarded as features imposed by the kimberlite. Finally, if released from easily weathered kimberlite, diamond lying in streambed deposits known as "placers" and in crudely sorted sedimentary rocks known as "conglomerates" can take on new surface features. Crystal rounding and percussion marks form when a diamond is transported in high-energy fluvial environments. Green and brown radiation stains are surface features that are due to a diamond's proximity to radioactive fluids or minerals.

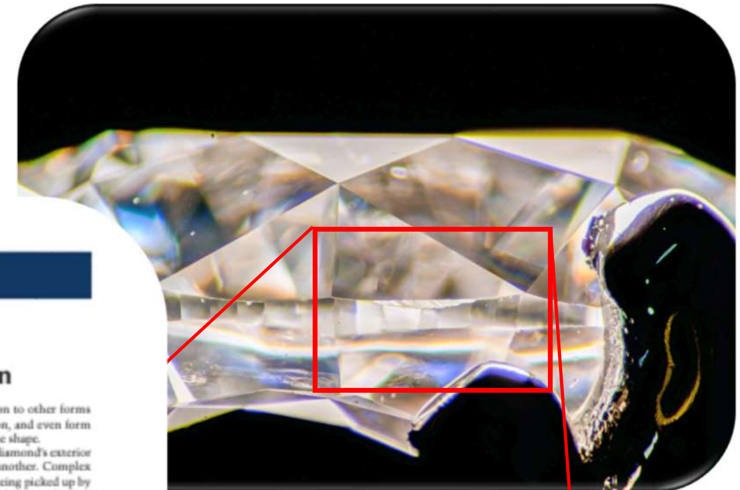
Dissolution During Kimberlite Transport and Mantle Storage

Unless a diamond is weathered out of kimberlite, kimberlite eruption will produce the last visible resorption effects, as it is the last event affecting the diamond before it reaches Earth's surface. Features produced by the kimberlite will overprint or even remove those features produced in the mantle. Once kimberlite effects are studied and understood, we can peer beyond them to a diamond's earlier history in the mantle. But why does kimberlite magma attack diamonds in the first place?

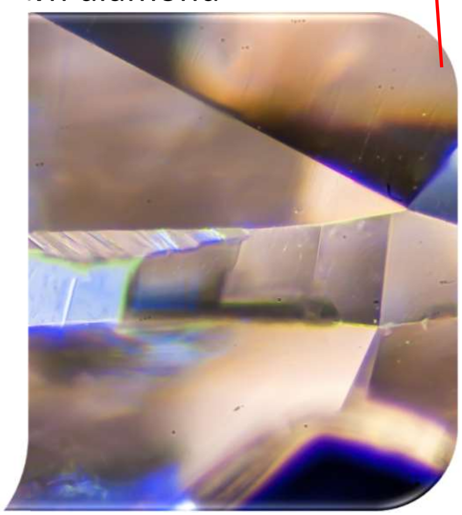
Successful diamond transport and delivery occurs because kimberlites erupt very fast (transiting 150–200 km in <10 hours to ~2 days; Russell et al., 2019). This rapid eruption means that any entrained mantle components—such as xenoliths and diamonds—lose pressure very quickly, are violently tumbled with upward movement, and can break apart.

Because kimberlites are more oxidizing than diamonds, they typically are in the process of dissolving diamonds—it's just that this process has often not gone to completion. The chemical composition of the kimberlite and its volatile components (such as carbon dioxide and water) are important factors. For example, as pressure drops during ascent, the kimberlite magma is not able to dissolve as much carbon dioxide, and a fluid rich in carbon dioxide and water exsolves from the magma (figure 1; Brey and

Gems & Gemology, Vol. 56, No. 1, pp. 148–155.



wth remnant of HPHT-
wn diamond

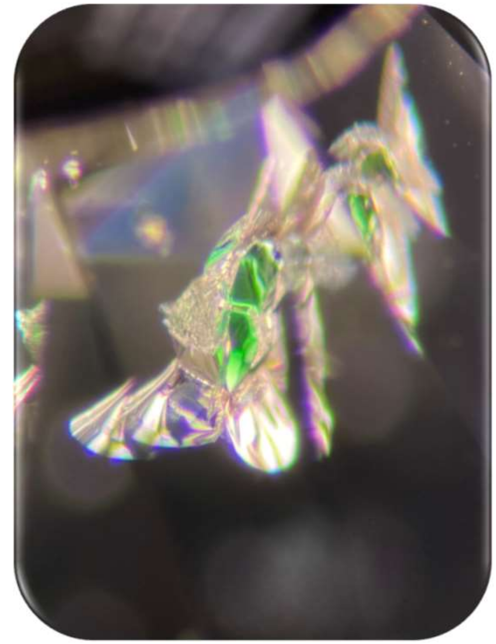


Photos by R. Lightfoot

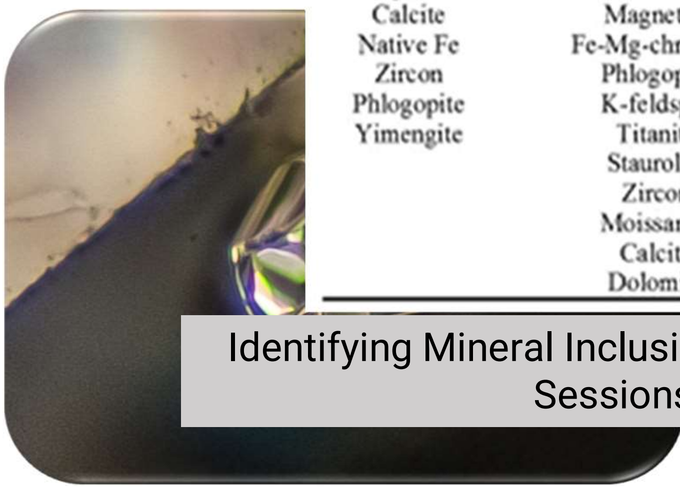
Natural Diamond Inclusions

Pyrope Xtl

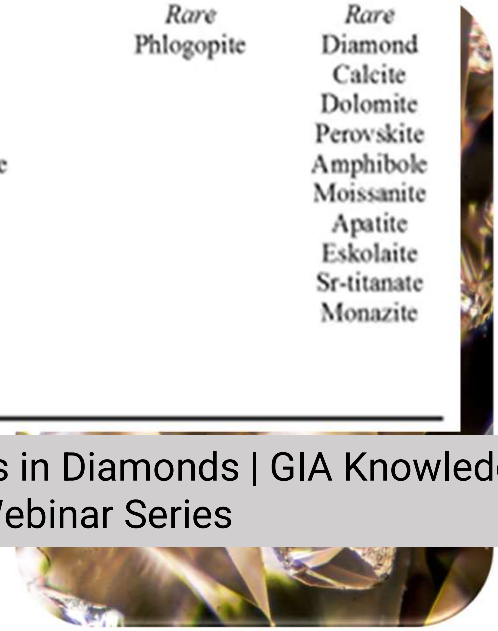
Peridotitic	Eclogitic	Websteritic	Uncertain
Common	*Common*	*Common*	*Common*
Cr-pyrope	Grossular-almandine-pyrope	Almandine-pyrope	Graphite
Olivine	Omphacitic clinopyroxene	Diopside-augite	
Enstatite	Fe sulfides*	Enstatite	
Cr-diopside			
Mg-chromite			
Fe-Ni sulfides*			
	Occasional	*Occasional*	
	Rutile	Coesite	
	Coesite	Olivine	
Rare	*Rare*	*Rare*	*Rare*
Coesite	Kyanite	Phlogopite	Diamond
Mg-ilmenite	Corundum		Calcite
Magnesite	Ilmenite		Dolomite
Calcite	Magnetite		Perovskite
Native Fe	Fe-Mg-chromite		Amphibole
Zircon	Phlogopite		Moissanite
Phlogopite	K-feldspar		Apatite
Yimengite	Titanite		Eskolaite
	Staurolite		Sr-titanate
	Zircon		Monazite
	Moissanite		
	Calcite		
	Dolomite		



Diopside Xtl



Possible Omphacite Xtl



sartine Xtl

Identifying Mineral Inclusions in Diamonds | GIA Knowledge Sessions Webinar Series

Photos by R. Lightfoot

Natural Diamond Inclusions

Brownish internal graining

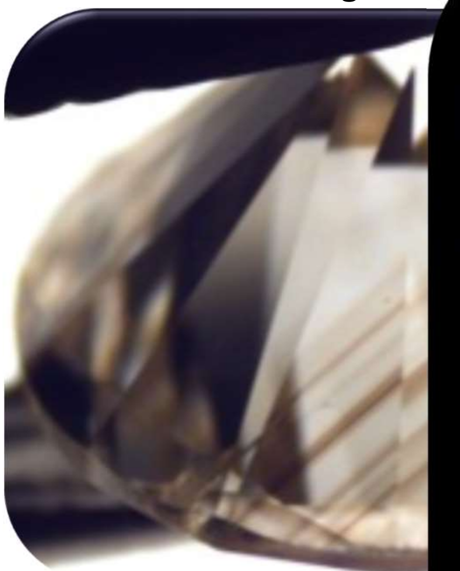
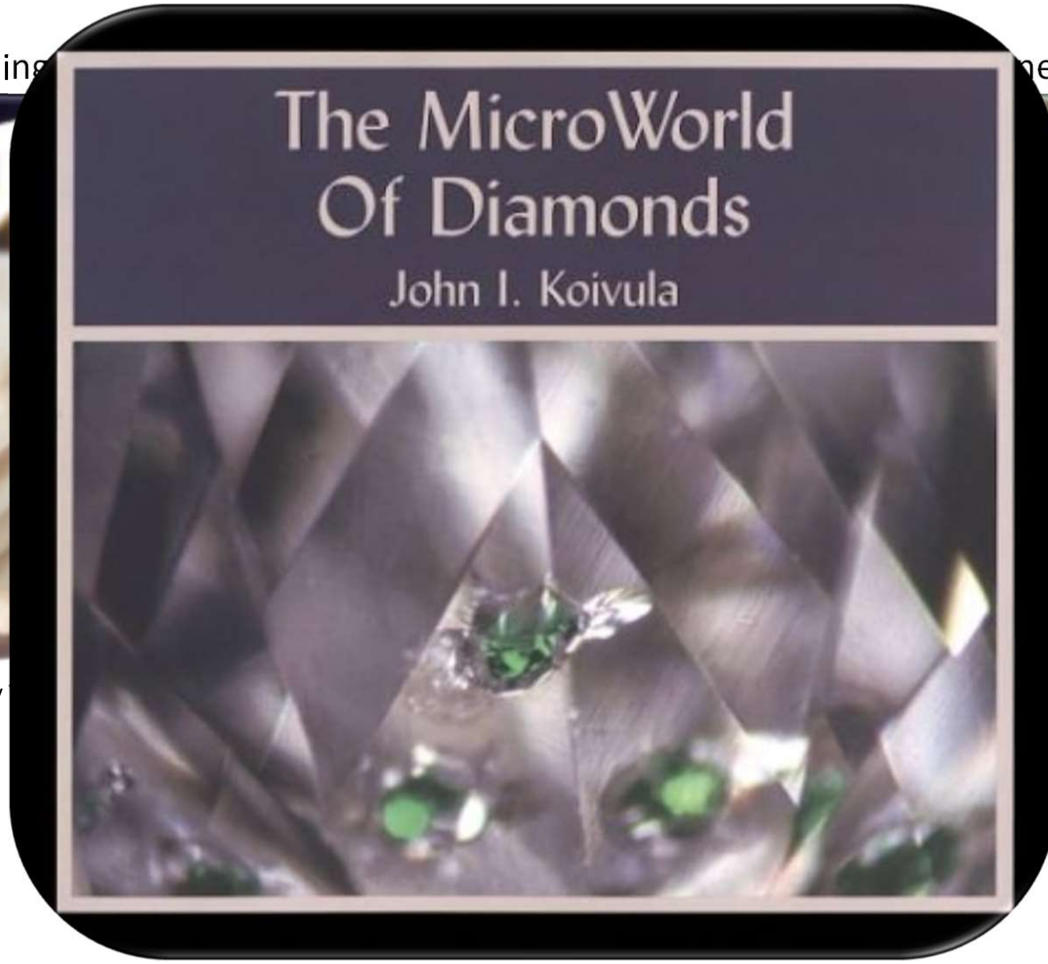


Photo by

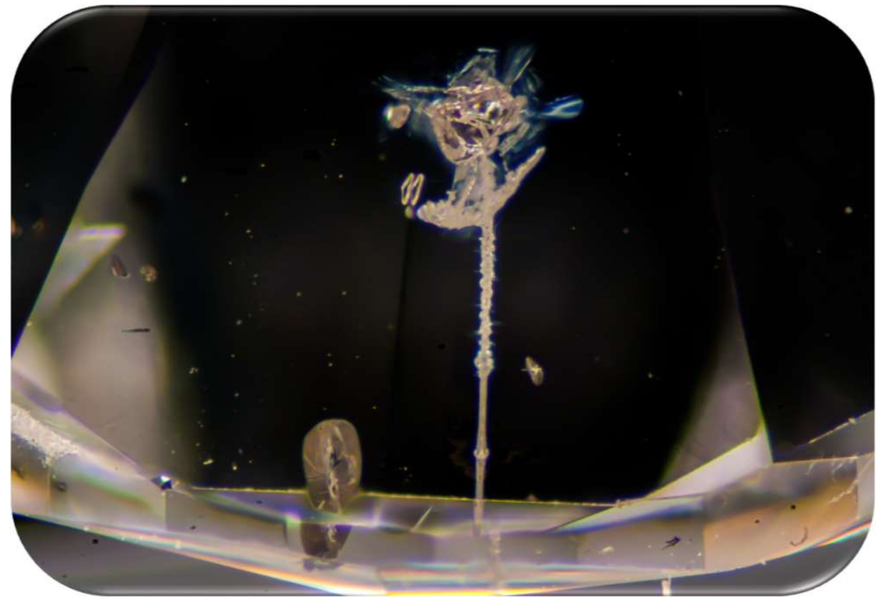


neral inclusions using CPF

htfoot

Diamond Clarity Enhancements

While not impossible to find in lab-grown diamonds, clarity enhancements such as fracture-filling, laser drillholes, and internal laser drilling are routinely observed in natural diamonds.



Photos by R. Lightfoot

Anomalous Birefringence (*i.e., strain*)

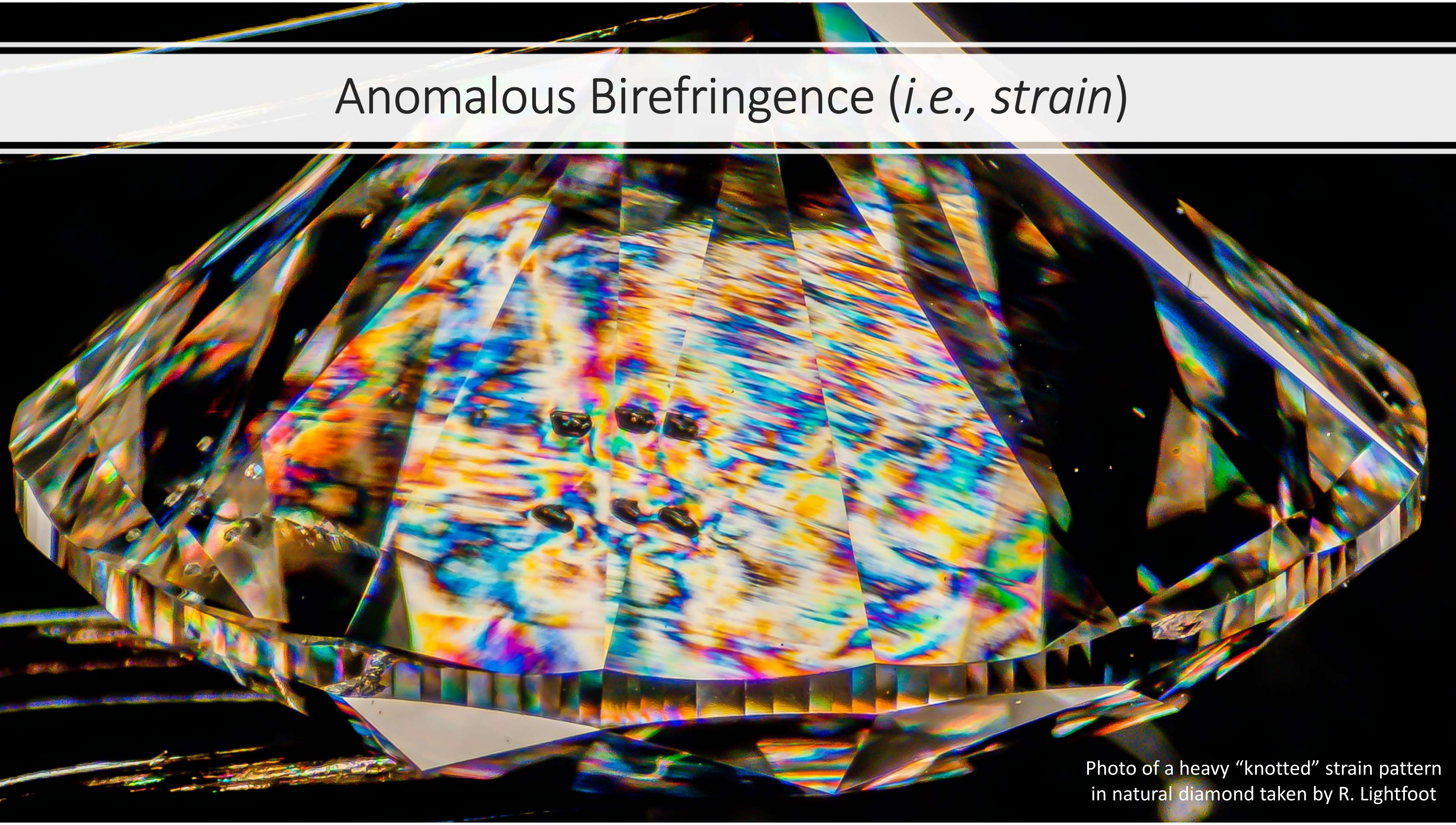
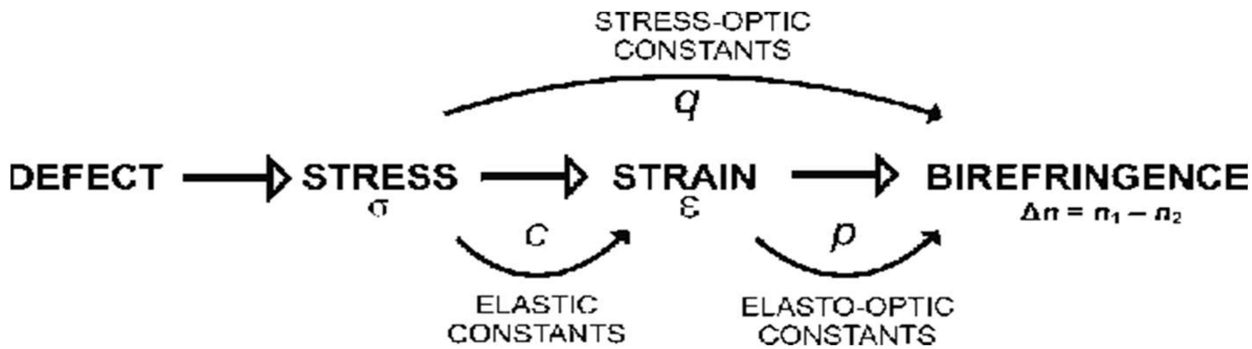


Photo of a heavy "knotted" strain pattern in natural diamond taken by R. Lightfoot

Cross-Polarized Filters (CPF)



Anomalous birefringence is what we observe as colors (strain) in cross-polarized illumination.

Natural Diamond

DF Illumination

CPF

D. Howell (2011): Strain-Induced Birefringence in Natural Diamon: A Review
GIA Gems & Gemology, Volume V, Summer of 1945, Number 2

Photos by R. Lightfoot

Cross-Polarized Filters (CPF)

What you could typically expect…

Pay attention to the distribution of strain!

Natural

- Smudgy, uneven, random
- Can follow the {111} octahedral plane
  - Can be part of with internal graining
- Modified strain caused by treatment
  - Could resemble what is observed in CVD-grown diamonds
- Depending on the severity of strain…
  - Weak anomalous birefringence (blues, grays, browns) (1ORC sometimes necessary)
    - strain more likely caused by distribution of point defects
  - Stronger anomalous birefringence (all other colors) (1ORC not necessary)
    - strain more likely caused by extended defects

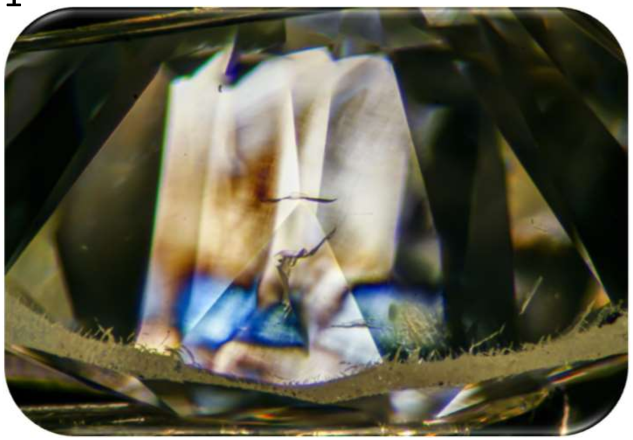
Lab-Grown

- **HPHT-Grown** = extraordinary lack of birefringence (*not the same as no birefringence*)
  - Can sometimes have very weak strain patterns that can mimic smudgy strain patterns seen in natural diamond
- **CVD-Grown**
  - Parallel, columnar growth pattern that is evenly distributed throughout *(attributed to untreated material)*
  - Tatami/crosshatch pattern that is also evenly distributed throughout *(attributed to post-growth treatment for color)*
  - Irregular patterns that resemble natural diamond strain
    - *This mostly concerns the exceptions to the rule, CVD-Grown diamonds that make up a smaller percentage whose stain patterns mimic what we observe in natural diamonds*

- ***Strain patterns suggest clues to diamond origin (i.e., natural vs lab-grown)***
- ***Theoretically, strain cannot be removed from the lattice through treatment, only altered depending on pre-existing defects, irradiation type & penetration, P, T, & t.***

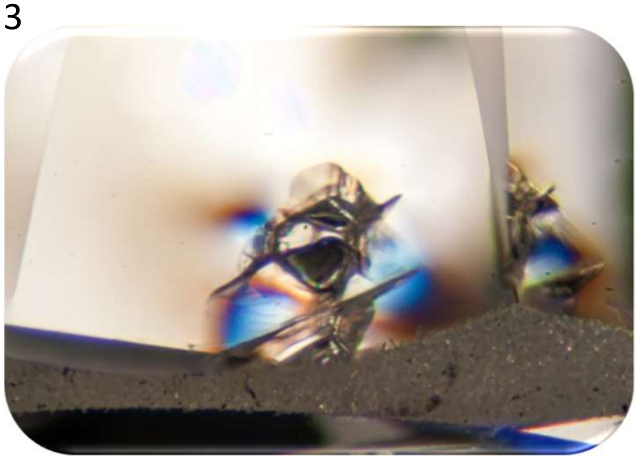
Typical Strain Patterns in Natural Diamond

1

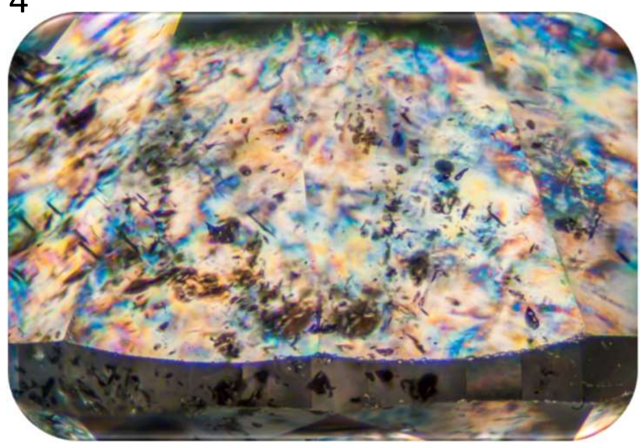


2

3



4



No 1ORC Necessary

1: Smudgy, uneven appearance

2: Strain that can follow {111} octahedral planes or other planes of weakness

3: Strain in the form of elastic deformation around a crystal inclusion

4: Heavily “knotted” strain throughout suggesting severe plastic deformation combined with elastic deformation of the crystal lattice around inclusions

Photos by R. Lightfoot

Cross-Polarized Filters (CPF)

1st Order Red Compensator (1ORC)

Natural Diamond

1ORC exaggerates difficult to see strain patterns in diamonds containing weaker strain

Weak anomalous birefringence = strain comprising **grays**, **blues**, and **browns**

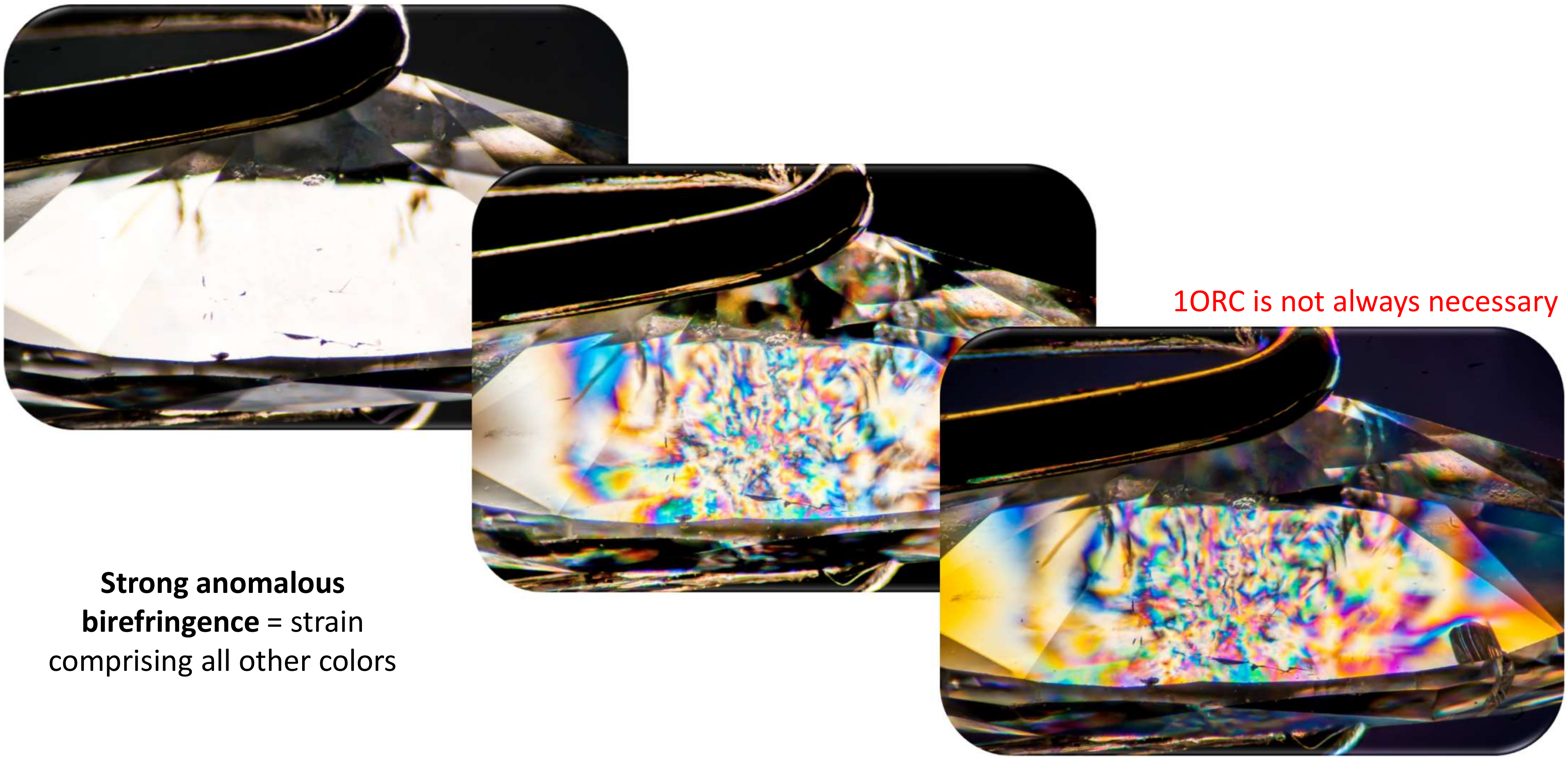
Photos by R. Lightfoot

Cross-Polarized Filters (CPF)

1st Order Red Compensator

Natural Diamond

1ORC is not always necessary

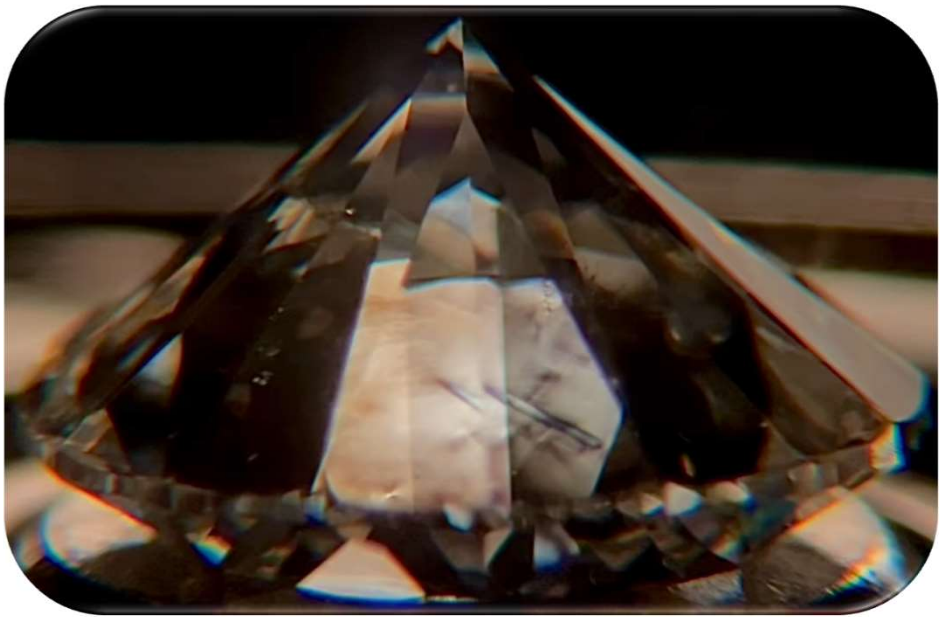


Strong anomalous birefringence = strain comprising all other colors

Photos by R. Lightfoot

Cross-Polarized Filters (CPF)

Natural Diamond



Be sure to observe the diamond in its entirety
or as mounting conditions allow if set.

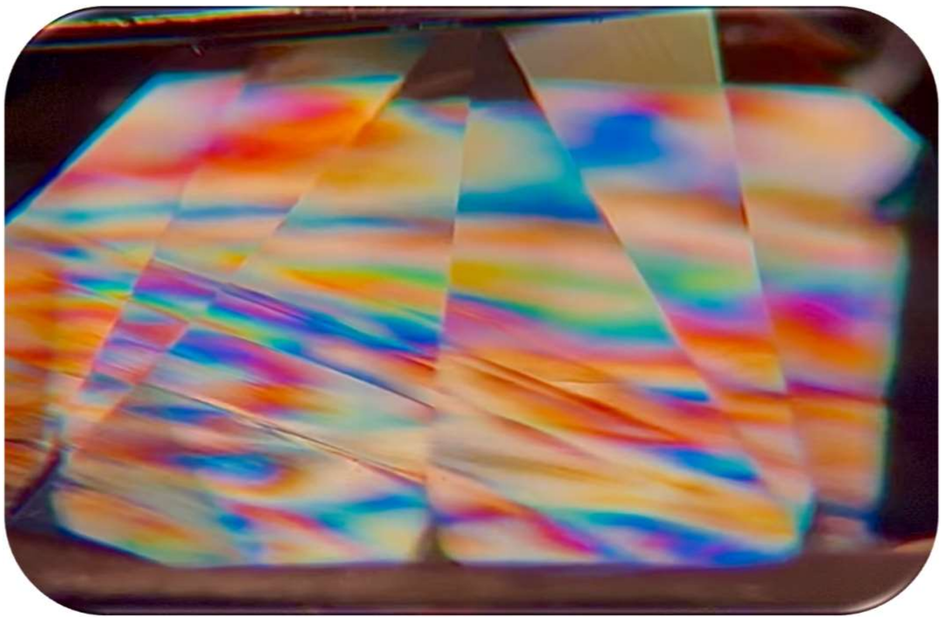
Limitations of CPF

- Diamonds less than ~0.10ct depending on magnification capability
- Poorly cut diamonds (i.e., shallow)
- Heavily included diamonds
- Highly saturated diamonds
- Mounting restrictions if set
- Knowledge of diamond formation, natural and lab-grown
- Cannot be relied upon to determine if a natural diamond is treated for color
- CPF is not 100% conclusive

Video by R. Lightfoot

Cross-Polarized Filters (CPF)

Natural Diamond



Be sure to observe the diamond by rotating the polarizer, achieving both plane and cross-polarized light, to see how the strain migrates through the diamond.

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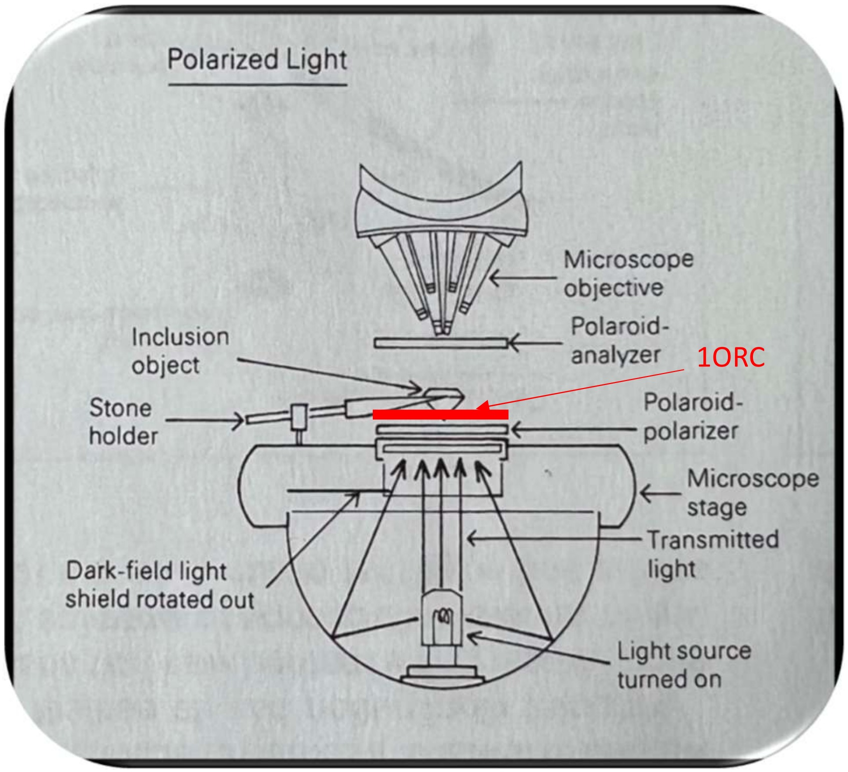
Video by R. Lightfoot

Cross-Polarized Filters (CPF)



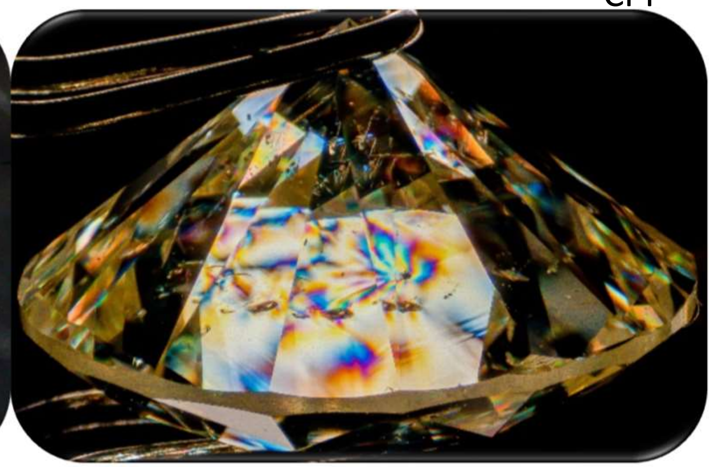
Volume 2 of the Photoatlas of Inclusions in Gemstones by J. Koivula & E. Gubelin

https://www.youtube.com/watch?v=_buf7VJVWsc (The Three Microteers Chat About Photomicrography)

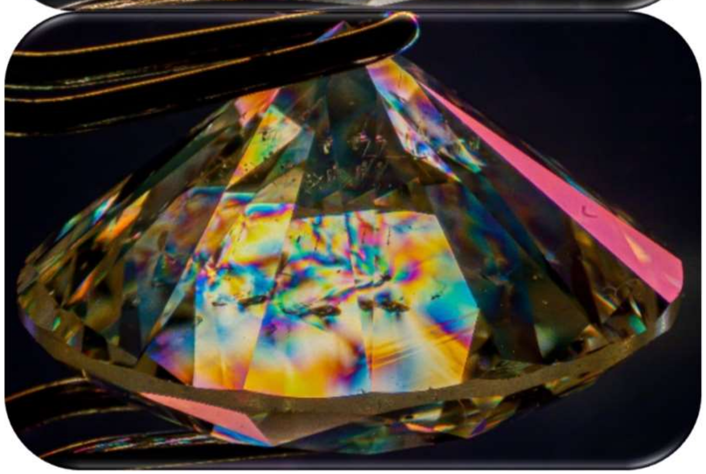
Natural Diamond

DF

CPF



365nm UV



CPF 1ORC

Strain comprising stronger anomalous birefringence that is unevenly distributed throughout

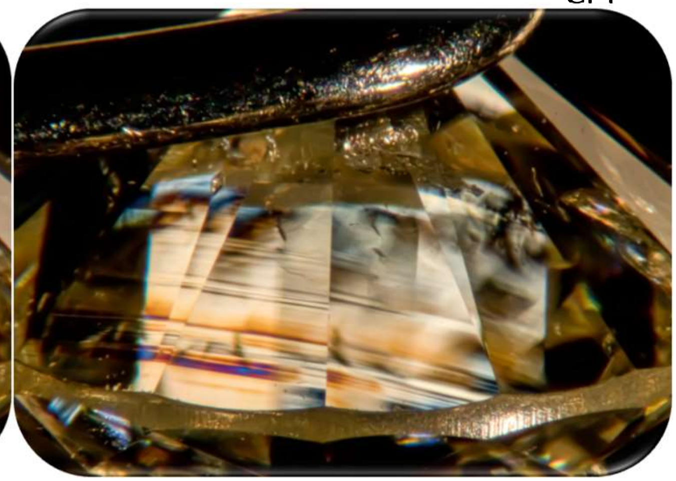
254nm UV

Photos by R. Lightfoot

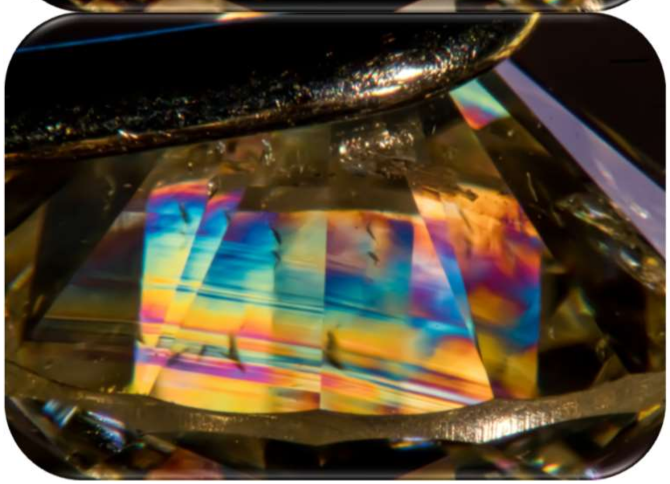
Natural Diamond

DF

CPF



365nm UV



CPF 1ORC

Strain comprising smudgy weak and strong anomalous birefringence that also follows numerous {111} octahedral planes and is unevenly distributed throughout

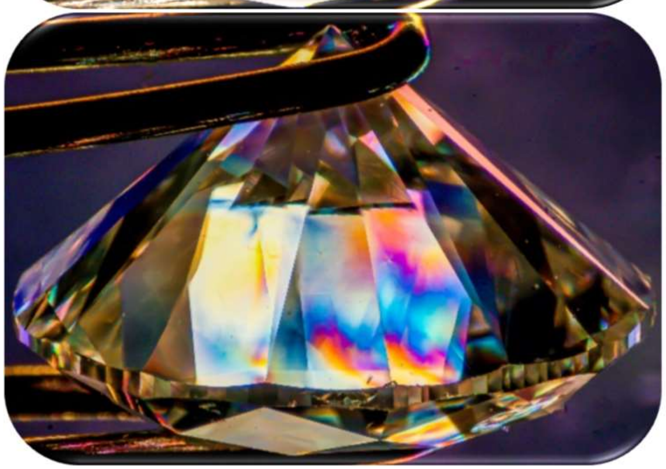
254nm UV

Photos by R. Lightfoot

Natural Diamond

DF

CPF



CPF 1ORC

Strain comprising smudgy weak and strong anomalous birefringence that is unevenly distributed throughout

365nm UV

254nm UV

Photos by R. Lightfoot

HPHT-Grown Diamond

DF

CPF

365nm UV

CPF 1ORC

Extraordinary lack of strain

Phosphorescence exceeded 10 seconds in this case

254nm UV

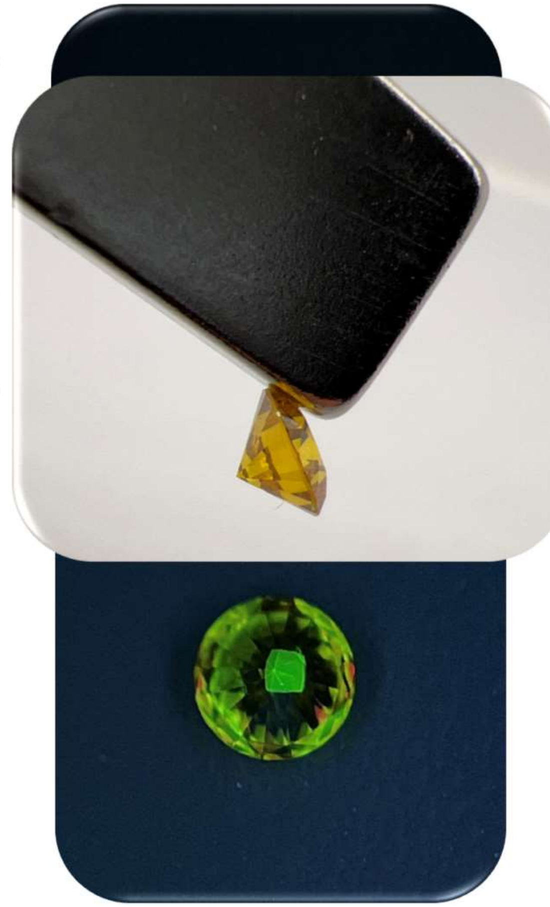
Photos by R. Lightfoot

HPHT-Grown Diamond

DF

CPF

365nm UV



254nm UV

CPF 1ORC

Very weak strain

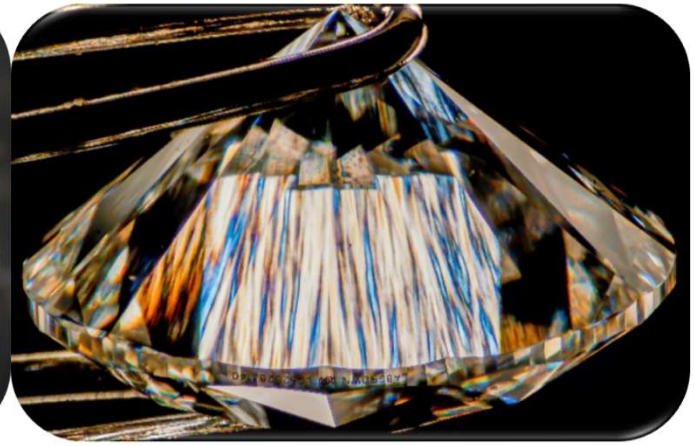
Phosphorescence exceeded 10 seconds in this case

Photos by R. Lightfoot

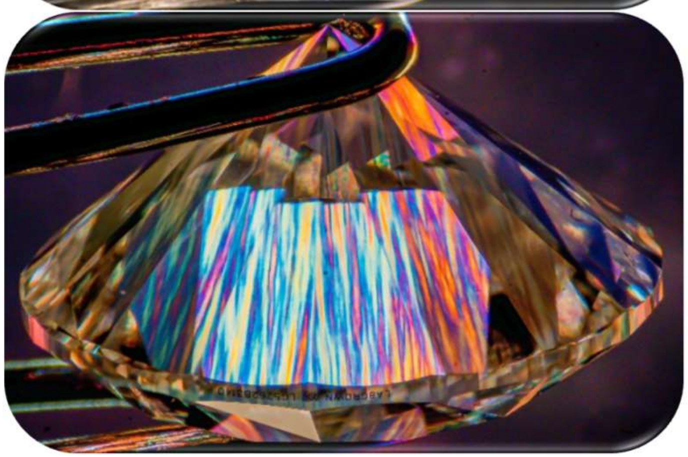
CVD-Grown Diamond

DF

CPF



365nm UV



CPF 1ORC

Strain comprised of a parallel, columnar pattern of weaker anomalous birefringence that is evenly distributed throughout

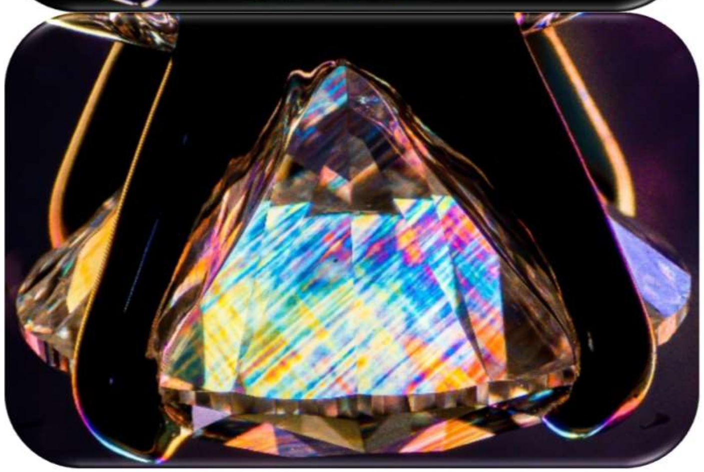
254nm UV

Photos by R. Lightfoot

CVD-Grown Diamond

DF

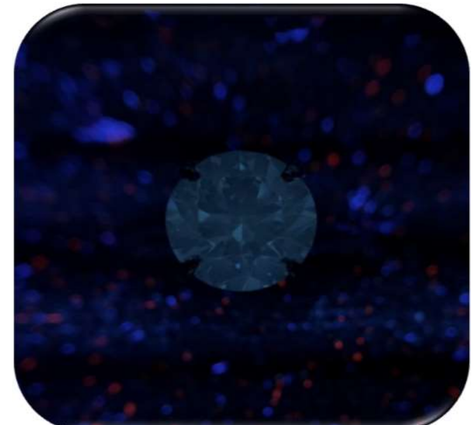
CPF



CPF 1ORC

Strain comprised of a broader [tatami] crosshatch pattern of weaker anomalous birefringence that is evenly distributed throughout (*most common strain pattern in CVD-grown diamonds from what I have experienced*)

365nm UV



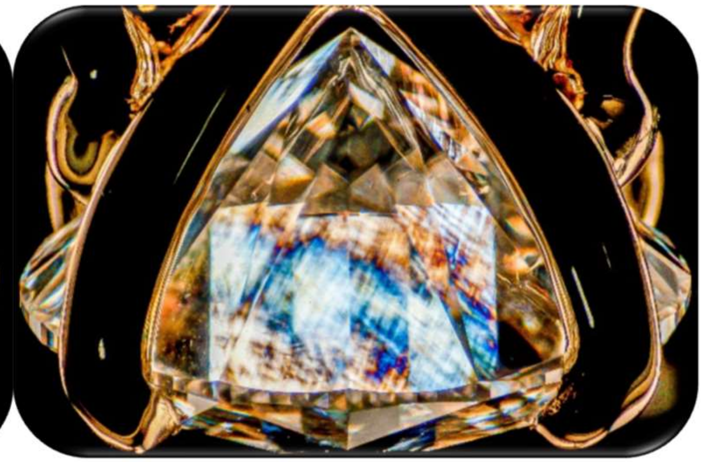
254nm UV

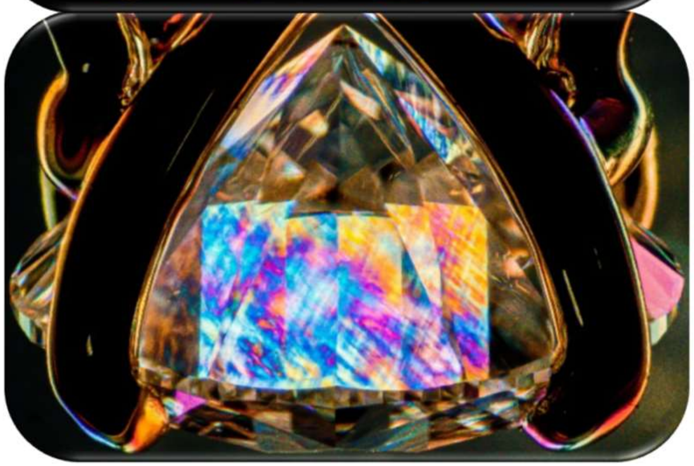
Photos by R. Lightfoot

CVD-Grown Diamond

DF

CPF



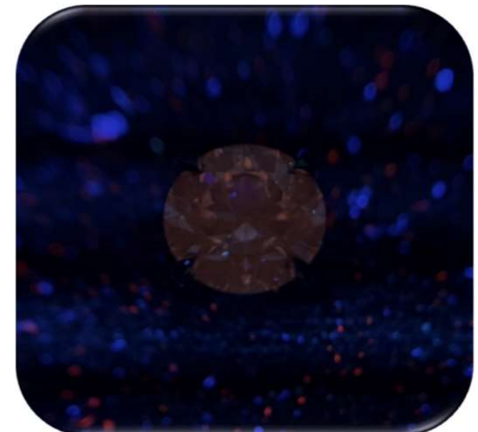


CPF 1ORC

Strain comprised of a finer [tatami] crosshatch pattern of weaker anomalous birefringence

Notice how this seemingly irregular and uneven pattern can be confused for what we see in some natural diamonds

365nm UV



254nm UV

Photos by R. Lightfoot

Natural Diamond

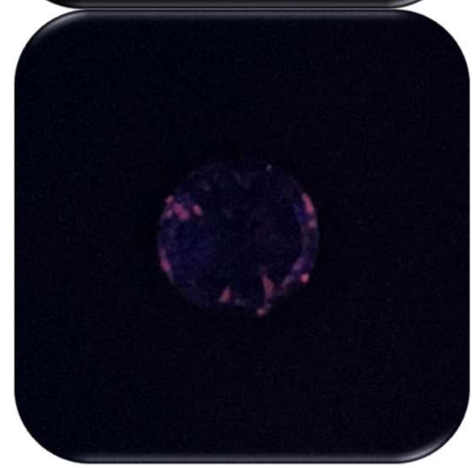
DF

CPF

365nm UV

CPF 1ORC

Strain comprised of a fine [tatami] crosshatch pattern of weak and strong anomalous birefringence



254nm UV

Photos by R. Lightfoot

CPF (CROSS POLARIZED FILTERS) TECHNIQUE FOR SCREENING & ID OF DIAMONDS: NATURAL, LAB-GROWN & POST-GROWTH TREATED

Randy Lightfoot (USA) and Branko Deljanin (Canada)

INTRODUCTION

An often-overlooked illumination technique, cross-polarized filters (CPF), offers a way to identify clues of diamond origin (i.e. natural vs. lab-grown) and screening for diamond type. CPF is one standard technique that, with practice and careful observation, can prove to be a viable method in the absence of optical spectroscopy or as an addition to other standard screening methods. By observing anomalous birefringent patterns (i.e., strain) of natural and lab-grown diamond, a gemologist can usually make conclusions with high confidence, especially when combined with other standard techniques such as inclusion identification and UV illumination. These strain patterns are also significant to diamond cutters because they reveal areas of stress in diamonds prior to cutting and can help gemologists identify strain patterns in other SiC stones containing ADR. Strong anomalous birefringence is synonymous with higher-order strain (i.e., greater diversity of colors) while weaker anomalous birefringence is synonymous with lower-order strain (i.e., mostly indistinct patterns comprising blue, brown, and gray). Stronger anomalous birefringence is caused by extended defects such as plastic deformation resulting from geological stresses on the crystal lattice during and/or after crystal growth. Conversely, weaker anomalous birefringence is understood to be more so caused by an uneven distribution of point defects (trace elements and lattice vacancies) within the crystal lattice. Another critical observation is that strain patterns in CVD-grown diamonds (treated or as-grown) tend to be evenly distributed throughout the diamond because of a controlled growth environment. This is generally not the case with natural diamonds as the environment for natural diamonds fluctuates heavily during and after crystal growth. As a result, strain patterns in natural diamonds, particularly Type I, will very often appear random and not so uniform throughout the diamond compared to CVD-grown diamonds. HPHT-grown diamonds typically does not show any observable strain under CPF. If they do, then it is generally of weaker anomalous birefringence.

CPF TECHNIQUE

Setting up any standard gemological microscope for CPF is relatively easy and inexpensive. Just like the portable polariscope, place one of two polarizers over the light-well and fix the other just below the objective lens. This way, a diamond can be held between the filters. Be sure both filters are crossed so the background is dark (nearly black, but sometimes blue depending on the filter being used). Generally, diamond should be positioned in brightfield illumination in pavilion view (i.e., inclusions should appear dark against a bright background). However, strain can, in some instances, be observed through the table using the StrainView instrument. Be sure to rotate the diamond 360-degrees or as much as possible if mounted to ensure strain patterns are observed in more than one orientation. For diamonds with weaker anomalous birefringence, the use of a 1st Order Red Compensatory (1ORC) filter may be used to exaggerate strain to make it more visible. Simply place a 1ORC filter between the diamond and the polarizing filter resting over the light-well and rotate it so the background is a magenta color. It is not necessary to use a 1ORC filter with diamonds having strong anomalous birefringence, though it is visually pleasing. One of the polarizing filters may be rotated to observe a diamond in both plain polarized light and crossed polars. This can help to observe weaker anomalous birefringence and show how the strain is distributed throughout the diamond. In most instances a diamond should be held with tweezers table to culet as the pattern under CPF is easier to see through the pavilion of the stone (as seen in most of accompanying photos).

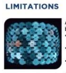
OVERLAP ISSUES OF CPF PATTERNS (HELP OF FLUORESCENCE TECHNIQUE)

Although CPF can prove to be a reliable screening method, there are strain patterns within natural Type I diamonds and lab-grown diamonds that resemble each other. As with any standard method of identification, solely using CPF is not recommended, and in cases where patterns cannot be relied upon, the use of UV illumination can help. It is well documented that natural diamonds most commonly fluoresce blue under 365nm longwave UV due to the presence of the N3 defect center. Reliably, these very same diamonds that fluoresce blue in longwave UV are generally weaker or inert in 254nm shortwave UV. The reverse is generally true for lab-grown diamonds (CVD and HPHT alike). For lab-grown diamonds, stronger reactions will generally be observed in shortwave UV. However, other indications could be similar strength reactions in both long and shortwave UV as well in new generation of CVD-grown diamonds. Additionally, prolonged phosphorescence (luminesce after the UV source has been shut off) is a strong indication that a diamond is lab-grown. HPHT-grown diamonds reliably phosphoresce in excess of several tens of seconds. CVD-grown diamonds that are post-treated by the HPHT process typically phosphoresce, but for a shorter period of time (<3 sec) and is not so obvious as is with HPHT-grown diamonds. Keep in mind that some natural diamonds with strong LWUV reaction could also phosphoresce, but shortly (<1 sec). Chameleon and Type IIb blue diamonds phosphoresce stronger under SW, but these stones are rare.

OVERLAP ISSUES OF CPF PATTERNS (HELP OF FTIR AND PL SPECTROSCOPY - EXA)

Natural and lab-grown diamonds are classified into four basic types based on the relative presence of nitrogen and boron impurities. Around 97% of all natural diamonds are Type Ia containing both A and B centers, and are therefore classified as Type Ia(AB). There are no pure Type Ia lab-grown diamonds on the market, though there could be mixtures of Type Ia + Ib that are lab-grown. Almost 1% of natural diamonds are Type Ib, where nitrogen exists predominantly as isolated nitrogen atoms that replace single carbon atoms. Yellow and pink lab-grown diamonds are Type Ib. All colorless HPHT-grown and CVD-grown diamonds are Type IIa, whereas only about 2% of natural diamonds belong to this group in which nitrogen is not detectable by infrared (FTIR) spectroscopy.
In addition, many Type IIa HPHT-grown diamonds show extra small boron peaks in their FTIR spectra. Type IIb natural diamond shows much weaker boron peaks than B-rich HPHT-grown diamonds. When a diamond has a CPF pattern that is not conclusive and LWUV=SWUV or if it is a melee diamond set in jewelry, it is good to use a PL (365nm laser system like the EXA by MAGILABS). This instrument will either "pass" natural diamonds with Cape lines or "refer" those 3% of natural diamonds with uncommon fluorescence, without 415nm line and diamonds showing Ni lines around 890nm (not present in stones grown with other catalysts) in HPHT-grown diamond or the Si-V line at 737nm that is characteristic of CVD-grown diamond.

LIMITATIONS



Although CPF can prove to be a viable standard method, it does have limitations. CPF tends not to be a useful method with with loose and solitaire diamond rings:

- Mounting restrictions that prevent observing a diamond in brightfield illumination. (e.g. a bezel setting that obscures the pavilion of a diamond completely)
- Small diamonds (generally <0.10ct). It can be difficult to observe strain patterns in small diamonds with the CPF technique.
- Highly included diamonds (i.e., too many inclusions can obscure any strain in the body of the diamonds)
- Highly saturated body color
- Poor cutting (e.g., a shallow pavilion can prevent achieving brightfield illumination depending on the mode of observation. StrainView allows observation of strain directly through the table facet of shallow cuts, but in some microscope setups this may not be achievable).
- CPF should not be used to determine if a diamond (natural or lab-grown) has been treated for color as certain strain patterns can overlap between natural or as-grown and post-treated.

SUMMARY

CPF is technically the simplest and cheapest screening and identification method. CPF can also be extremely quick provided the observer is well-versed in understanding diamond defects and their resulting strain patterns. Reliable use of the CPF method calls for constant practice. This really means to screen at least hundreds of diamonds of different colors, clarities, types, shapes, and origins. We strongly recommend enrolling in one of BrankoGems' half-day or full-day workshops on the "Use of Portable Instruments to Screen and Identify Laboratory-Grown Diamonds," where there are types and colors of natural and lab-grown diamonds to screen using standard methods and verify with optical spectroscopy.

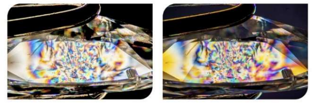
Keep in mind that CPF is not meant to be used alone as a conclusive way to distinguish between natural and lab-grown diamond or determine exact diamond type. Like other standard methods, CPF is another technique to support other methods in one's pursuit of identification. We strongly advise using a combination of at least three standard identification methods and, where possible, advanced instruments to positively identify natural and laboratory-grown diamonds and possible post-growth treatment for color.

ABOUT THE AUTHORS

RANDY LIGHTFOOT GG, CG, CM, RGA
Randy focused on volcanology, mineralogy, and petrology with his B.A. in the geological sciences. This foundation has supported his collaborating research while practicing as a qualified jewelry appraiser. Randy is credentialed through the AGS, NAJA, and ISO while also volunteering on multiple committees and task forces with the AGS and the Appraisal Foundation. For Randy, photomicrography and microscopy are daily disciplines.

BRANKO DELJANIN B.Sc., GG, FGA, DUG
A research gemologist with extensive experience in advanced testing of diamond. He is expert in ID of natural, treated and synthetic diamonds and gems for subsequent certification and works with standard instruments and advanced spectrometers to determine origin of color for colored diamonds and gems, and provenance of pink diamonds. He is teaching on-line gemology and has held workshops in 20 countries on 4 continents for BrankoGems Academy.

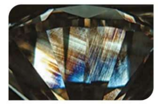
NATURAL DIAMONDS



Near-colorless Natural (Type Ia) Diamond - 0.75ct, SI2, G: Strong anomalous birefringence in a random, uneven pattern, typical for natural Type I diamonds that exhibit plastic deformation from geological conditions imposed on the diamond during and/or after crystal growth (Left: CPF / Right: CPF with 1ORC).

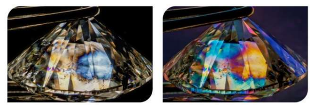
Colorless Natural (Type IIa) Diamond - 0.60ct, SI2, D: Fine crosshatching of weak and strong anomalous birefringence. The use of 1ORC in this case helps to exaggerate the fine crosshatching, also known as "tatami" pattern (Left: CPF / Right: CPF with 1ORC).

Near-colorless Natural (Type Ia) Diamond - 0.55ct, VS2, I: This weak anomalous birefringence that appears random, smudgy, and uneven is indicative of Type Ia diamond. However, this could be confused for certain HPHT-grown diamonds (Left: CPF / Right: CPF with 1ORC).



Colorless Natural (Type IIa) Diamond: Finer crosshatching ("tatami" pattern') of weaker anomalous birefringence (photo by Sharrie Woodring) (CPF only).

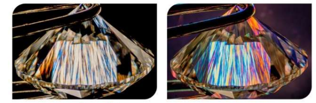
Pink Natural (Type Ia) Diamond: Pink and brown diamonds typically show plastic deformation along slip planes as seen in this Argyle pink diamond viewed through the pavilion (photo by John Chapman using the StrainView) (CPF only).



Near-colorless Natural (Type Ia) Diamond - 2.03ct, SI2, G: Weak and strong anomalous birefringence combined appears in a random, uneven pattern, which is very strong evidence that this diamond is natural (Left: CPF / Right: CPF with 1ORC).

Treated Colored Natural (Type IIa) Diamond - 1.02ct, VS2, Fancy Bluish Green: This example demonstrates that CPF is not useful for determining if a natural diamond has been treated for color and this pattern can be confused with some treated CVD-grown diamonds (Left: CPF / Right: CPF with 1ORC).

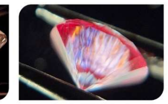
CVD-GROWN DIAMONDS



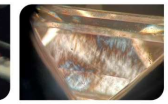
Colorless CVD-grown (Type IIa) Diamond - 2.00ct, VS1, F: Broad parallel, columnar growth pattern of weaker anomalous birefringence. CVD-grown diamonds with patterns like this perpendicular to table facet are generally understood to be as-grown (i.e., not post-growth treated) (Left: CPF / Right: CPF with 1ORC).

Blue CVD-grown (Type IIa): When observed in different positions as shown, this diamond's strain changes from a broad crosshatched pattern to an unusual granular-like pattern, a reminder that a diamond should be observed in as many positions as possible (photos of same diamond).

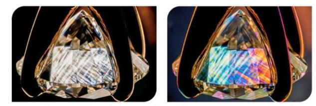
Colorless CVD-grown (Type IIa) Diamonds Left: Weaker anomalous birefringence in columnar growth patterns like this perpendicular to table facet are understood to be as-grown (i.e., not post-growth treated for color). **Right:** Broad crosshatching pattern in post-growth-treated CVD-grown diamond by "Diamond Foundry" (photos by Branko Deljanin of different diamonds).



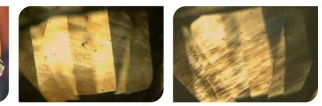
Pink CVD-grown (Type Ib): Showing columnar patterns characteristic of CVD-growth. This photo was taken using the StrainView instrument (photo by John Chapman).



Colorless CVD-grown (Type IIa) Diamond - 4.70ct, VS2, E: Inconclusive weak anomalous birefringence in as-grown CVD diamond that resembles a pattern observed in Type IIa natural diamonds (photo by Branko Deljanin).



Colorless CVD-grown (Type IIa) Diamond - 1.85ct, VS2, F: Broad crosshatched pattern of weak anomalous birefringence. Notice how this strain appears evenly distributed throughout, unlike natural diamonds where the strain pattern will more likely appear randomly throughout (Left: CPF / Right: CPF with 1ORC).

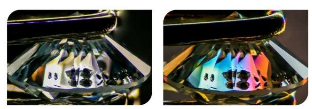


Near-Colorless CVD Experimental Stone (Type IIa): HPHT-treated for 1 hour at a temperature of 2100 oC. The weak strain pattern can be confusing, and the diamond could be misidentified as natural Type II diamond. UV-VIS absorption and PL spectroscopy are required for proper identification. (photos by Dusan Simic of the same diamond in different positions).

HPHT-GROWN DIAMONDS

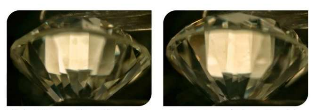
Colorless HPHT-grown (Type IIa) Diamond - 0.92ct, SI1, D: This untreated HPHT-grown diamond does not exhibit any observable anomalous birefringence (i.e. little to no strain), only metallic flux inclusions (Left: CPF / Right: CPF with 1ORC).

Pink HPHT-grown (Type Ib) Diamond - 0.15ct, I1, Fancy Light Pink: Weak, smudgy anomalous birefringence can be observed in this treated HPHT-grown diamond. This is one example where an HPHT-grown diamond can resemble natural Type Ia diamond strain patterns (Left: CPF / Right: CPF with 1ORC).

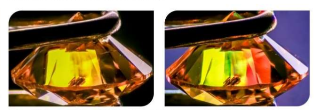


Blue HPHT-grown (Type IIb) Diamond - 0.27ct, I2, Fancy Blue: This blue HPHT-grown diamond displays an extraordinary lack of anomalous birefringence, which is typical of HPHT-grown diamonds. Large metallic inclusions support lab-grown origin in this case (Left: CPF / Right: CPF with 1ORC).

Pink HPHT-grown (Type Ib) Diamond - 0.15ct, SI1, Fancy Light Pink: Resembling what can be seen in natural Type Ia diamonds, this treated HPHT-grown diamond displays weak, smudgy anomalous birefringence that can confuse an inexperienced observer. Notice localized strain around small metallic inclusions (Left: CPF / Right: CPF with 1ORC).

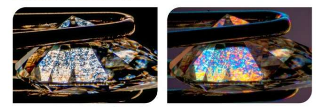


Colorless HPHT-grown (Type IIa) Diamond: Absence of strain is strong indication that this colorless diamond is HPHT-grown. Some HPHT-grown diamonds doped with nitrogen may show very weak strain patterns following the cube-octahedral growth structure (photos by Dusan Simic of the same diamond in different positions).



Yellow HPHT-grown (Type Ib) Diamond - 0.32ct, SI2, Fancy Vivid Yellow: Although as-grown colorless HPHT-grown diamonds typically exhibit an extreme lack of anomalous birefringence, yellow HPHT-grown diamonds are likely to show weak, smudgy strain patterns as they contain nitrogen (Left: CPF / Right: CPF with 1ORC).

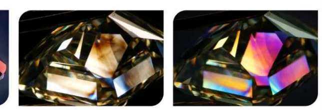
PROBLEMATIC PATTERNS



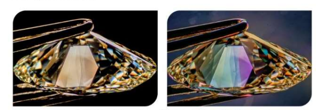
Natural or **Colorless CVD-grown (Type IIa) Diamond - 0.51ct, VS2, G:** This granular-like pattern of weak anomalous birefringence can be tricky as this can resemble what we see in natural Type Ia diamond as "random and uneven." Close observation will reveal that this diamond's pattern is evenly repeated throughout, which indicates a controlled growth environment (Left: CPF / Right: CPF with 1ORC).

Natural or **Colorless CVD-grown (Type IIa) Diamond - 2.65ct, VS2, G:** Weak anomalous birefringence in a finer crosshatch pattern in this CVD-grown diamond can mimic the random, uneven strain pattern of natural Type IIa diamond (Left: CPF / Right: CPF with 1ORC).

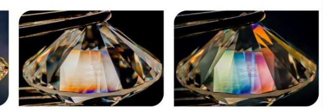
Natural or **Colorless CVD-grown (Type IIa) HPHT-treated Diamond - 4.18ct, VS2, H:** Weak and strong anomalous birefringence can be seen in this CVD-grown diamond. This kind of strain pattern with strong interference colors should always be supported using other methods to conclude origin (Left: CPF / Right: CPF with 1ORC).



HPHT-grown Diamond or **Yellow Natural (Type Ia) Diamond - 1.76ct, VVS1, Fancy Yellow:** Weak anomalous birefringence in a random, smudgy, uneven pattern is indicative of Type Ia diamond, but could be confused with some colored HPHT-grown diamonds (Left: CPF / Right: CPF with 1ORC).



HPHT-grown or **Very light Yellow Natural (Type Ia) Diamond - 1.51ct, VS2, N:** Some observers could be confused with the kind of weak anomalous birefringence in certain HPHT and CVD-grown diamonds, and in some positions might not see a pattern at all. This can result in the misidentification of natural diamond's origin (Left: CPF / Right: CPF with 1ORC).



Natural or **Colorless CVD-grown Type IIa Diamond ("Lightbox") - 2.00ct, VS1, H:** This CVD-grown diamond by DeBeers' Lightbox would be difficult to identify as CVD-grown using CPF due to similar weak, smudgy patterns seen in natural Type Ia diamonds (Left: CPF / Right: CPF with 1ORC).

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All photos are by **Randy Lightfoot** unless otherwise specified within caption.
Note: We are proud to include the 2023 Gem-A Photographer of the Year winning photo by Randy Lightfoot of a brown rough diamond octahedron taken using CPF.

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