De Beers
Group of Companies

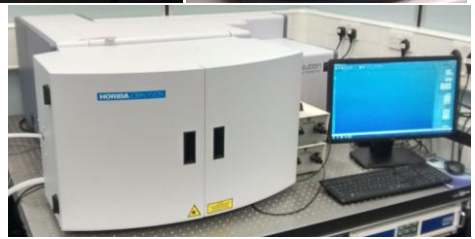
SYNTHETIC DIAMOND AND ITS IDENTIFICATION

GemFest Basel
22nd March 2015

Dr Simon Lawson, De Beers Technologies UK

RESEARCH RESOURCES

- De Beers Group
  - Over 65 years of fundamental research on diamond
- De Beers Technologies UK
  - 30 years of Consumer Confidence Technical Research (CCTR)
  - Contract synthesis and treatment research at specialist laboratories
- De Beers Technologies supports
  - Diamond research at UK universities
  - Centre for Doctoral Training in Diamond Science & Technology
  - Annual Diamond Conference
- 65th De Beers Diamond Conference was held at Warwick University 7-10 July 2014

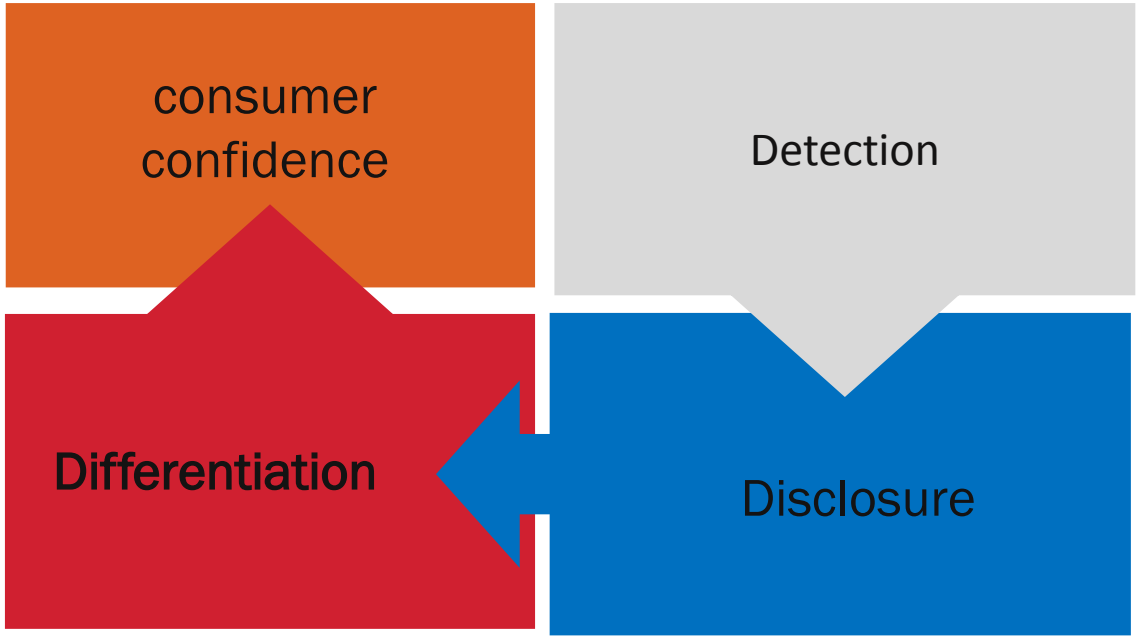


elementsix™

DST Diamond Science Technology Centre

DE BEERS CONSUMER CONFIDENCE PROGRAMME

maintaining & enhancing consumer confidence in the mystique & integrity of diamonds



TRADE DEFINITION OF DIAMOND & TERMINOLOGY

"A diamond is a natural mineral consisting essentially of pure carbon crystallised with a cubic structure."

– Source: FTC & CIBJO

What is a synthetic diamond?

– A diamond that has been either partially or wholly crystallised or re-crystallised artificially in a laboratory

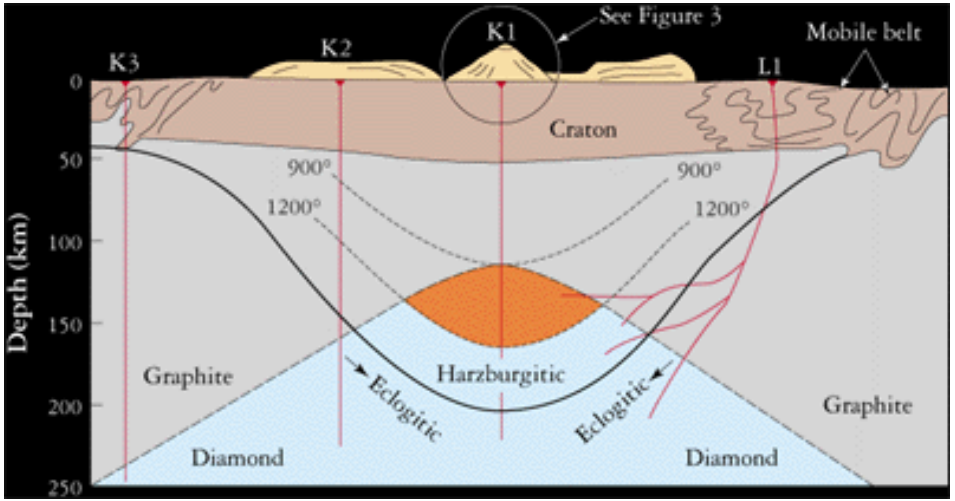
What are its properties

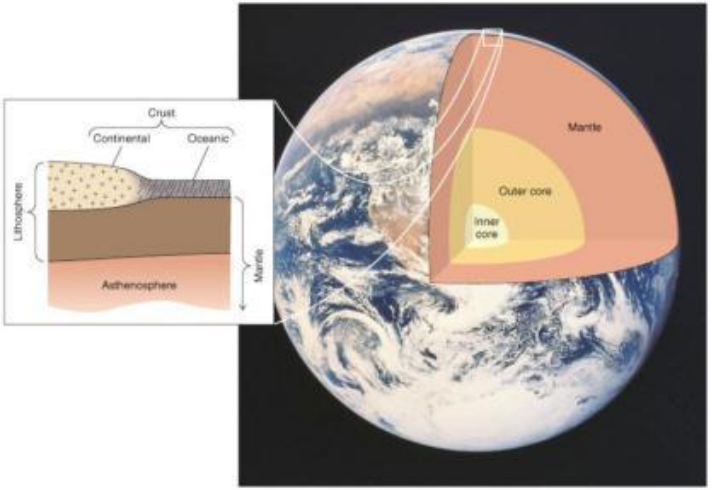
– Synthetic diamonds have the same chemical and physical properties as natural diamonds, but have different growth structures and impurities which enable rapid identification using specialist equipment

- 'Synthetic' is from the Greek 'Sunthetikos' meaning 'expert in putting together' and is applied to 'a substance or material made artificially by chemical reaction'
- This entirely appropriate term was applied by the scientists who first synthesised diamond in the 1950's
  - General Electric in the US and ASEA in Sweden
- Using the term 'grown diamonds' is ambiguous and potentially deceptive since it does not clearly differentiate natural diamonds from synthetic
  - Natural diamonds are 'grown' by mother nature

DIAMOND FORMATION

- Formed in the earth's mantle at depths of 150 - 200 km and temperatures of 900 – 1200°C
- Formed 0.9 – 3.5 billion years ago (from isotopic analysis of inclusions)
- Stored under cratons at least 110 km below the earth's surface
- Until brought up in Kimberlite / lamproite eruptions

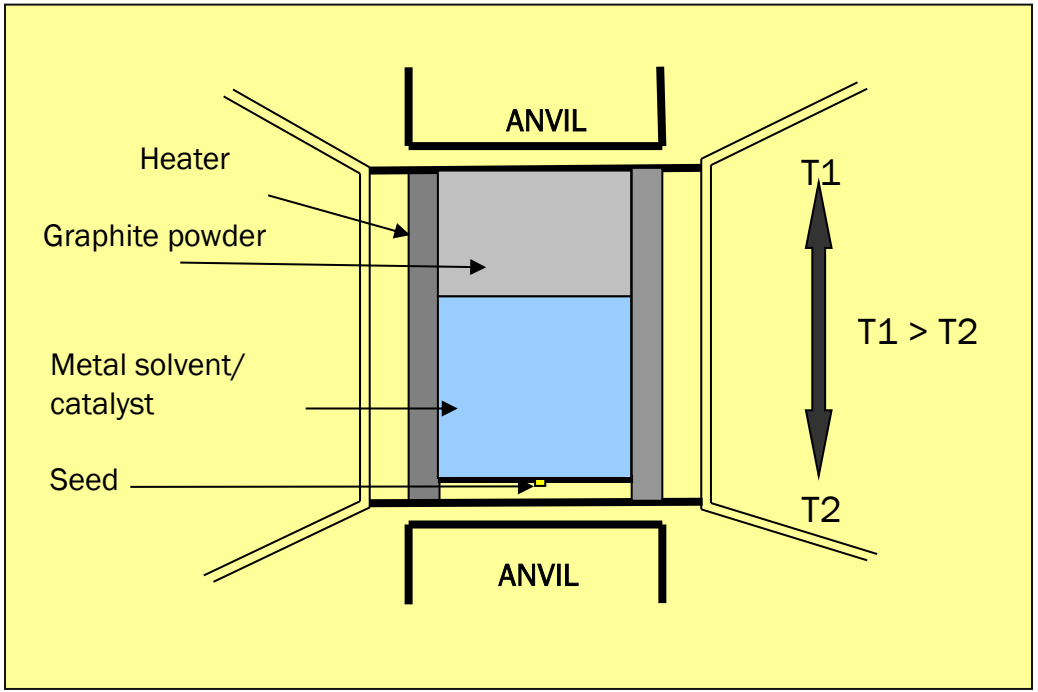




SCHEMATIC DIAGRAM: HPHT SYNTHESIS

Temperature-gradient method

Metal solvent/catalyst
Nickel/Iron
Cobalt/Iron



- Temperature = 1300 – 1500°C
- Pressure = 50 - 60 kbar

DIFFERENT GROWTH CONDITIONS LEAD TO DIFFERENCES IN SHAPE

Natural diamonds

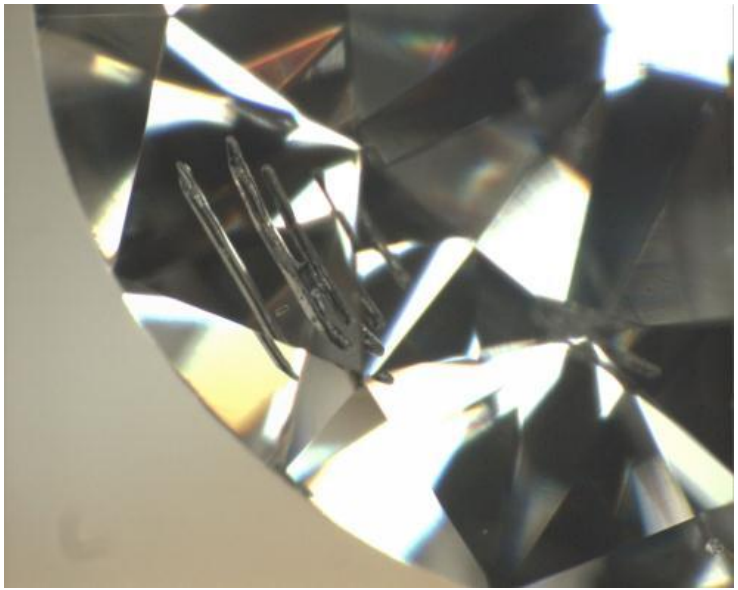
- Octahedral/dodecahedral

HPHT Synthetics

- Mainly cubo-octahedral
- Minor facets present

IDENTIFICATION FEATURES - INCLUSIONS

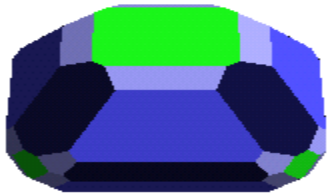
- Metallic inclusions
  - — From solvent/catalyst
    - Rod-shaped
    - May be attracted to a magnet

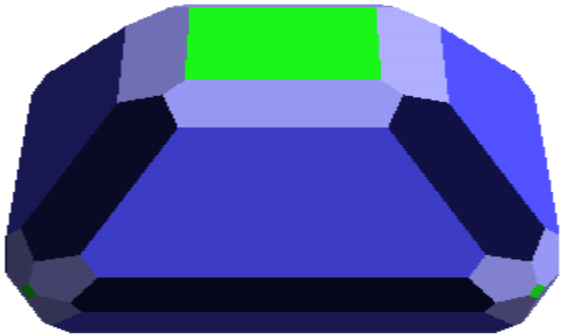


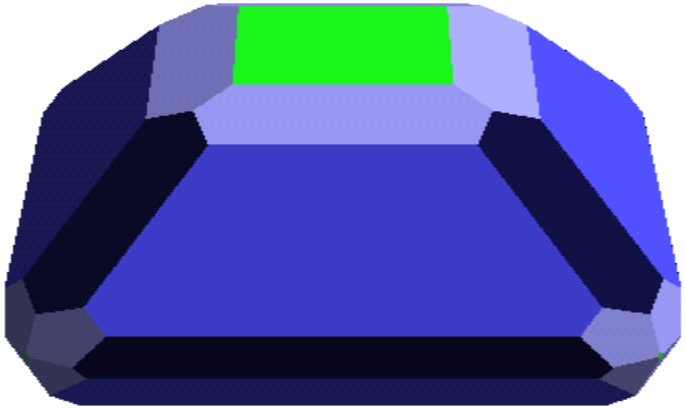
HPHT SYNTHESIS V. NATURAL FORMATION

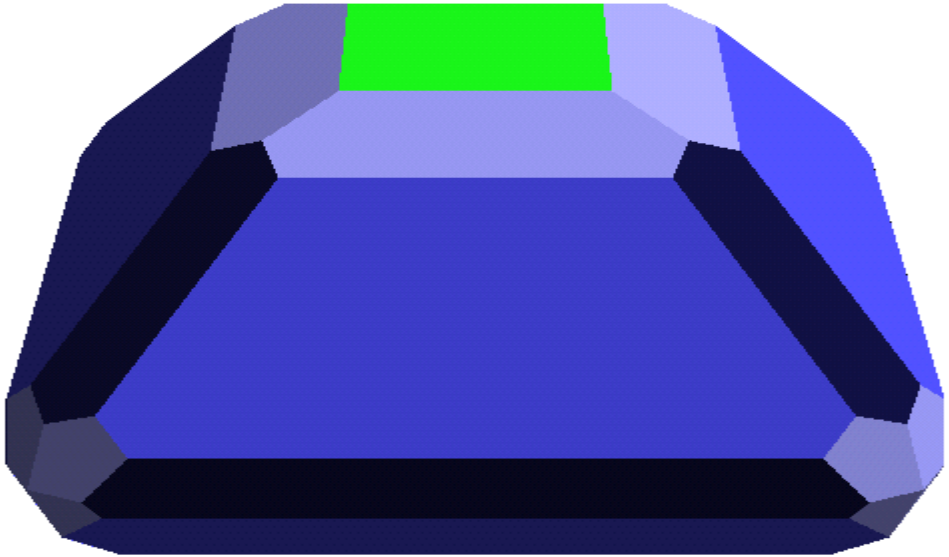
- HPHT synthesis relative to natural growth
  - Uses a different chemical environment
    - Metallic inclusions: visual inspection
  - Takes place at a higher temperature
    - Different crystal shape: DiamondView
  - Uses an engineered temperature gradient
    - Different crystal shape and development: DiamondView

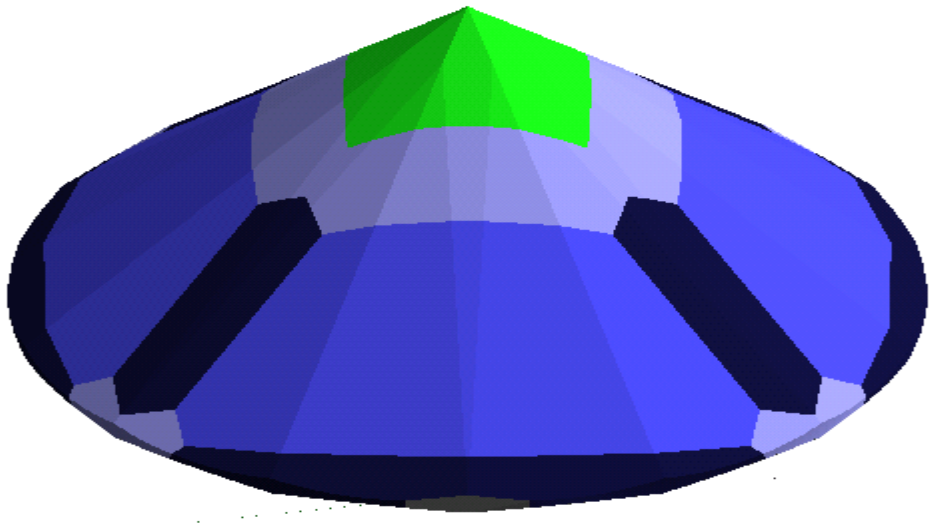
- Synthetics have not been at high T for hundreds of millions of years
    - Less/different aggregation of nitrogen impurity
    - The DiamondSure screening instrument makes use of this difference

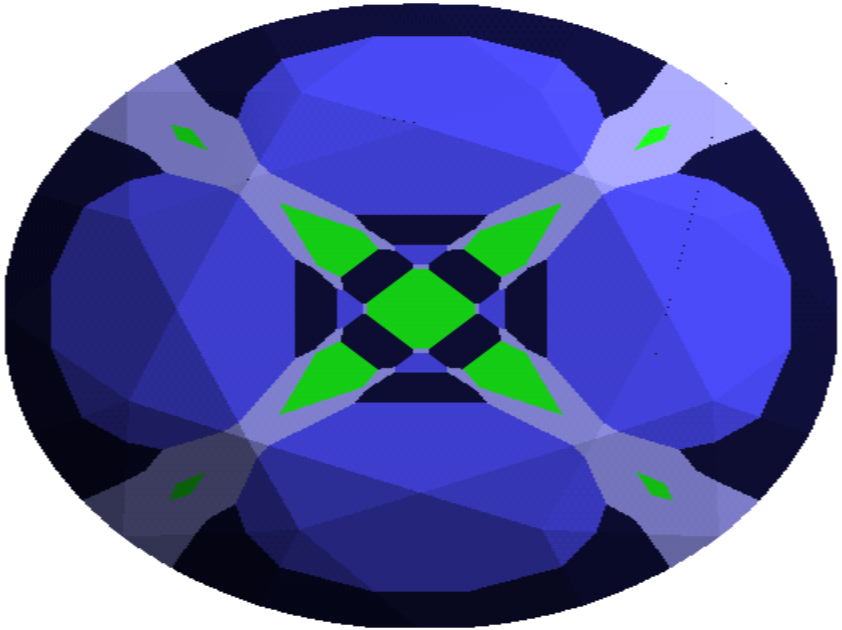




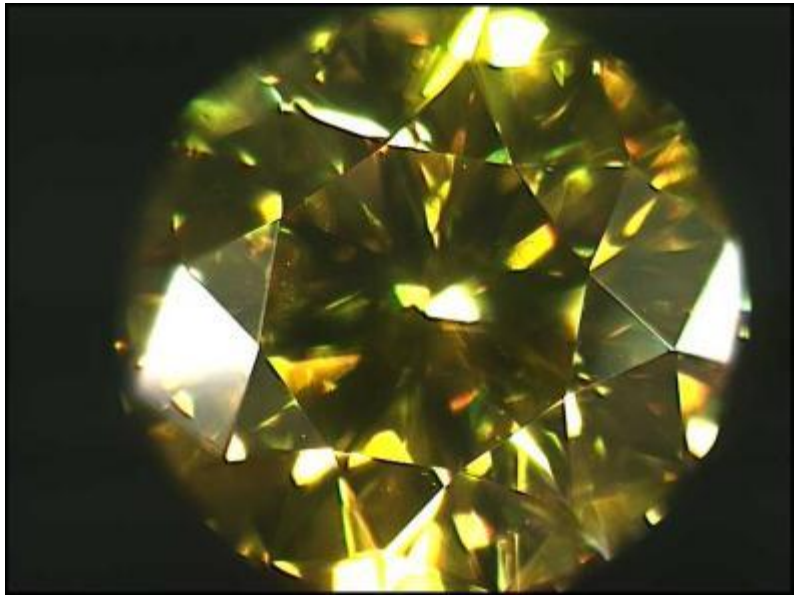


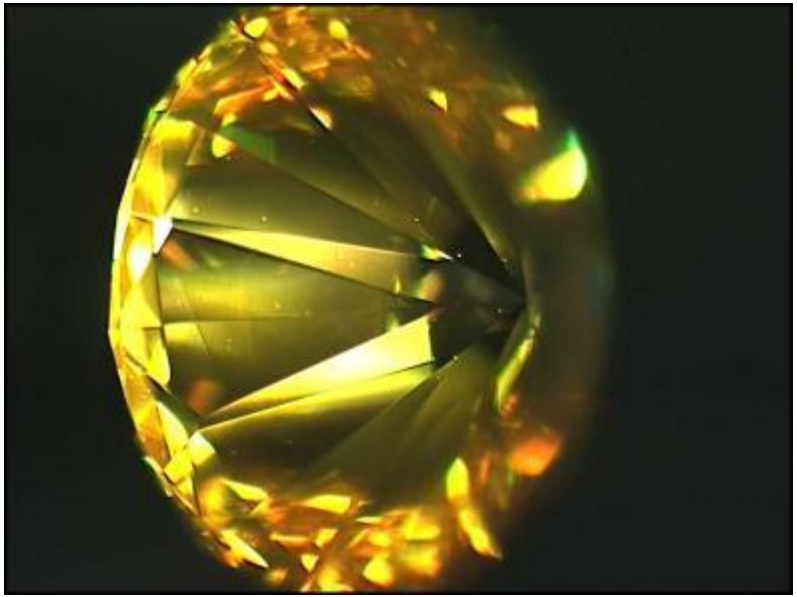




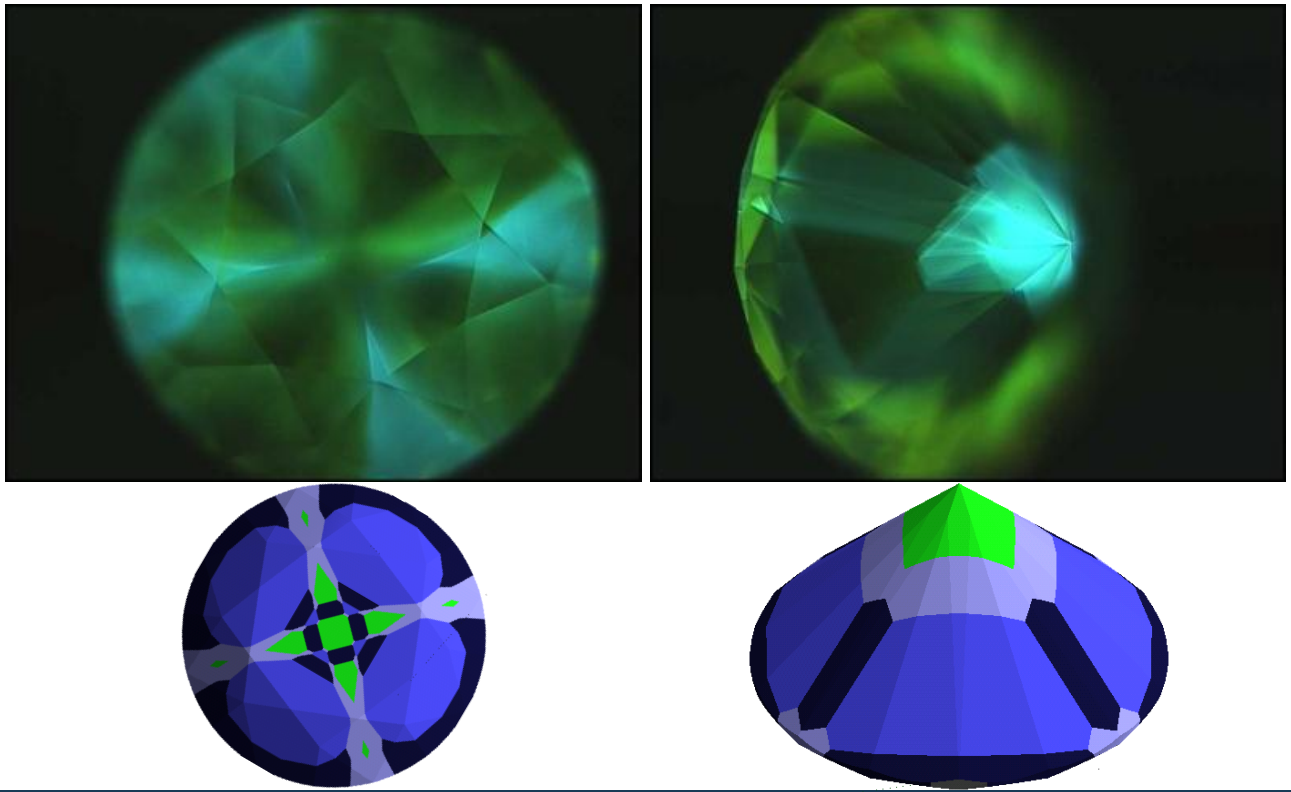


POLISHED HPHT-GROWN SYNTHETIC DIAMONDVIEW WITH VISIBLE ILLUMINATION





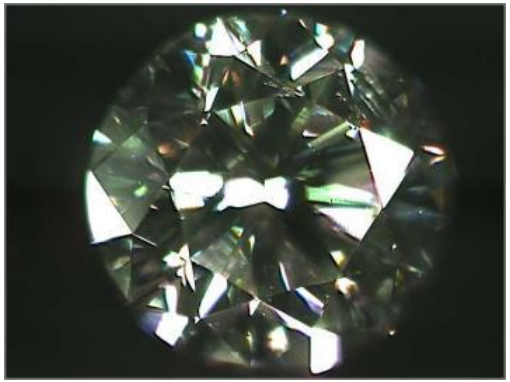
POLISHED HPHT-GROWN SYNTHETIC UV ILLUMINATION: FLUORESCENCE



DIAMONDVIEW IMAGES

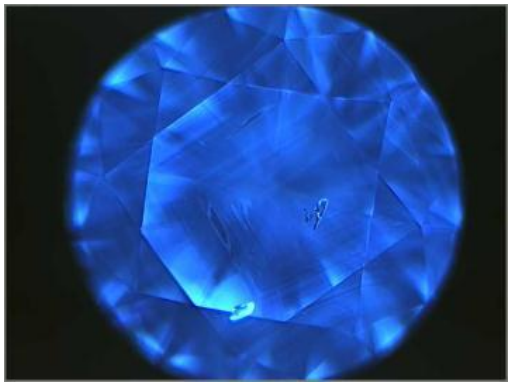
Colourless
Diamond

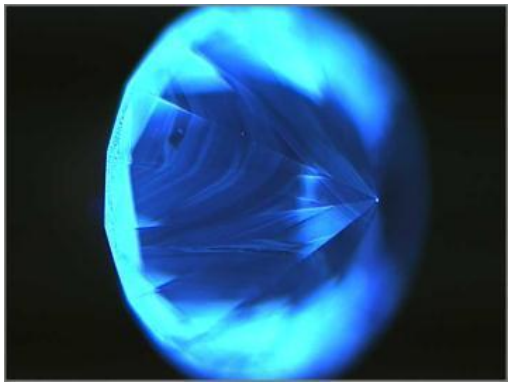
Colourless
HPHT
Synthetic



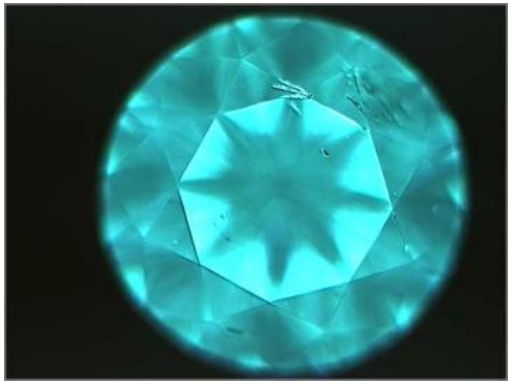
DIAMONDVIEW IMAGES - FLUORESCENCE

Colourless
Diamond





Colourless
HPHT
Synthetic



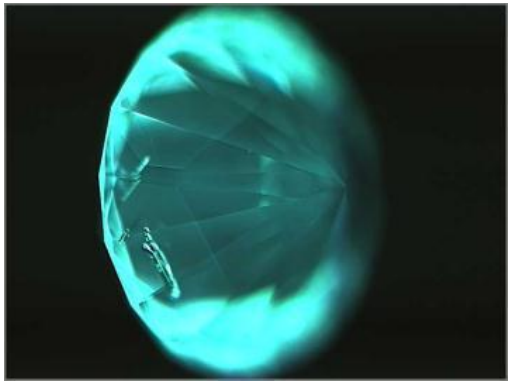
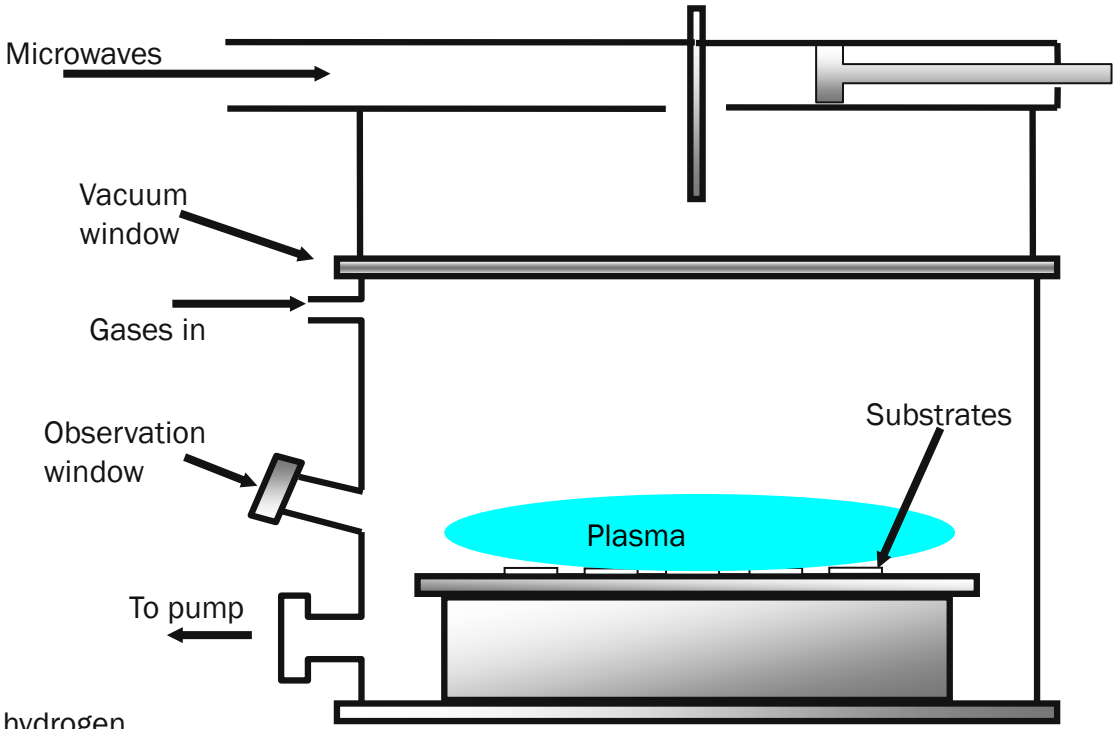


DIAGRAM OF MICROWAVE CVD REACTOR



Pressure ~ 0.1- 0.2 bar
Gases: typically methane and hydrogen

CVD SYNTHETICS IN A CVD REACTOR DURING GROWTH

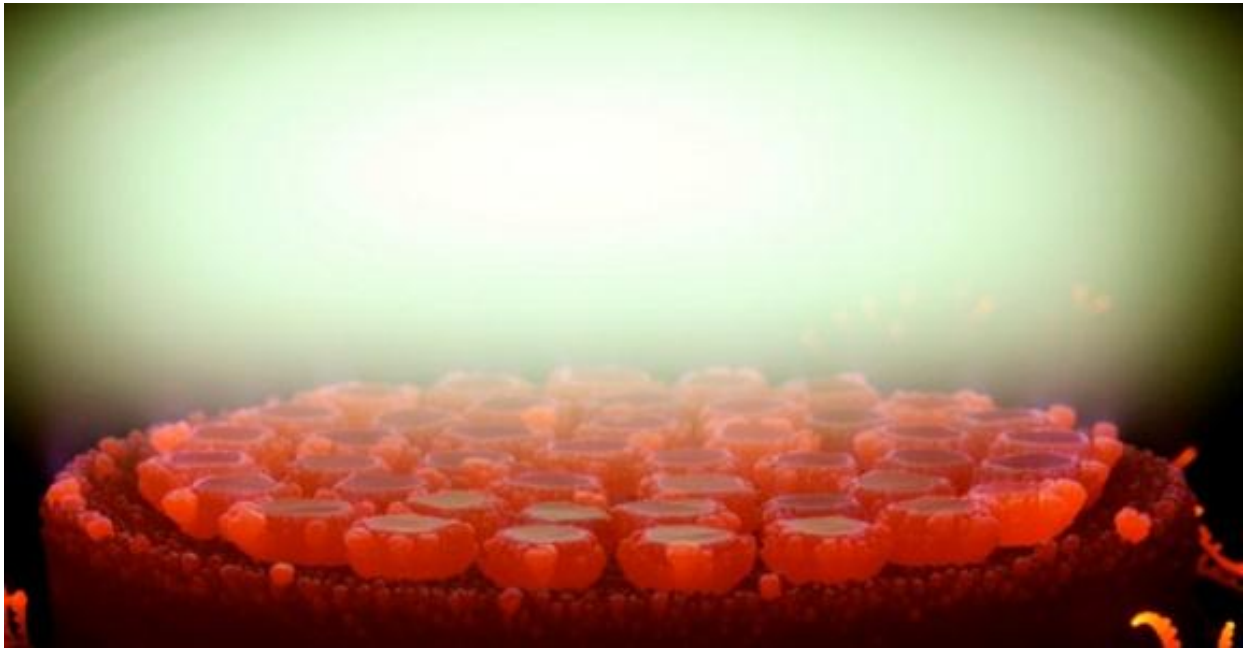


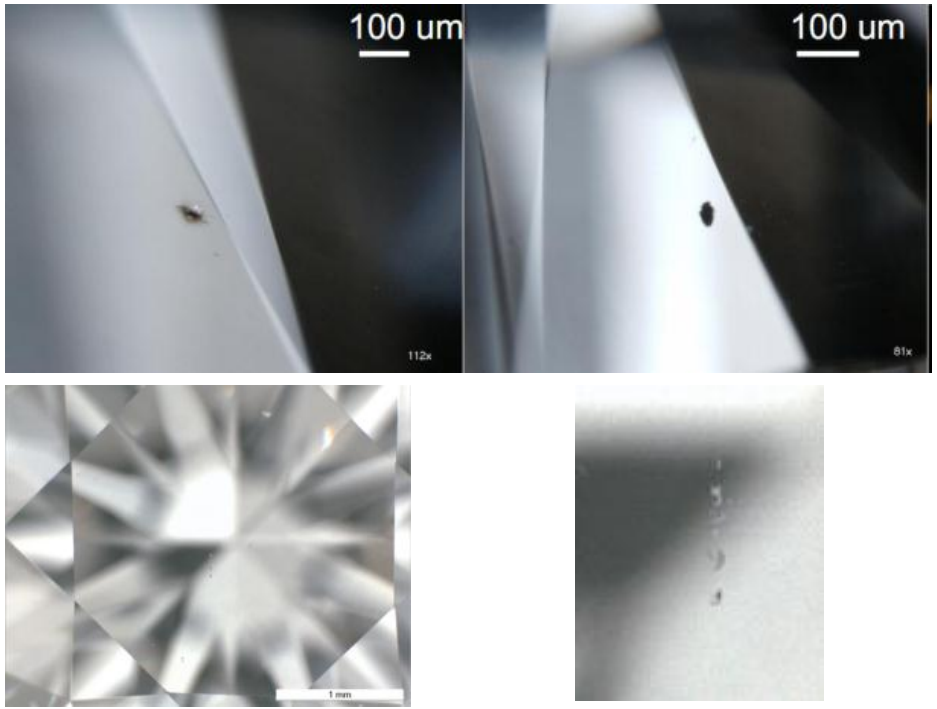
Image from Scio Diamond – Built in America:
http://www.youtube.com/watch?v=iQXVya-HAOk

EXAMPLES OF PART-PROCESSED CVD SYNTHETICS

Approx. 5 mm x 5 mm x 3 mm
(after removal of low quality
edge material by laser sawing)

IIa Technologies CVD synthetics
after laser sawing

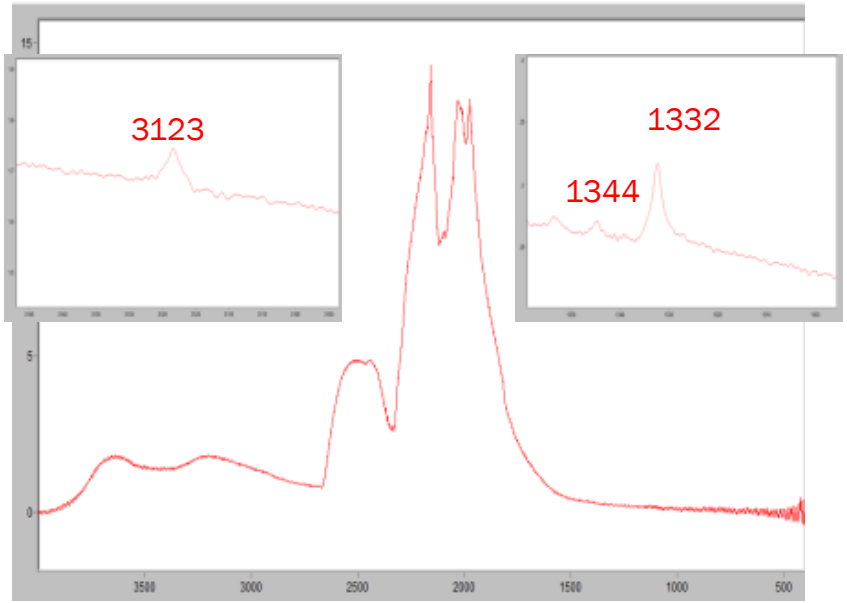
KEY FEATURE: INCLUSIONS



Examples of dark and light inclusions observed in heat treated CVD synthetics

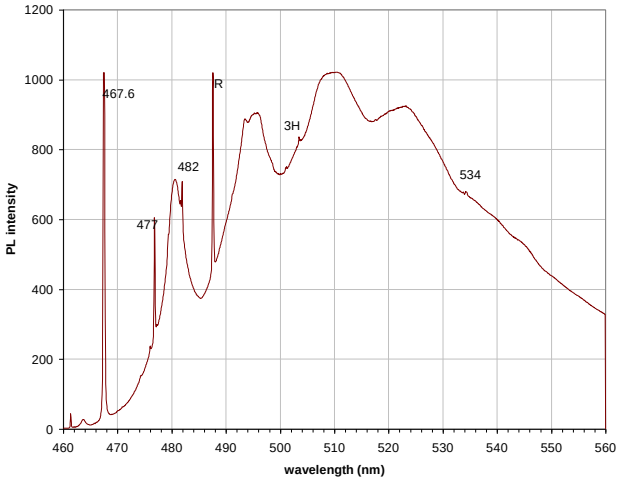
Inclusions in CVD synthetics can be strikingly similar to natural inclusions.
Microscopy is insufficient for identification of CVD synthetics.

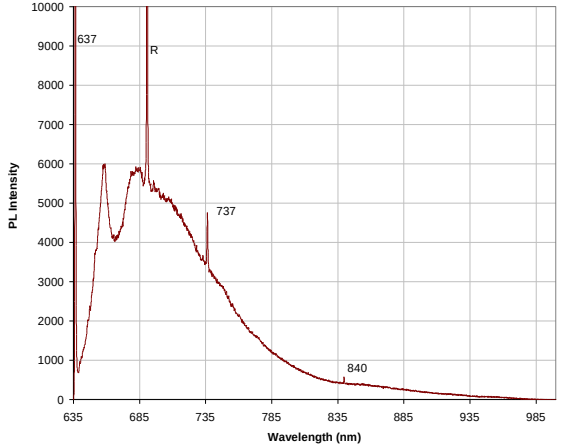
INFRARED SPECTROSCOPY



- Near-colourless CVD synthetics are nominally type II (DiamondSure & IR)
- **1332 and 1344 cm^{-1}** (N_S)
- **3123 cm^{-1}** Not present after annealing

PHOTOLUMINESCENCE SPECTROSCOPY

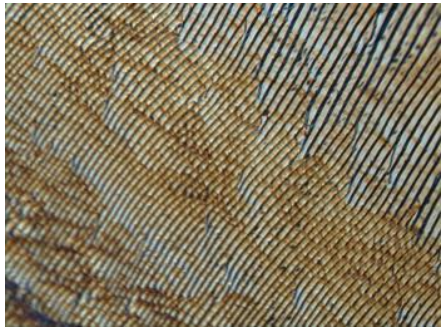


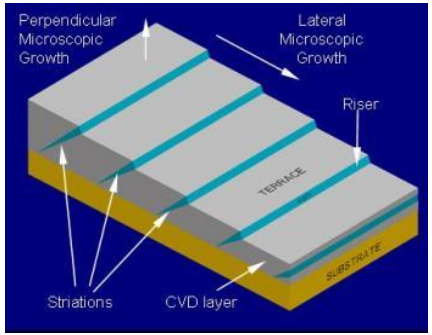


- **468 and 533 nm lines**
  - Commonly shown by as-grown CVD synthetics
- **737 nm line** is caused by impurity silicon
  - difficult to eliminate / remove

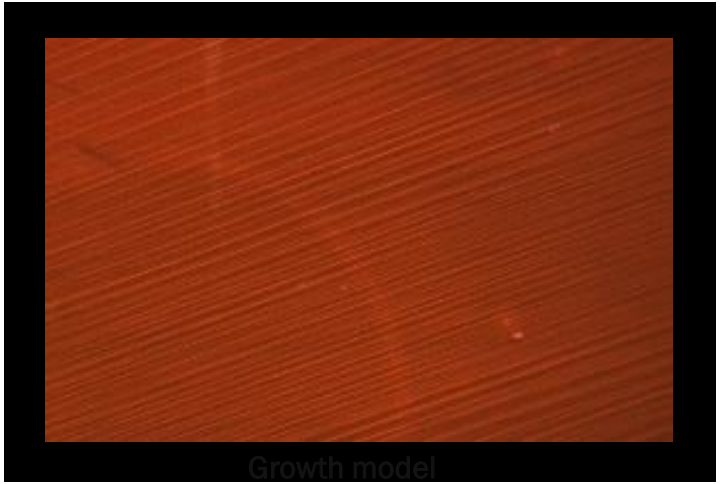
KEY FEATURES: FLUORESCENCE / STRIATIONS

Micrograph of the surface of an unprocessed CVD synthetic



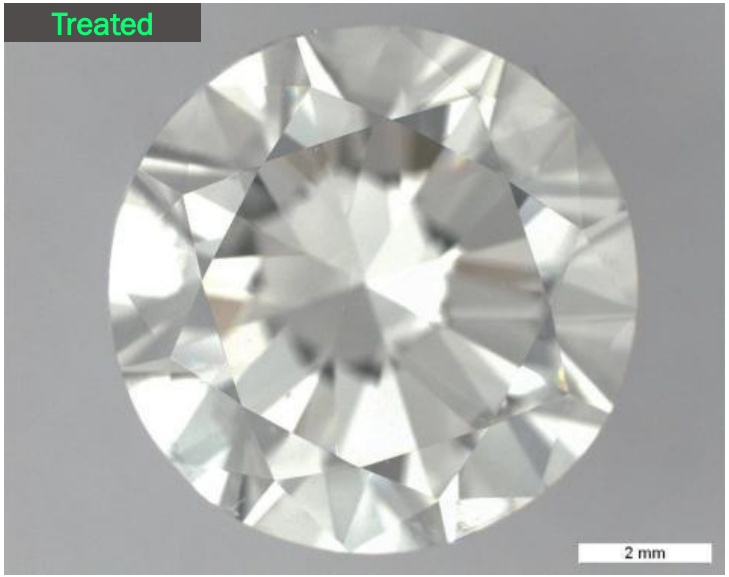


DiamondView of a polished cross section of an as-grown CVD synthetic



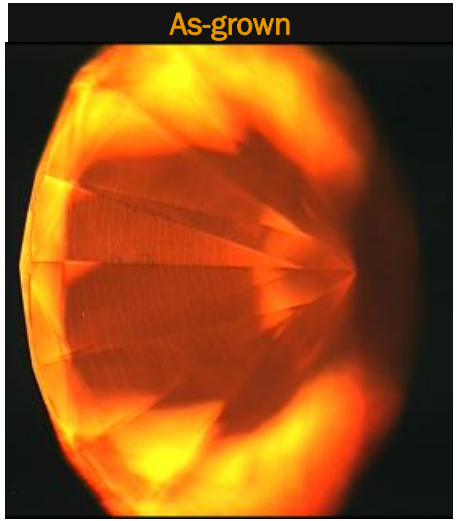
In as-grown CVD synthetics, the *orange fluorescence* is caused by nitrogen-vacancy defects

Striations result from the differential uptake of defects on different surfaces (risers versus terraces) during growth



- This CVD synthetic gemstone was high temperature treated in an HPHT press (temperatures >1600°C).
- There is a very noticeable colour improvement from P-T colour to I colour.

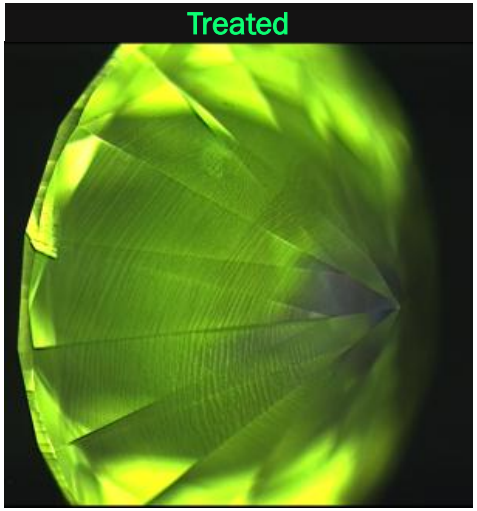
DIAMONDVIEW FLUORESENCE IMAGES OF CVD SYNTHETICS



Orange fluorescence

Striations normally present

Sometimes zoning observed (caused by growth events)

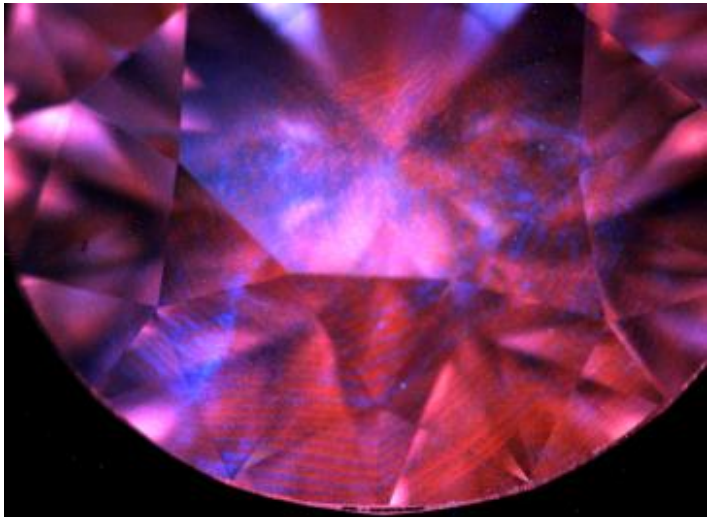


Orange luminescence replaced by green or greenish blue fluorescence

Phosphorescence generated

Striations / zoning remain

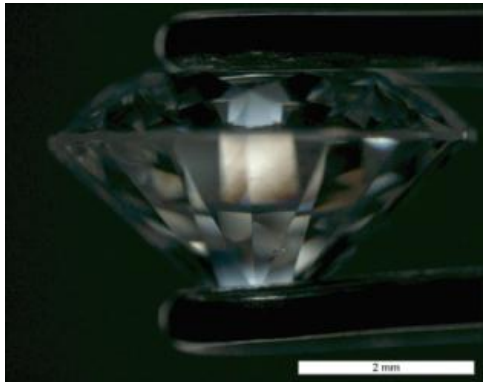
APOLLO / SCIO CVD SYNTHETICS
EXAMPLES SEEN 2007-2010

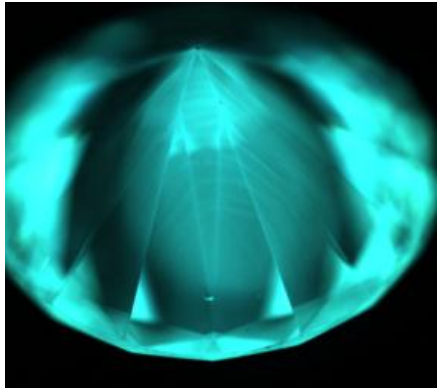


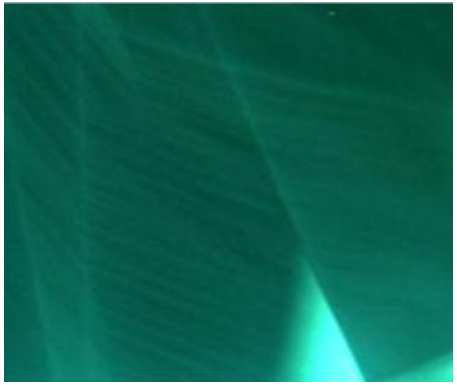
Colourless material

- Moderate size
- Orange fluorescence & striations
- Relatively high purity
- Not heat treated

GEMESIS CVD SYNTHETICS







Birefringence indicates relatively low strain

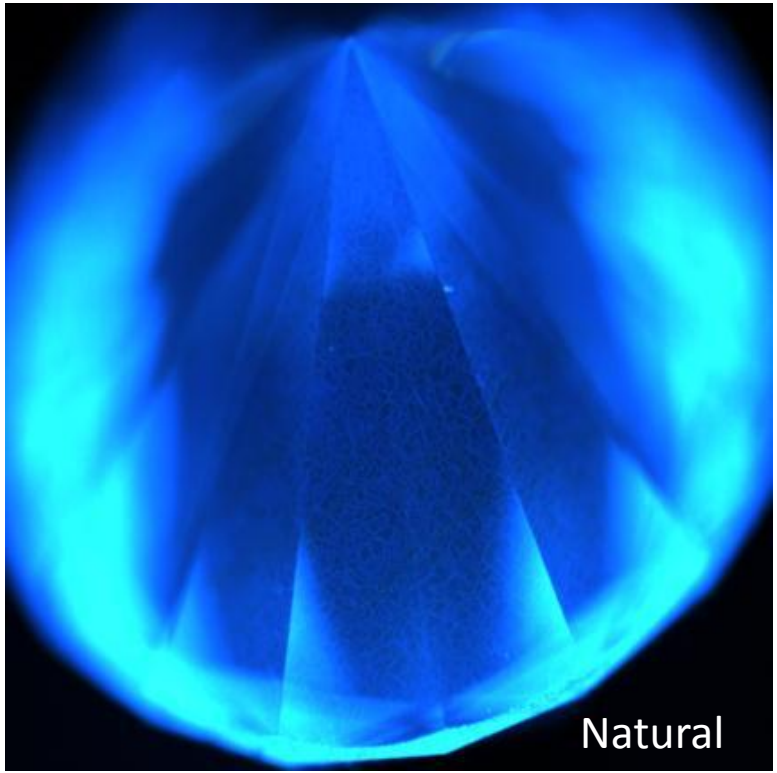
Bluish green fluorescence and blue phosphorescence

Fine-to-medium striations, and sometimes zoning in DiamondView images

DIAMONDVIEW (DV3F)

- New improved DiamondView
- Interchangeable filters
- Improves detection of CVD synthetics
- Improved dislocations imaging in natural diamonds
- Plan to make available from beginning of H2, 2015

DIAMONDVIEW – IMPROVED DETECTION WITH FILTERS



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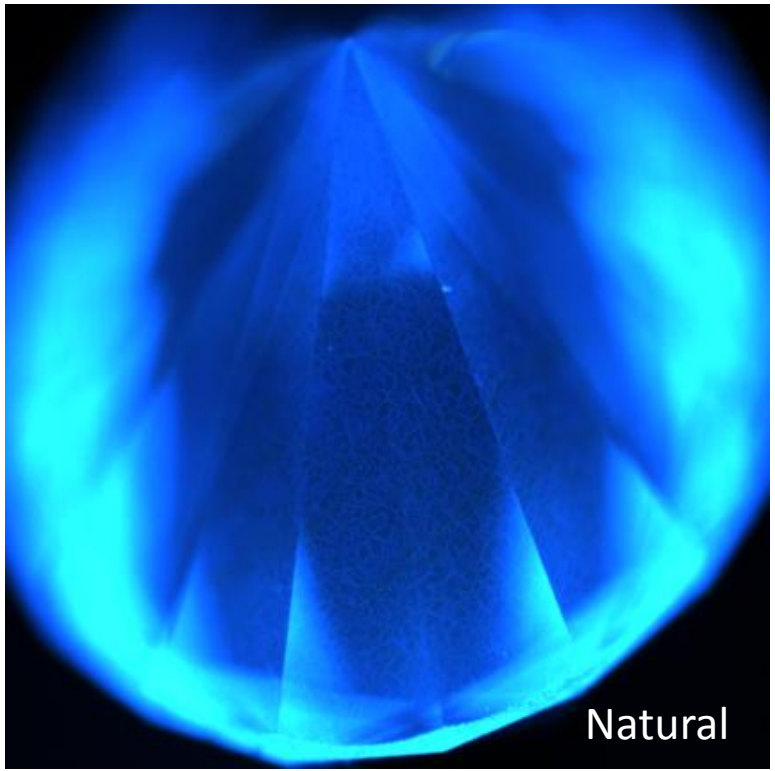

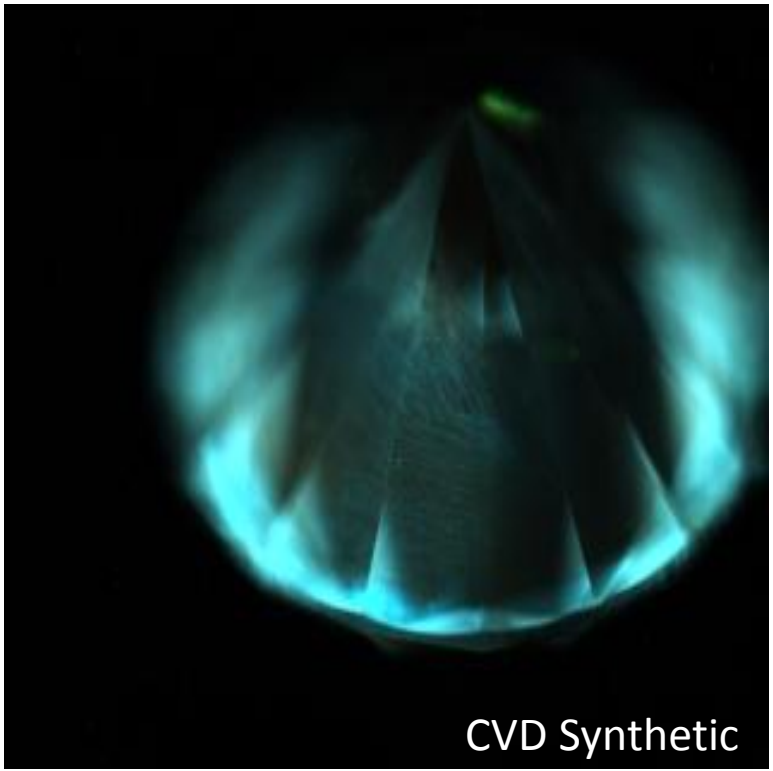

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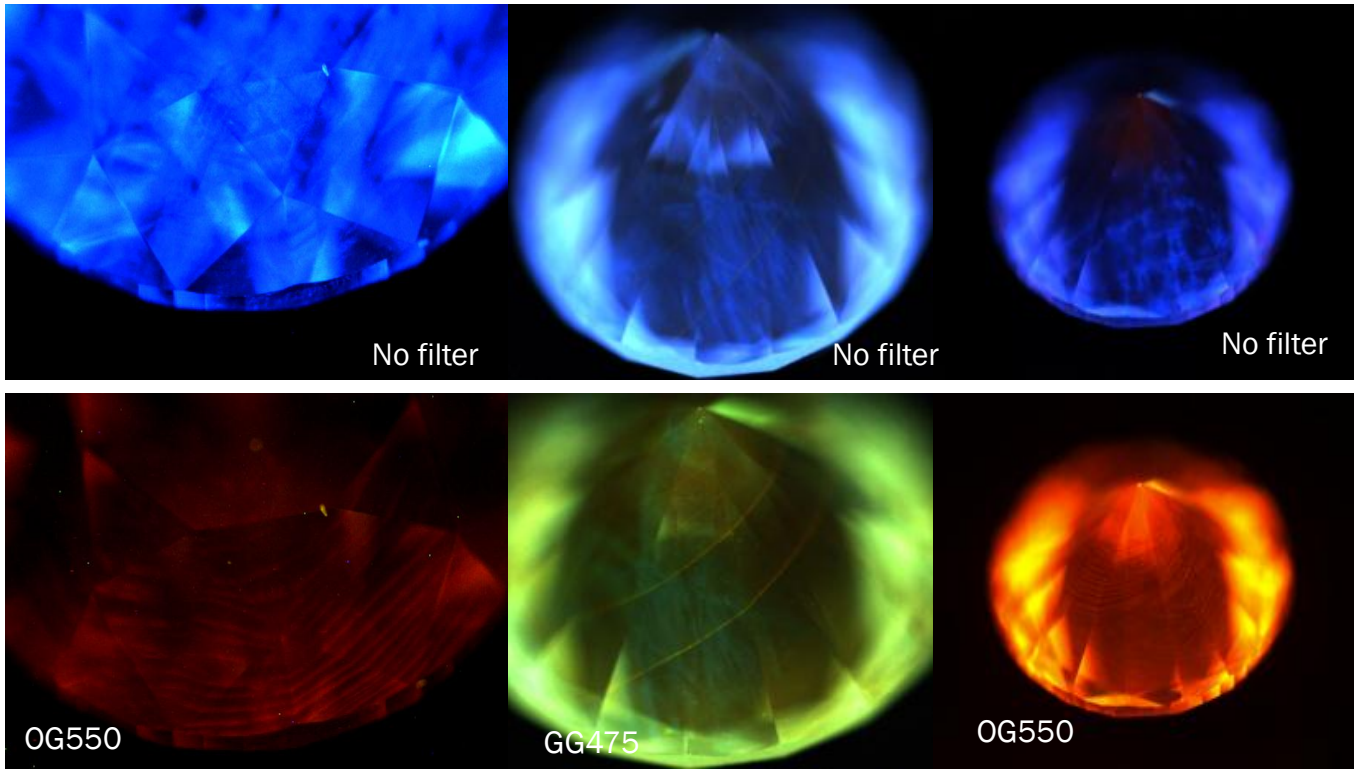
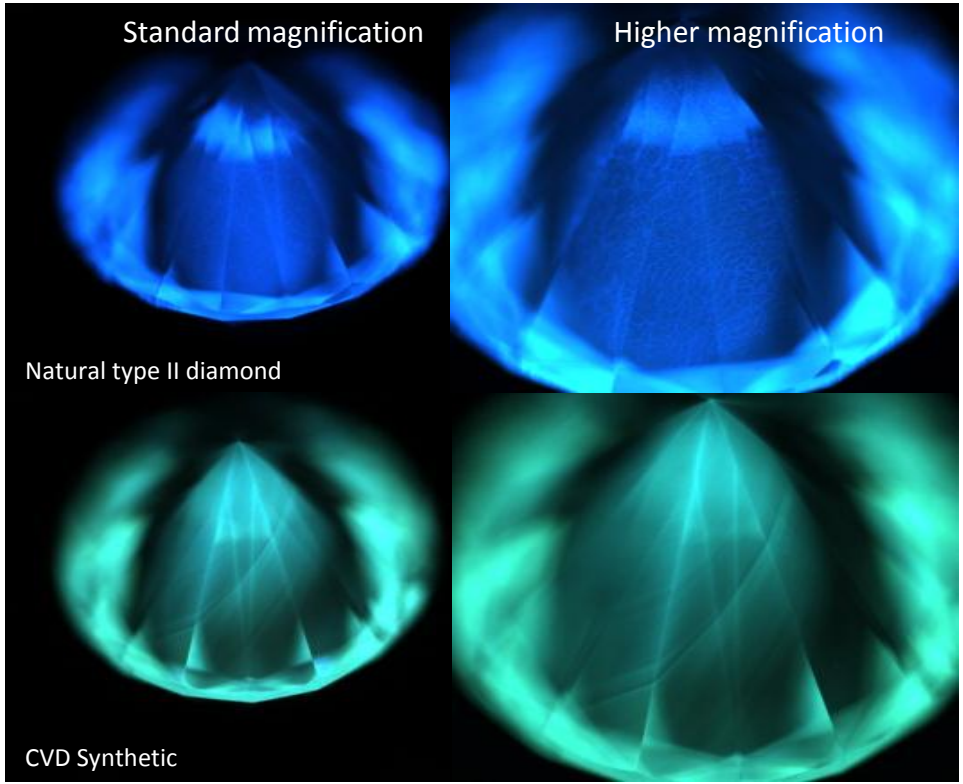
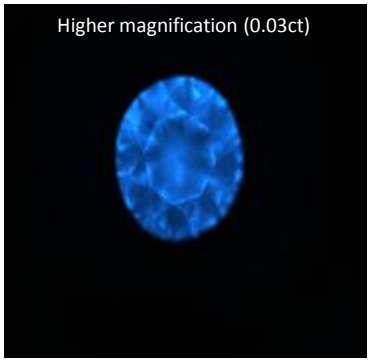


COMPARISON OF STANDARD MAG VS HIGHER MAG SYSTEM



- x1.6 higher optical magnification
- Further magnification possible digitally
- Useful for looking at fine detail
    - Natural type II diamonds
    - CVD-grown synthetics
- Higher mag system useful for AMS referrals (smaller sizes)



DIAMONDVIEW – SAMPLE HOLDER DEVELOPMENT

Instrument Screening Flow Chart

DiamondSure

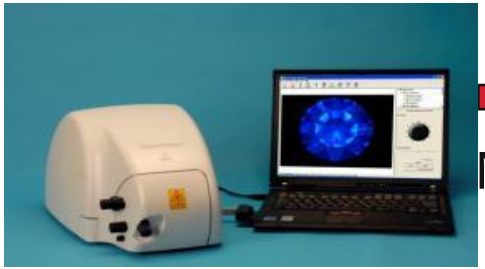
All polished goods

~98% Pass
(No further testing required*)

*however, fancy colour type I Pass results will need additional testing for HPHT treatment

All synthetics/ simulants
+ ~2% of natural diamonds

DiamondView



Natural type II

(HPHT treatments test)

DiamondPLus

DIAMONDSURE™

Measures the way diamonds absorb light

- Rapid screening instrument
- Very easy to operate
  - Measurement time: 4 seconds
- ALL synthetics & simulants are referred for further tests
  - Type II diamond
  - Synthetic Moissanite
- Mounted goods tested with extendable probe
  - Auto-detect capability for initiating measurement
- Removable dish for testing melee goods

DIAMONDVIEW™

- All DiamondSure referrals are tested on DiamondView
- Generates a surface fluorescence image from which synthetics may be identified
- Loose and mounted goods
- Needs user interpretation

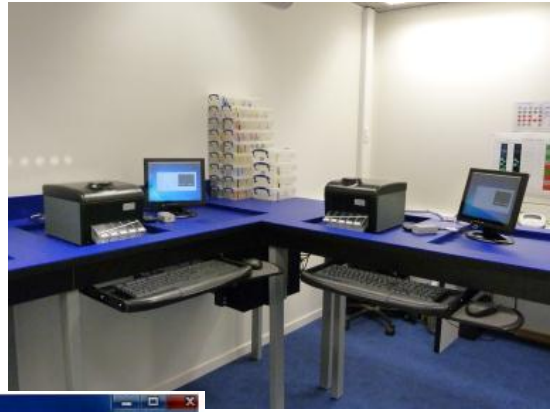
AUTOMATED MELEE SCREENING (AMS)

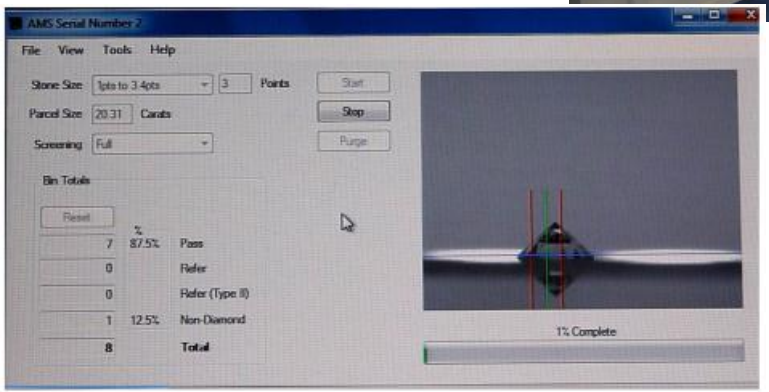
- Designed for testing
  - Colourless and near-colourless
  - 0.01 – 0.20 ct
  - Round brilliants
- Automatic feeding, testing and dispensing
  - Speed: 360 stones/hr
- Can be left unattended
  - One person can run many machines while carrying out other tasks
  - Overnight running is possible

AMS OUTPUT CATEGORIES

- Pass
  - not synthetic or simulant
- Refer
  - Rare result: further testing required
- Refer Type II
  - Low nitrogen. Could be synthetic. Further testing required.
- Non diamond
  - Simulant or synthetic

- Typical pass rates for natural diamond
  - 10 pts: 98%
  - 5 pts: 97%
  - 1 pt: 96%





SUMMARY

- Current synthetics can be detected using IIDGR diamond verification instruments used by key grading labs and regarded as an industry standard
  - Sold by IIDGR (https://www.iidgr.com/)
- Automated melee screening equipment is available for sale to De Beers Sightholders and a screening service has been launched in China and will be launched in India from the beginning of H2 this year.
- Our forward looking research continues to probe potential weaknesses of the identification methods so that improvements can be implemented if required
- Practical detection technology will be part of the solution to the challenge that the trade currently faces in maintaining consumer confidence

ACKNOWLEDGEMENTS

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