Selecting a Diamond Verification Instrument Based on the Results of the Assure Program: An Initial Analysis

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ABSTRACT: Recently, the rapid growth in synthetic diamond production—particularly in melee sizes—and the salting of melee parcels with synthetics have generated a commensurate increase in the need for diamond verification instruments (DVIs). Ongoing independent third-party testing of these instruments is being done through the Assure Program. DVI performance is tested in a UL laboratory using carefully developed testing standards and sample sets (i.e. natural diamonds and as-grown and treated synthetics, as well as simulants as appropriate). The initial phase of testing was performed during latter 2018 and the first part of 2019, and as of July 2019 results for 16 widely available devices from 12 DVI manufacturers were published online in the Assure Directory (https://diamondproducers.com/assure/assure-directory). From these test results, the authors have evaluated several important parameters that will help users select the best instrument for their needs. Performance results from several additional DVIs are expected to be released in the near future, and further testing and publication of the data will occur as new instruments are introduced and existing ones are updated.

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Conversations within the gem and jewellery trade on how to separate natural from synthetic diamonds have been ongoing for decades. General Electric succeeded in growing synthetic diamonds in the mid-1950s (Bruton 1978), but several decades passed before such products became commercially available in sizes and qualities suitable for gems (i.e. in the mid-1980s from Sumitomo Electric Industries in Japan; Shigley *et al.* 1986). Today, synthetic diamonds are readily available for gem and jewellery use, both legitimately—when they are sold and identified as such—and nefariously, when they are intentionally represented as natural or the customer is allowed to infer that they are natural without proper disclosure from the seller (Rapaport 2013). Large quantities of small-sized synthetics (especially <0.05 ct) produced using high-pressure, high-temperature (HPHT) growth methods are readily available in variable clarities and in the D–N colour range, particularly from Chinese manufacturers (Eaton-Magaña *et al.* 2017). Chinese factories produce approximately 200,000 carats of HPHT-grown melee per month (Shigley 2017), and production capacity continues to increase. In addition, synthetic diamonds grown by chemical vapour deposition (CVD) are improving in quality and are undergoing limited commercial production for the gem industry (Eaton-Magaña & Shigley 2016). At the same time, reports have been circulating of melee diamond parcels (e.g. Figure 1) and jewellery being salted with synthetics (e.g. Poon *et al.* 2016; Bhoir *et al.* 2017; Ambalathveettil *et al.* 2018), causing concern in the trade. Stories on the Internet and in other consumer

Figure 1: There is growing concern in the gem and jewellery industry over the presence of synthetics and simulants in diamond parcels, particularly for melee-sized goods such as those shown here. Photo courtesy of De Beers Group Industry Services.

media have also highlighted problems surrounding undisclosed synthetics and simulants, and the average jeweller must contend with the fact that they could unknowingly be dealing in these products.

An experienced gemmologist who remains current on the growth technology and properties of the synthetics (both HPHT and CVD grown) can, in some cases, distinguish between natural and laboratory-grown diamonds through the use of classical gemmological tools. However, this is impractical for situations in which numerous stones (often melee-sized) must be quickly and cost-effectively tested on a regular basis. While several gem-testing laboratories offer melee screening services (e.g. Figure 2), it can be expensive and impractical to send quantities of diamonds to labs, and the cost and lost time make it desirable in some cases to have access to in-house instrumentation.

Numerous diamond verification instruments (DVIs) are currently on the market for diamond testing, and as of this writing the authors have identified 49 devices from 24 manufacturers (Table I). Some DVIs have been available for more than two decades (e.g. Welbourn *et al.* 1996), but many have only recently been released. Manufacturers claim their instruments can separate colourless to near-colourless natural from synthetic diamonds and from some simulants or, at a minimum, refer those in question for further testing. These instruments range from relatively inexpensive to very costly, and present a diverse array of marketing claims and features (Drucker & Phillips 2018). Hundreds of businesses in the supply chain have acquired these instruments and base their hard-earned reputations on the results they produce. However, until recently, there was no independent means to verify the accuracy and reliability of such testing and screening devices.

In 2017, the Diamond Producers Association (DPA) proactively sought to address this problem by creating an initiative named Project Assure (Freedman 2017), which was subsequently renamed the Assure Program. This initiative is managed by DPA with support from Signet Jewelers (Akron, Ohio, USA). As of July 2019, the results

Figure 2: Melee screening services are offered by several gem-testing laboratories. The diamonds in this parcel were identified as natural by the International Institute of Diamond Grading & Research. Photo courtesy of De Beers Group Industry Services.

Table I: Assure-tested and untested diamond verification instruments.[a]

Instrument	Manufacturer	Website
Assure tested		
AMS2	De Beers Group Industry Services (UK)	www.debeersgroupservices.com/instruments/automated-melee-testing
ASDI	SATT Gems (Switzerland)	www.sattgems.ch/asdi
DiamondDect 3	Taidiam Technology (Zhengzhou) Co. Ltd (China)	http://en.taidiam.com/product/11.html
DiamondDect 5	Taidiam Technology (Zhengzhou) Co. Ltd (China)	http://en.taidiam.com/product/11.html
DiamondSure	De Beers Group Industry Services (UK)	www.debeersgroupservices.com/instruments/diamondsure
DiamondView	De Beers Group Industry Services (UK)	www.debeersgroupservices.com/instruments/diamondview
G-Certain	Massive Tech Lab (India)	www.massivetechlab.com/g-certain
GemPen	Gemometrics (Sweden)	https://gemometrics.com/product/gempen
GIA iD100	Gemological Institute of America (USA)	www.gia.edu/id100
GV5000	National Gemstone Testing Center (China)	www.ngtc.com.cn/index.php?m=Article&a=show&id=485
J-Certain	Massive Tech Lab (India)	www.massivetechlab.com/j-certain-a-synthetic-diamond-detector-for-studded-jewellery
Leo[b]	Gemlogis (Hong Kong)	www.gemlogis.com/product-details/leo
M-Screen+[c]	HRD Antwerp (Belgium)	http://hrdantwerp.com/en/equipment/detail/m-screen
Sherlock Holmes[d]	Yehuda Diamond Co. (USA)	www.yehuda.com/shop/hphtmachine
SYNTHdetect	De Beers Group Industry Services (UK)	www.debeersgroupservices.com/instruments/synthdetect
Synthetic Diamond Screener II	Presidium (Singapore)	https://presidium.com.sg/psdproduct/synthetic-diamond-screener-ii-sds-ii

from 16 tested instruments (see Table I and Figure 3) have been published in the Assure Directory (https://diamondproducers.com/assure/assure-directory), both as summary web pages and as more detailed downloadable PDF files. The results are complicated and somewhat confusing to interpret due to the wide variety of parameters, as well as the range of DVI features and capabilities. For example, it is necessary to simultaneously consider whether an instrument is designed for screening or testing, can take loose and/or mounted stones, can test for simulants, and will provide results that are automated or require the user's interpretation, as well as several other variables (speed, cost and reliability). These choices and considerations can be overwhelming, and until now the results of the testing done so far and their implications have only been briefly discussed (e.g. Freedman 2019).

This article describes the Assure Program's initiative of rigorously evaluating the performance of several commercially available DVIs (as of July 2019). The authors summarise the testing procedures, sample sets and results of instrument performance, and consider implications for selecting an appropriate DVI from those tested so far.

BACKGROUND

Both authors work in the diamond and jewellery wholesale business and have considerable experience with testing diamond parcels using various DVIs. Neither author is associated with the Assure Program or its affiliates, nor were they involved in the testing of the DVIs. During the preparation of this article, the authors obtained information from Lisa Levinson, DPA's strategic project manager, and Thomas Gelb, a technical consultant to the Assure Program who assisted with the development of testing standards but did not take part in the actual DVI evaluation process.

For the initial phase of testing, DPA reached out to DVI manufacturers representing the most widely available devices in the market. Many responded, but not all. Those DVI manufacturers that chose to participate paid a fee directly to the testing organisation (UL, described below) to cover the cost of the testing process. In 2018, final arrangements were made with 11 manufacturers to test 18 DVIs, and as of July 2019 the results obtained for 16 of them (see Table II) were published in the Assure Directory. After undergoing the

Table I: (continued)

Instrument	Manufacturer	Website
Not Assure tested		
Alpha Diamond Analyzer	HRD Antwerp (Belgium)	https://hrdantwerp.com/en/equipment/detail/alpha-diamond-analyzer
Alrosa Diamond Inspector	Alrosa Technology (Russia)	https://alrosa-inspector.com
D-Guard	Sparrow Technologies (India)	http://sparrowdg.com
D-Screen[e]	HRD Antwerp (Belgium)	https://hrdantwerp.com
D•Secure+	DRC Techno (India)	https://drctechno.com/products/gemological/d-secure-plus
D-Tect	HRD Antwerp (Belgium)	https://hrdantwerp.com/en/equipment/detail/d-tect
DFI Mid-UV Laser+	GGTL Laboratories (Liechtenstein and Switzerland)	www.ggtl-lab.org/products.html
DiamondPlus	De Beers Group Industry Services (UK)	www.debeersgroupservices.com/instruments/diamondplus
Diasure	Maruti Enterprises (India)	www.diatech.co.in
DiaTrue CL	OGI Systems Ltd (Israel)	www.ogisystems.com/diatruexl.html
DiaTrue CM	OGI Systems Ltd (Israel)	www.ogisystems.com/diatrue.html
DiaTrue CS	OGI Systems Ltd (Israel)	www.ogisystems.com/diatruecs.html
DiaTrue Mobile	OGI Systems Ltd (Israel)	www.ogisystems.com/diatruemobile.html
DS2000	Nanjing Baoguang Testing Technology (China)	www.bgyq.cn/spe/spe.html
DS5000	National Gemstone Testing Center/Nanjing Baoguang Testing Technology Co. Ltd (China)	www.ngtc.com.cn/index.php?m=Article&a=show&id=486
GEM-3000 Jewelry Detector	Guangzhou Biaoqi Optoelectronics Technology Development Co. Ltd (China)	www.gzbiaoqi.com/ProductShowen.asp?ArticleID=9
GEM-Smart Portable Jewelry Detector	Guangzhou Biaoqi Optoelectronics Technology Development Co. Ltd (China)	www.gzbiaoqi.com/ProductShow.asp?ArticleID=387
GIA DiamondCheck	Gemological Institute of America (USA)	https://store.gia.edu/DiamondCheck-p/215000.htm
GLIS-3000	Guangzhou Biaoqi Optoelectronics Technology Development Co. Ltd (China)	www.gzbiaoqi.com/ProductShowen.asp?ArticleID=66
J•Detect 9000	DRC Techno (India)	https://drctechno.com/products/gemological/j-detect-9000
J•Mini	DRC Techno (India)	https://drctechno.com/products/gemological/j-mini
J-Screen (formerly EXA by Magilabs)	HRD Antwerp (Belgium)	https://hrdantwerp.com/en/equipment/detail/j-screen
J•Smart Pro	DRC Techno (India)	https://drctechno.com/products/gemological/j-smart-pro
Jewellery Inspector	Gemetrix Pty Ltd (Australia)	www.gemetrix.com.au/JewelleryInspector.html
Melee Inspector	Gemetrix Pty Ltd (Australia)	www.gemetrix.com.au/melee.html
NDC-415 Natural Diamonds Chooser	Guangzhou Biaoqi Optoelectronics Technology Development Co. Ltd (China)	www.gzbiaoqi.com/ProductShow.asp?ArticleID=388
PL-3000	Guangzhou Biaoqi Optoelectronics Technology Development Co. Ltd (China)	www.gzbiaoqi.com/ProductShowen.asp?ArticleID=67
PL5000	National Gemstone Testing Center (China)	www.ngtc.com.cn/index.php?m=Article&a=show&id=487
PL-Inspector	Gemetrix Pty Ltd (Australia)	www.gemetrix.com.au/PLinspector.html
Q-Chk++	Gemological Institute of India and Arotek Scientific Instruments (India)	https://giionline.com/q-chk-adc
Screen-I	SmartPro (Thailand)	www.smartproinstrument.com/event-2/screen-1
SSEF Diamond Spotter	Swiss Gemmological Institute SSEF (Switzerland)	www.ssef.ch/instruments-books
Vista	Gemlogis	www.gemlogisusa.com/gemlogis-vista.html

[a] To the authors' knowledge, this list was current as of 1 July 2019, and is subject to change as instruments are updated, newly released and/or discontinued.
[b] Leo has been discontinued. The tested device was acquired on the open market, so Gemlogis is not an Assure Partner.
[c] Succeeded by M-Screen 4.0.
[d] Succeeded by Sherlock Holmes 2.0.
[e] According to HRD Antwerp, the D-Screen was still available at press time, although it is no longer being produced and is not shown on their website.

Figure 3: As of July 2019, the Assure Program had tested 16 diamond verification instruments. From left to right, these are: (top row) AMS2, ASDI, DiamondDect 3 and DiamondDect 5; (second row) DiamondSure, DiamondView, G-Certain and GemPen; (third row) GIA iD100, GV5000, J-Certain and Leo; (bottom row) M-Screen+, Sherlock Holmes, SYNTHdetect and Synthetic Diamond Screener II. These photos were supplied to the Assure Program by the instrument manufacturers.

testing, the instruments were returned to the submitting manufacturers.

The Assure Tested Certification Mark (Figure 4) is made available only to Assure Partners, that is, manufacturers that have agreed to submit their instruments for testing by the Assure Program. The certification mark simply indicates that a particular DVI has been tested by the Assure Program, and does not indicate any performance criteria or results. Therefore it is important to look beyond the certification mark and evaluate the actual test results.

Figure 4: The Assure Tested certification mark may be used only by DVI manufacturers that submit their instruments for testing in the Assure Program.

Table II: Specifications of the Assure-tested instruments.[a]

Instrument	Portability	Dimensions (W × D × H, in cm)	Weight (kg)	Operation category[b]	Detects or refers synthetics	Sample size range (ct)	'Smalls Sample' tested
AMS2	Desktop	31.5 × 40 × 55	25	3	Detects	0.0033–0.20	Yes
ASDI	Floor	170 × 90 × 160	350	2	Refers	0.002–0.20	Yes
DiamondDect 3	Portable	22 × 20 × 12	3	1	Detects	0.005–10	Yes
DiamondDect 5	Desktop	20 × 23 × 29	7	1	Refers	0.005–10	Yes
DiamondSure	Portable	17 × 26 × 10	3.5	1	Refers	0.005–10	No
DiamondView	Desktop	20 × 40 × 25	13	1	Detects	0.01–10	No
G-Certain	Desktop	30 × 30 × 37	12	1	Detects	0.001–10	Yes
GemPen	Portable	24 × 3.6 × 3.2	1	1	Detects	Any	Yes
GIA iD100	Portable	16.5 × 20 × 8	1	2	Refers	0.005+	Yes
GV5000	Desktop	50 × 25 × 61	17	3	Detects	0.002–20	Yes
J-Certain	Desktop	43 × 34 × 52	22	1	Detects	0.002–10	Yes
Leo[f]	Portable	20.3 × 14 × 11.4	0.73	3	Refers	0.01–12	No
M-Screen+	Desktop	45 × 30 × 55	45	2	Refers	0.005–0.20	Yes
Sherlock Holmes	Portable	15 × 24 × 15	2.2	1	Detects	Any	Yes
SYNTHdetect	Desktop	31 × 34 × 45.8	30	2	Refers	0.001–100	Yes
Synthetic Diamond Screener II	Portable	13 × 10 × 6.5	0.2	1	Refers	0.02–10	No

Instrument	Colour range	Shapes allowed	Single or multiple samples[c]	Mounted jewellery	Auto-feed and dispense	Operator skill level[d]	Cost (USD, Feb. 2019)
AMS2	D–J	All	Multiple	No	Automatic	Novice	45,000
ASDI	D–J	Round	Multiple	No	Automatic	Novice	Not listed
DiamondDect 3	D–J	All	Single	Yes	Manual	Novice	5,730
DiamondDect 5	D–J	All	Multiple	Yes	Manual	Novice	5,730
DiamondSure	D–J	All	Single	Yes	Manual	Novice	18,200
DiamondView	All	All	Single	Yes	Manual	Expert	35,000
G-Certain	D–Z	All	Multiple	Yes	Manual	Novice	9,999
GemPen	D–Z[e]	All	Multiple	Yes	Manual	Expert	2,300
GIA iD100	D–J	All	Single	Yes	Manual	Novice	4,995
GV5000	D–N	All	Multiple	Yes	Manual	Expert	43,200
J-Certain	D–Z	All	Multiple	Yes	Manual	Novice	13,999
Leo[f]	D-M	All	Single	Yes[g]	Manual	Novice	499
M-Screen+	D–J	Round	Multiple	No	Automatic	Novice	63,000
Sherlock Holmes	D–K	All	Multiple	Yes	Manual	Expert	6,495
SYNTHdetect	D–J	All	Multiple	Yes	Manual	Expert	17,000
Synthetic Diamond Screener II	D–J	All	Single	Yes[g]	Manual	Novice	599

[a] Sample size range, colour range and shapes allowed are as reported by the manufacturer.
[b] Operation category is illustrated in Figure 5.
[c] Single = tests one sample at a time; multiple = tests more than one sample at a time.
[d] Interpretation of results: novice = instrument automatically displays results (or auto-sorts the samples, as for AMS2, ASDI and M-Screen+); expert = user interprets luminescence (and growth structure when using DiamondView) to obtain results.
[e] Not designed for Fancy yellows.
[f] Device dimensions and weight obtained from Gemlogis website.
[g] Only handles open-back settings.

INSTRUMENT CATEGORIES

Thirteen of the 16 instruments are *screeners*, for which the results indicate either a natural diamond or that a sample should be 'referred' for further testing. The latter samples could consist of natural diamonds (typically type IIa), synthetic diamonds (HPHT- or CVD-grown) or simulants (e.g. cubic zirconia, synthetic moissanite, etc.). High referral rates generate extra work and expense, either in house or by sending samples to a laboratory to obtain conclusive results.

Three of the 16 instruments are *testers*, which give a conclusion as to the identity of a stone. Testers are designed to identify samples as either natural diamonds, synthetic diamonds (CVD or HPHT) or simulants. However, such instruments sometimes may 'refer' more challenging samples.

DVIs are grouped by the Assure Program into three categories based on their claimed capabilities to identify simulants and differentiate synthetics from simulants (Figure 5).

Category 1

Manufacturers of Category 1 devices state that they can correctly separate natural from synthetic diamonds in most cases. However, they cannot identify diamond simulants. They also cannot identify the specific type of synthetic diamond (HPHT or CVD). Therefore, users of Category 1 DVIs must pre-screen all samples to ensure that no simulants are present. If knowledge of the type of synthetic diamond is required, such samples will need further testing. Category 1 includes the majority (nine of 16) of the DVIs tested so far.

Category 2

Manufacturers of Category 2 instruments state that they can correctly separate natural from synthetic diamonds and simulants. Unlike Category 1, the Category 2 DVIs can recognise that synthetic diamonds and simulants are 'non-natural diamonds' and group them together under that description. They cannot tell the difference between a synthetic diamond and a simulant, just that it is not a natural diamond. Thus, samples identified by Category 2 DVIs as 'non-natural diamond' need further testing to determine whether they are synthetic diamonds or simulants. Category 2 includes four of the 16 DVIs tested so far.

Category 3

Manufacturers of Category 3 devices state that they can correctly identify and separate natural and synthetic diamonds and simulants. However, samples identified

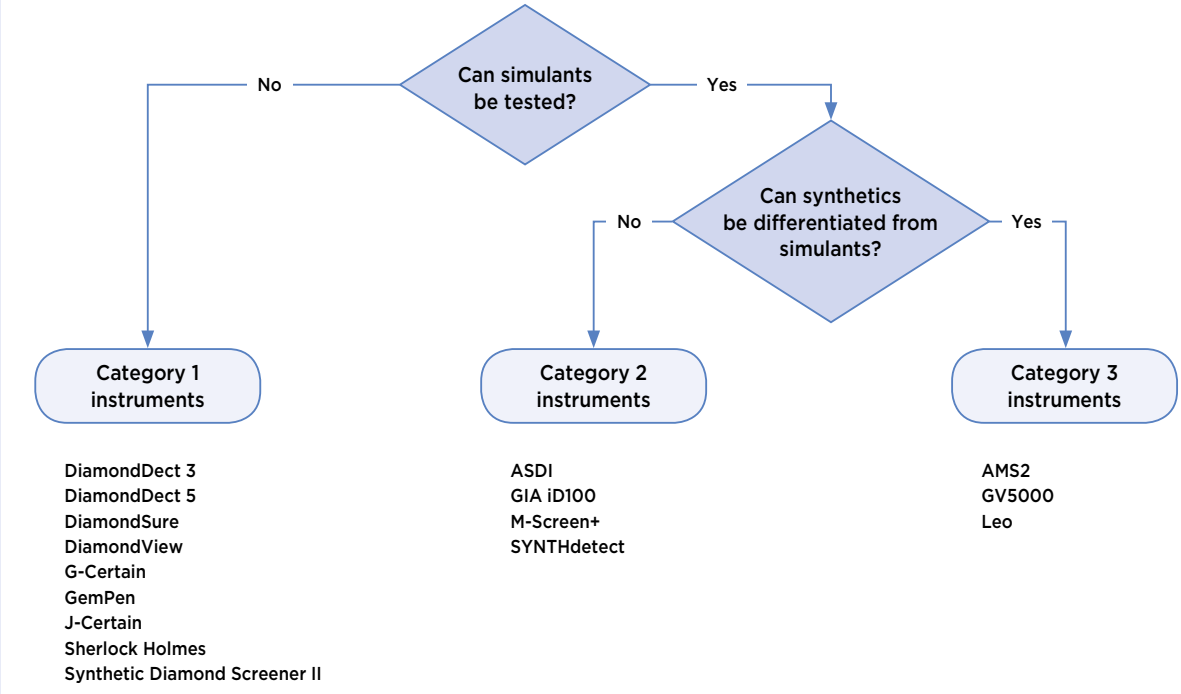

Figure 5: This flowchart shows the process for determining a DVI's operational category. The instruments listed were Assure tested as of July 2019. Courtesy of DPA.

as other than natural diamond probably will need further testing to determine the specific type of synthetic diamond or simulant. Category 3 is the most robust testing category and includes only three of the 16 DVIs tested so far.

TESTING STANDARD

The methodology by which instruments are tested by the Assure Program is called the DVI Standard, which is used to evaluate device performance in testing/screening for synthetic diamonds and/or diamond simulants. The DVI Standard was developed and applied in collaboration with UL, a well-known global standards testing company headquartered in the USA. According to the company website (www.ul.com/media-center/company-information), since 1894 UL has helped to set more than 1,600 standards defining safety, security, quality and sustainability, and the company operates in more than 143 countries and across more than 20 industries. The DVI testing was done at a UL laboratory in Canton, Massachusetts, USA, in a controlled environment with the goal of giving accurate and quantifiable testing information on the instruments.

Development of the DVI Standard was supported by the manufacturers, who collaboratively shared basic information about how their instruments operate. Efforts by the authors to obtain information from DVI manufacturers pertaining to their instruments' technology were met with limited success (see Table III), which is expected considering the desire to avoid disclosing proprietary information and perhaps also the status of pending patent applications. In any case, such technical details are beyond the scope of the present article.

The first draft of the DVI Standard was developed in early 2018 and subjected to an initial testing phase using three different instruments to ensure practical applicability. Throughout the development of the DVI Standard, expertise was provided by a technical committee of leading scientists, academics and gemmological laboratory personnel from around the world. Contributors included De Beers Group Industry Services (UK), the Federal State Budgetary Institution of the Technological Institute for Superhard and Novel Carbon Materials (Russia), Gemmological Institute of India, Gemological Institute of America, National Gemstone Testing Center (China), Scientific and Technical Research Center for Diamond (Wetenschappelijk en Technisch OnderzoeksCentrum voor Diamant or WTOCD; Belgium) and Swiss Gemmological Institute SSEF (Switzerland). All DVIs were tested using the same sample set(s) and conditions (see below) to ensure the performance results are comparable.

Table III: Instrument technology for Assure-tested DVIs, as provided by the manufacturers.

Instrument	Technology
AMS2	Time-resolved photoluminescence using short-wave UV radiation to view fluorescence and short- and long-lived phosphorescence; also takes an additional photoluminescence measurement
ASDI	Raman spectroscopy and short-wave UV transparency
DiamondDect 3	(Manufacturer did not respond)
DiamondDect 5	(Manufacturer did not respond)
DiamondSure	Visible-range absorption spectroscopy
DiamondView	Luminescence imaging of fluorescence or long-lived phosphorescence using ultra-short-wave UV radiation
G-Certain	(Manufacturer did not respond)
GemPen	'Ultra Spectrum Optical Filtering' technology that uses unique combinations of UV wavelengths and filtering to provoke variable fluorescence and phosphorescence
GIA iD100	Fluorescence spectroscopy
GV5000	(Manufacturer did not respond)
J-Certain	(Manufacturer did not respond)
Leo	(Manufacturer did not respond)
M-Screen+	(Manufacturer did not respond)
Sherlock Holmes	(Manufacturer would not disclose)
SYNTHdetect	Time-resolved photoluminescence using short-wave UV radiation to view fluorescence and short- and long-lived phosphorescence
Synthetic Diamond Screener II	Short-wave UV transparency vs. short-wave UV opacity

DPA has made the DVI Standard available exclusively to Assure Partners to create an incentive for them to submit their instruments for testing. It gives manufacturers an opportunity to do in-house testing for internal research-and-development purposes in accordance with the Standard, even in the absence of using the Assure Program's sample sets.

Testing Environment

The DVI Standard specifies particular conditions for lighting, room temperature and humidity, and no manufacturer asked to have their instrument tested outside of those parameters. Other conditions, such as the ideal power supply (i.e. operating voltage and amperage requirements), were set in accordance with the device operating manuals. These factors are important to consider because an instrument's test environment was not necessarily designed to replicate the ordinary commercial setting in which DVIs might be used. Therefore, the Assure Program specifies that the 'test results are not necessarily an indicator of how effectively the instrument would perform in normal commercial operating conditions' (Diamond Producers Association 2019). For commercial settings, DVI users should read the operating manual to learn important information about achieving optimal performance and understanding the limitations of the screening/testing instrumentation.

Sample Sets

Two main sample sets were developed by the Assure Program. The Core Sample was used for testing every instrument, while the Smalls Sample was utilised only for those instruments that could handle melee-sized stones (i.e. ≤2.0 mm diameter; see Table II). The Core Sample (e.g. Figure 6) included 1,000 natural diamonds, 200 synthetic diamonds and, when applicable, 200 diamond simulants. The Smalls Sample had a similar composition and number of specimens as the Core Sample. The very high proportion of synthetic diamonds (20%), as compared to what might be encountered in the marketplace (~2%), enabled the instruments to be tested on a broad range of synthetic diamond material. The Core Sample also included challenging custom-made synthetic diamonds that are not currently commercially available, as they are too difficult to produce and/or prohibitively costly for commercial purposes. The Assure Program used these outliers for two reasons: (1) to 'future-proof' the sample set (in anticipation of the next generations of synthetics) and (2) to help UL differentiate effectively and fairly among the instruments. Consequently, an instrument's performance in a commercial setting is likely to be better than under the test conditions (but only if the manufacturer's optimum operating conditions are adhered to).

Some further details of the sample sets are as follows:

- Core Sample: round brilliant cuts with >2.0 mm girdle diameter (~0.03–0.20 ct), D–J colour (with hints of either yellow or brown), and SI_2 or better clarity.
- Smalls Sample: round brilliant cuts with 1.0–2.0 mm girdle diameter (~0.005–0.03 ct), D–J colour (with hints of either yellow or brown), and SI_2 or better clarity. (Note that five DVIs are claimed to be able to test diamonds below 1.0 mm in diameter—AMS2, ASDI, GV5000, J-Certain and Sherlock Holmes—but the Smalls Sample did not test this range.)

Figure 6: These photos show some of the natural diamonds (left) and simulants (colourless sapphires; right) in the Assure Core Sample. Photos courtesy of DPA.

- The natural diamonds in both sets have a consistent distribution of type Ia/IIa stones.
- The synthetic diamonds include both HPHT- and CVD-grown samples, and some of them were treated (e.g. irradiated or HPHT processed after CVD growth to improve their colour).
- The simulants include cubic zirconia, synthetic moissanite, foil-backed glass and colourless synthetic corundum.

Additional sample sets were developed specifically to include lower colour grades (K–Z) and mounted jewellery (see Table IV). These sets were only used for testing those instruments described by manufacturers as having the capability to handle such samples. The results of this additional testing are included for applicable DVIs in the Assure Directory, but they are not evaluated in this article.

TEST RESULTS

Table V summarises the performance testing results for the Core and Smalls sample sets according to three parameters (listed in order of importance, as determined by the authors): false positive rate, accuracy and referral rate. The results for each of these performance metrics are expressed as percentages, and are reported separately for natural diamonds, synthetic diamonds and simulants (if applicable). The percentages may be calculated differently depending on the DVI category (1, 2 or 3), and examples illustrating the calculations for each of these cases can be downloaded from the Assure Project website at https://diamondproducers.com/app/uploads/2019/05/5.1.-ASSURE-Performance-Metrics-Infographic-20190523.pdf.

Diamond false positive rate is the most important—and most complicated—of the three performance metrics, and refers to the percentage of synthetic diamonds (and diamond simulants, if applicable) erroneously classified as natural diamond out of the total number of synthetic diamonds (and simulants) in the sample set. The optimal diamond false positive rate is 0%, meaning the instrument classified no synthetic diamonds or simulants as natural diamonds. By analogy, the *synthetic diamond false positive rate* refers to the percentage of natural diamonds (and simulants, if applicable) erroneously classified as 'synthetic diamond' out of the total number of natural diamonds (and diamond simulants, if applicable) in the sample set. The *simulant false positive rate* refers to the percentage of natural and synthetic diamonds erroneously classified as simulants out of the total number of natural and synthetic diamonds in the sample set.

Diamond accuracy is the percentage of natural diamonds that are correctly categorised as natural out of the total number of natural diamonds. The optimal diamond accuracy is 100%, in which all natural diamonds are correctly classified as natural. *Synthetic diamond accuracy* and *simulant accuracy* are defined as the fraction of test samples correctly classified by the DVI as synthetic diamonds and simulants, respectively.

Diamond referral rate is the percentage of natural diamonds that are referred for further testing out of the total number of natural diamonds in the sample set. Referred samples are unable to be classified by the DVI as natural or synthetic (and, where capable, synthetic or simulant), and require further testing to determine their identity. The lower the referral rate, the better. *Synthetic diamond referral rate* and *simulant referral rate* are the fractions of synthetic diamonds and simulants, respectively, which are referred by the DVI for further testing.

Novice or Expert Operator

The results in Table V are based on the 'Operator skill level' given in Table II, which indicates whether a novice or expert performed the testing of a particular DVI. A novice operator received an introductory level of training, which may have included reading the device's operating manual, watching video tutorials and receiving

Table IV: Additional sample sets developed by the Assure Program.

Sample set	Description
Sample B	>2.0 mm girdle diameter, K–Z colour, round brilliant cuts, mixed clarity
Sample D	1.0–2.0 mm girdle diameter, K–Z colour, round brilliant cuts, mixed clarity
Simple Jewellery	Open-back jewellery set with D–J colour, round brilliant cuts, mixed clarity
Intricate Jewellery	Closed-back jewellery set with D–J colour, round brilliant cuts, mixed clarity
Melee Jewellery	Open-back jewellery set with D–J colour, round brilliant cuts, mixed clarity

Table V: Summary of Assure Program test results for 16 diamond verification instruments.[a]

Instrument	Operation category	Core Sample test results (>2.0 mm)								
		Diamond			Synthetic diamond			Simulant		
		False positive rate	Accuracy	Referral rate	False positive rate	Accuracy	Referral rate[b]	False positive rate	Accuracy	Referral rate[b]
AMS2	3	0%	99.1%	0.7%	0.1%	70.9%	29.1%	0.1%	99.0%	1.0%
ASDI	2	0%	93.6%	6.4%	0%		100%	0%		100%
DiamondDect 3	1	0%	96.4%	0.6%	3.0%	99.5%	0.5%			
DiamondDect 5[c]	1	22.6%	91.6%	8.4%	0%		77.4%			
DiamondSure	1	0%	95.3%	4.7%	0%		100%			
DiamondView	1	0%	100%	0%	0%	100%	0%			
G-Certain	1	17.6%	99.7%	0.2%	0.1%	69.3%	13.1%			
GemPen	1	15.1%	98.7%		1.3%	84.9%				
GIA iD100	2	0%	96.7%	3.3%	0%		100%	0%		100%
GV5000	3	1.0%	98.5%		1.1%	97.5%		0.6%	98.0%	
J-Certain	1	19.6%	99.7%	0.2%	0.1%	67.3%	13.1%			
Leo	3	4.6%	51.6%	3.7%	0%		52.3%	45.2%	91.3%	0%
M-Screen+	2	0%	95.9%	4.1%	0%		100%	0%		100%
Sherlock Holmes	1	0%	97.5%		2.5%	100%				
SYNTHdetect	2	0%	99.3%	0.7%	0%		100%	0%		100%
Synthetic Diamond Screener II	1	0%	84.5%	15.5%	0%		100%			

[a] Includes results released as of 1 July 2019. Shaded areas indicate 'not applicable' (i.e. beyond the device's testing capability or the way it classifies samples; see the detailed test summary report PDFs in the Assure Directory).

in-person basic training as indicated by the manufacturer. The results obtained by a novice operator are to be expected for someone who has recently purchased and just begun using the device. Conversely, an expert operator is a representative from the DVI manufacturer or a UL technician trained by the manufacturer so that they are deemed an expert at operating the instrument. The results obtained by an expert operator are expected to be consistent with someone who is very familiar with using a specific instrument.

Instruments tested by an expert operator are also tested by a novice user for comparison, and the results for both types of operators can be found in the detailed reports available in the Assure Directory. As expected, better results overall were obtained for these DVIs when operated by an expert rather than a novice (e.g. Table VI).

SELECTING A DVI

To select the most appropriate DVI, users should first assess their needs to help match their business requirements to the capabilities of the instruments (e.g. Table VII). For example, is speed important? Are simulants to be pre-screened? Will the testing be limited to loose diamonds? If so, as principal centre stones or as batches of melee? In what colour range? Will finished jewellery be tested? If an expert operator is required, is one currently on staff? Is automation needed for volume processing, or is manual operation sufficient? Does the instrument need to be portable? And, of course, instrument cost is another important criterion.

Screening (eliminating any non-natural diamonds) is distinctly different from detection (positive identification of a synthetic diamond or a simulant). Therefore, it may be helpful to start with identifying an appropriate DVI category (again, see Figure 5). If it is necessary to simply separate synthetics from natural diamonds, then a DVI of at least Category 1 is sufficient, and the user can consider

Table VI: Example of test results for novice and expert operators of the same instrument (here, SYNTHdetect).

Parameter	Novice	Expert
Diamond false positive rate	0%	0%
Diamond accuracy	98.6%	99.3%
Diamond referral rate	1.4%	0.7%
Speed (stones/hour)	225	583

Table V: (continued)

Smalls Sample test results (1.0–2.0 mm)									Average speed (samples tested/ hour)	Instrument
Diamond			Synthetic diamond			Simulant				
False positive rate	Accuracy	Referral rate	False positive rate	Accuracy	Referral rate[b]	False positive rate	Accuracy	Referral rate[b]		
0%	98.9%	0.7%	0.1%	87.4%	12.6%	0.3%	99.5%	0.5%	2,677	AMS2
0%	93.2%	6.8%	0%		100%	0%		100%	6,511	ASDI
1.0%	90.6%	4.0%	5.5%	99.0%	0%				289	DiamondDect 3
9.4%	97.8%	2.2%	0%		90.6%				557	DiamondDect 5[c]
									193	DiamondSure
									112	DiamondView
4.7%	99.3%	0.6%	0.1%	95.3%	0%				908	G-Certain
4.7%	99.5%		0.5%	95.3%					813	GemPen
0%	95.8%	4.2%	0%		100%	0%		100%	440	GIA iD100
0.3%	97.5%		1.4%	95.3%		1.4%	100%		296	GV5000
5.8%	99.3%	0.3%	0.4%	93.7%	0.5%				792	J-Certain
									219	Leo
0%	90.9%	9.1%	0%		100%	0%		100%	12,317	M-Screen+
0%	97.8%		2.2%	100%					530	Sherlock Holmes
0%	98.1%	1.9%	0%		100%				583	SYNTHdetect
									240	Synthetic Diamond Screener II

[b] Referral rates for synthetic diamonds and simulants vary widely depending on the way each DVI categorises these sample types.
[c] Although the DiamondDect 5 can only handle HPHT-grown synthetics, the Assure sample sets contain both HPHT- and CVD-grown samples.

Table VII: Assure-tested DVIs listed according to various requirements.[a]

Requirement	Capable instruments
Identifies diamond simulants	AMS2, ASDI, GIA iD100, GV5000, Leo, M-Screen+, SYNTHdetect
Tests multiple stones at once	AMS2, ASDI, DiamondDect 5, G-Certain, GemPen, GV5000, J-Certain, M-Screen+, Sherlock Holmes, SYNTHdetect
Auto-feed and dispense	AMS2, ASDI, M-Screen+
Size <0.01 ct	AMS2, ASDI, DiamondDect 3, DiamondDect 5, DiamondSure, G-Certain, GemPen, GIA iD100, GV5000, J-Certain, M-Screen+, Sherlock Holmes, SYNTHdetect
Fancy shapes	AMS2, DiamondDect 3, DiamondDect 5, DiamondSure, DiamondView, G-Certain GemPen, GIA iD100, GV5000, J-Certain, Leo, Sherlock Holmes, SYNTHdetect, Synthetic Diamond Screener II
Mounted jewellery	DiamondDect 3, DiamondDect 5, DiamondSure, DiamondView, G-Certain, GemPen, GIA iD100, GV5000, J-Certain, Leo[b], Sherlock Holmes, SYNTHdetect, Synthetic Diamond Screener II[b]
Automatic interpretation of results	AMS2, ASDI, DiamondDect 3, DiamondDect 5, DiamondSure, G-Certain, GIA iD100, J-Certain, Leo, M-Screen+, Synthetic Diamond Screener II
Portable	DiamondDect 3, DiamondSure, GemPen, GIA iD100, Leo, Sherlock Holmes, Synthetic Diamond Screener II
Cost <USD10,000	DiamondDect 3, DiamondDect 5, G-Certain, GemPen, GIA iD100, Leo, Sherlock Holmes, Synthetic Diamond Screener II

[a] Instruments are listed in alphabetical order (see Table V for the performance results for each device). Leo has been discontinued, M-Screen+ has been succeeded by M-Screen 4.0 and Sherlock Holmes has been succeeded by Sherlock Holmes 2.0.
[b] Only handles open-back settings.

the full array of 16 DVIs (as of writing this article) in the Assure Program's test set. If simulant detection is required, then DVIs of at least Category 2 are appropriate, for which seven choices have been Assure tested. If Category 3 capabilities are needed—separating natural from synthetic diamonds, natural diamonds from simulants and synthetic diamonds from simulants—then currently there are three Assure-tested instruments with this capability.

Next, the authors suggest focusing on the most important performance metric in the test results: the diamond false positive rate (i.e. identifying a synthetic or simulant as a natural diamond). Ten of the 16 DVIs tested produced zero diamond false positive results for the Core Sample set (>2.0 mm diameter): AMS2, ASDI, DiamondDect 3, DiamondSure, DiamondView, GIA iD100, M-Screen+, Sherlock Holmes, SYNTHdetect and Synthetic Diamond Screener II. Furthermore, six of the 12 DVIs tested with the Smalls Sample set (1.0–2.0 mm) produced zero diamond false positive results: AMS2, ASDI, GIA iD100, M-Screen+, Sherlock Holmes and SYNTHdetect. In addition to diamond false positives, diamond accuracy and, finally, diamond referral rate should be considered. Across all three metrics, only one DVI scored perfectly in the Assure testing: the DiamondView at a cost of USD35,000 and requiring an expert operator.

Synthetic diamond dealers may also benefit from using a DVI, as they seek to protect their inventory from mixing with natural diamonds. For larger-sized samples (>2.0 mm) nine DVIs provided zero false positive results for synthetic diamonds (ASDI, DiamondDect 5, DiamondSure, DiamondView, GIA iD100, Leo, M-Screen+, SYNTHdetect and Synthetic Diamond Screener II). For smaller samples (1.0–2.0 mm), five DVIs had zero false positive results for synthetic diamonds (ASDI, DiamondDect 5, GIA iD100, M-Screen+ and SYNTHdetect).

When shopping for a DVI, the buyer should ask the seller 'What is the best use of this instrument?' Even more importantly, 'What are the limitations of this instrument?' In other words, what can't it do? An informed buying decision would also include questions relating to the skillset required to properly operate the instrument and any training that is offered, as well as warranty details and any service requirements/arrangements.

In the end, it is possible that more than one DVI may be required to meet one's business needs, since, for example, testing parcels of diamond melee and larger individual samples (or loose stones and jewellery) might not be practical with a single instrument.

CONCLUSIONS

Diamonds (e.g. Figure 7) are a critical component of the global gem and jewellery industry, and it is imperative to correctly separate natural stones from synthetics and simulants. Beyond statutory requirements, consumer confidence is the bedrock of the jewellery business worldwide. A single incidence of an undisclosed synthetic diamond sold as natural can cause reputational harm and even legal consequences for the seller. Furthermore, such instances may quickly reverberate across social media and potentially have far-reaching ramifications for the industry. While a false-positive result (identifying a synthetic diamond as a natural diamond) is perhaps the most egregious error, a false negative (calling a natural diamond a synthetic diamond) can also damage one's reputation.

To address such concerns, particularly for melee-sized goods, DVIs are now being sought by many segments of the jewellery supply chain (manufacturers, brokers, wholesalers and retailers). Until recently, however, there was no way to verify a DVI manufacturer's claims regarding the effectiveness of their device for screening or identifying natural and synthetic diamonds and simulants. The authors applaud the Assure Project for addressing this need, and we look forward to the release of future testing results for additional/updated DVIs as they are published in the Assure Directory.

The testing results released for the DVIs tested so far show an overall wide range of performance, and prove that not all devices are equally effective at identifying or

Figure 7: To maintain consumer confidence in diamonds, it is important to reliably separate natural, as-mined diamonds (such as the ~0.70 ct stones from Canada shown here) from synthetic diamonds or simulants. The use of one or more DVIs that have received high marks from the Assure Program can help with this endeavour. Photo courtesy of Dominion Diamonds.

screening synthetics and/or simulants. DVIs are evolving quickly, and some initially-released models have already been discontinued or replaced by second-generation units that have undergone technical and ergonomic improvements. The authors expect this 'upgrading' trend to continue as detection technology improves and stays current with advances in synthetic diamond growth technology. We therefore urge future device purchasers to check the Assure Directory for updates.

The diversity of DVI features and capabilities, combined with the testing results from the Assure Program, requires that several factors be considered when choosing an instrument. During the decision-making process, users should first determine their needs and requirements, and then consider the instrument categories and review the published Assure Program test results. In some cases, more than one DVI may be necessary to fulfil a company's business needs. Whatever instrument is used, it is critical for the operator to understand at least some of the fundamental operating science employed by it, as well as its limitations, to prevent lapsing into a 'black box' mentality of pressing a button and always expecting a correct answer. The topic is not that simple and never will be.

The synthetic diamond industry is developing rapidly and DVI manufacturers are following, not leading, the technology. As growth techniques evolve, DVIs will have to keep pace. Products such as CVD-coated simulants and 'composite diamonds' (natural diamonds with CVD synthetic overgrowths) will further challenge some of the existing instruments.

REFERENCES

Ambalathveettil, A.N., Al Muhari, N. & Singbamroong, S. 2018. Gem News International: Single HPHT synthetic diamond mixed in natural diamond ring. *Gems & Gemology*, **54**(4), 456–457.

Bhoir, M., Dhawale, P. & D'Haenens-Johansson, U. 2017. Lab Notes: Melee diamond parcel containing nearly one-third CVD synthetics. *Gems & Gemology*, **53**(2), 236–237.

Bruton, E. 1978. *Diamonds*. Chilton Book Co., Radnor, Pennsylvania, USA, 532 pp.

Diamond Producers Association 2019. ASSURE Test Process. https://diamondproducers.com/assure/assure-test-process, accessed 20 July 2019.

Drucker, R.B. & Phillips, J.C. 2018. Diamond screeners/testers. *GemGuide*, **37**(5), 1–5.

Eaton-Magaña, S. & Shigley, J.E. 2016. Observations on CVD-grown synthetic diamonds: A review. *Gems & Gemology*, **52**(3), 222–245, http://doi.org/10.5741/gems.52.3.222.

Eaton-Magaña, S., Shigley, J.E. & Breeding, C.M. 2017. Observations on HPHT-grown synthetic diamonds: A review. *Gems & Gemology*, **53**(3), 262–284, http://doi.org/10.5741/gems.53.3.262.

Freedman, J. 2017. DPA, Signet, De Beers working on 'Project Assure'. Rapaport, www.diamonds.net/News/NewsItem.aspx?ArticleID=58776, 9 April, accessed 20 June 2019.

Freedman, J. 2019. What makes a good synthetics detector? Rapaport, www.diamonds.net/News/NewsItem.aspx?ArticleID=63460, 12 March, accessed 20 June 2019.

Poon, T., Lo, C. & Law, B. 2016. Lab Notes: Mixing of natural diamonds with HPHT synthetic melee. *Gems & Gemology*, **52**(4), 416–417.

Rapaport, M. 2013. Sinthetics. *Rapaport*, **36**(12), 36–41.

Shigley, J.E. 2017. The latest on synthetic diamonds. Gemological Institute of America, www.gia.edu/UK-EN/gia-news-research-latest-on-synthetic-diamonds-video-presentation, accessed 20 July 2019.

Shigley, J.E., Fritsch, E., Stockton, C.M., Koivula, J.I., Fryer, C.W. & Kane, R.E. 1986. The gemological properties of the Sumitomo gem-quality synthetic yellow diamonds. *Gems & Gemology*, **22**(4), 192–208, http://doi.org/10.5741/gems.22.4.192.

Welbourn, C.M., Cooper, M. & Spear, P.M. 1996. De Beers natural versus synthetic diamond verification instruments. *Gems & Gemology*, **32**(3), 156–169, https://doi.org/10.5741/gems.32.3.156.

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