

A continuous line for automatic diamond color grading evaluation CEO-IOTSAI-SDI

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WANG Yuelin

WANG Ziqi

ZHANG Chun

- 1) **Background and Prior Arts**
- 2) **Key embodiments of the invention**
- 3) **Major claims and differences with the prior arts**
- 4) **Inventorship detail per claim**
- 5) **Patent Portfolio**
- 6) **Business Value**
- 7) **Which country to file**

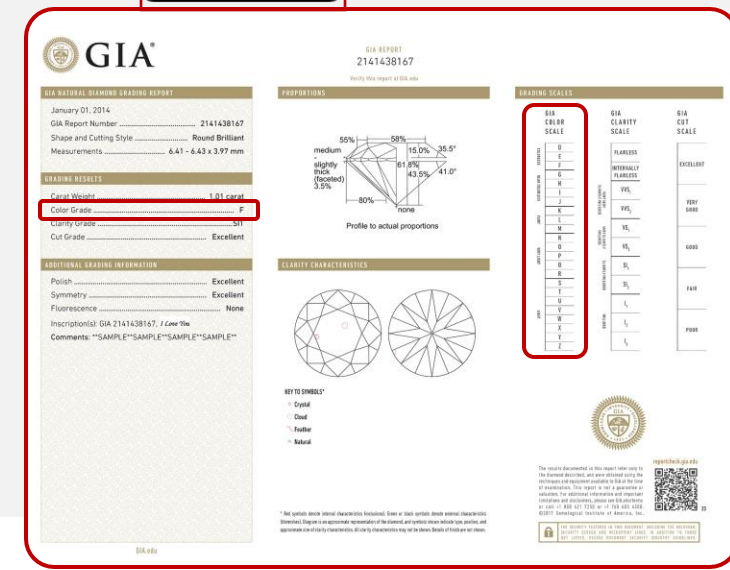
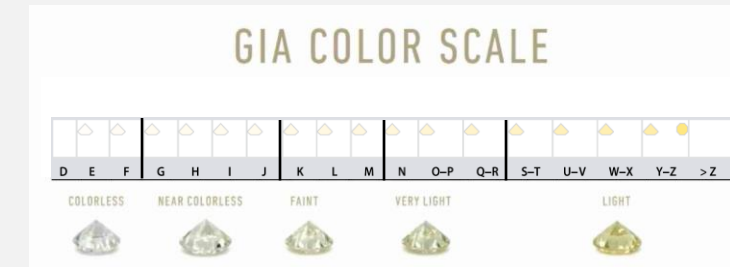
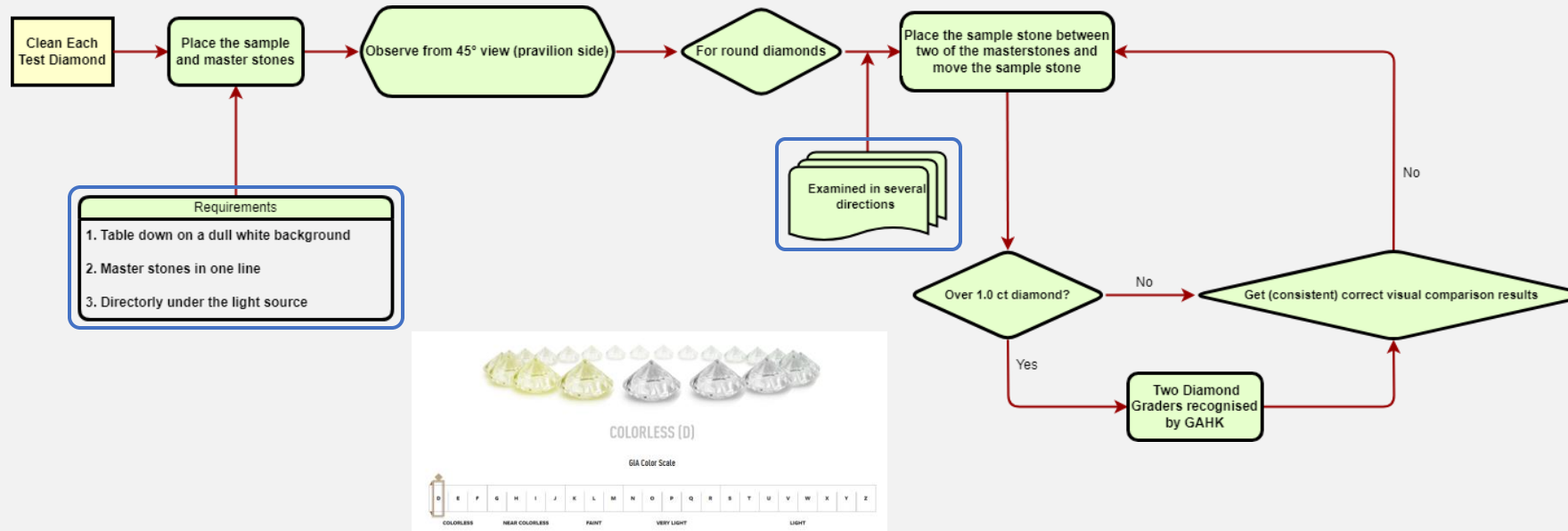
Remarks: for invention disclosure to be submitted to HQ Patent Committee, each aspect should not exceed 2 slides. For domain patent Committee review, you could have over 10 slides but please kindly follow the format such that only slight modification is needed when submitted to HQ

Background and Prior Arts (1/3)

Our Invention: A continuous line for automatic diamond color grading evaluation

❖ **Diamond Quality standard (4Cs): Color, Clarity, Cut and Carat weight.**

• **Manual** Color grading procedures in **Standard Methods for Testing Diamond for Hong Kong**



Since its introduction in the early 1950s, Gemological Institute of America (GIA)'s **D-to-Z** scale has been used to color grade the overwhelming majority of **colorless** to **light yellow** gem-quality polished diamonds on which laboratory reports have been issued. **D-to-Z** color grading is based on the observations of a **trained observer**, who compares a diamond to color **master stones** of known position on the grading scale. **GIA master stones** are located at the **highest point** in their respective grade range. A diamond equal to the G master is graded a G. If it has slightly less color, it would receive a grade of F.

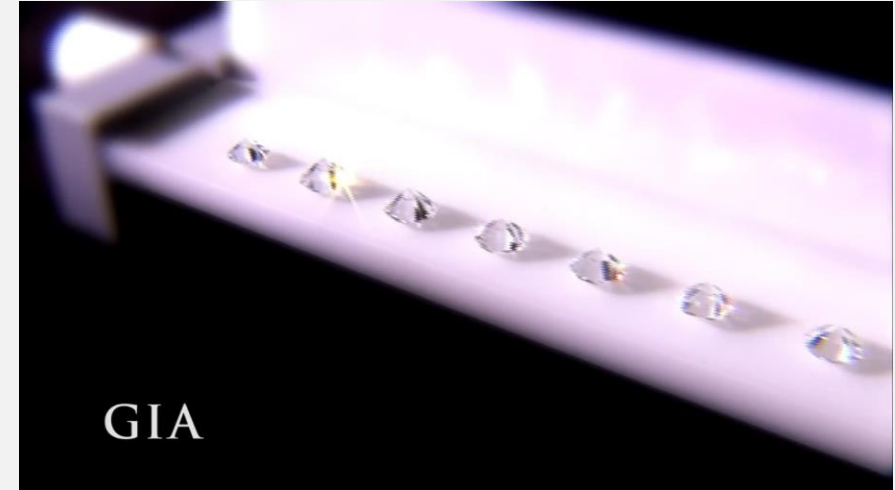


Background and Prior Arts (2/3)

- Trend from **manual** color grading in lab to **automatic** color grading on site

➤ **General requirements for round diamonds color grading in GIA:**

- I. Background: V-shaped **nonfluorescent white plastic** tray
- II. Light source: Color temperature(CT) in the **5500-6500K** range
- III. Viewing geometry: “0/45” (0° to the light source and 45° from the diamonds)
- IV. Reference: **Master stones set**
- V. View procedure: Sample stone examined **in several directions**



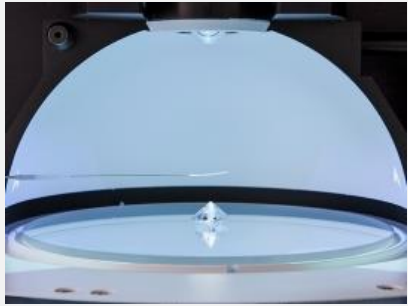
➤ **4 essential factors in automatic color grading system:**

1. Light source: Color temperature in the **5500-6500K**
2. Viewing angle: **45°** from the pavilion side
3. Imaging: capturing image at different angular and rotating the sample diamond **360°** in total
4. Evaluation: **CIE XYZ color space**



Background and Prior Arts (3/3)

- Pre-developments for **automatic** diamond color grading:



Sarine Color™ (2017)

Manual rotational platform, slow and need training, expensive.
Price: over 1M USD



VARNA-D (2019)

Accuracy: ± 1 Grade
Price: USD 5999

Essential factors	Sarine Color™	VARNA-D
Light source in 5500-6500K	√	√
45° viewing	√	×
Different angular position	√	×
Evaluation in CIE XYZ color space	√	√

Problems to be solved:

- ❖ Requirements from the manufacturer or jeweler:
 - Color grading accuracy: $\sim \pm 0.5$ grade
 - Perform **automatic process** of diamonds **sampling**.
- ❖ Even the pre-development of Sarine© achieved the mentioned **4 factors**, the grading results **cannot meet** the **accuracy** and the machine is not accepted by manufactures and jeweler.

Solutions to be included in this invention:

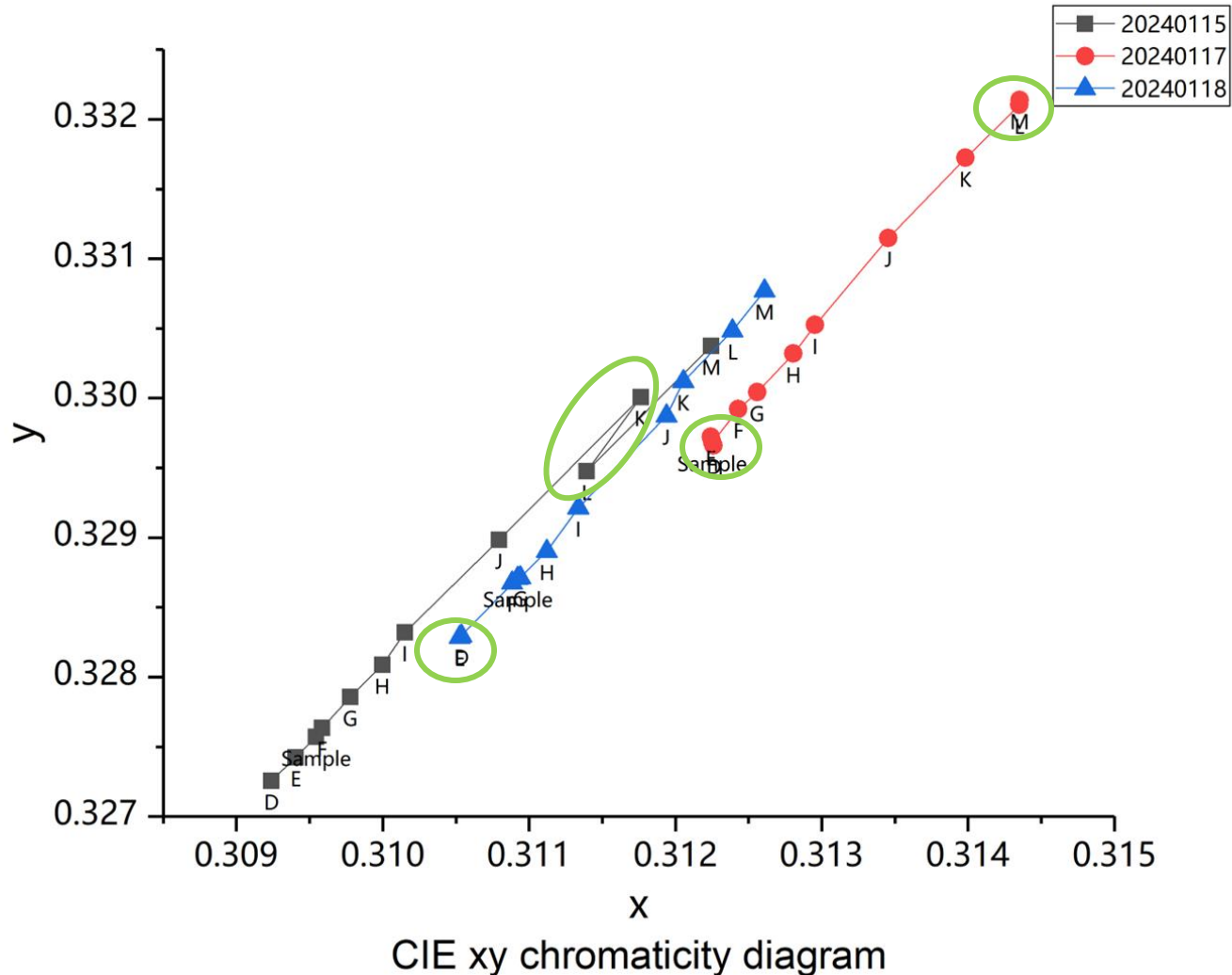
- Use **internal reference**:
 - Introduce a rotational platform, with the color images captured simultaneously with **sample diamond** and **master stones** placed rotationally symmetrically **under the same illuminate environment**.
- Achieve **automation**
 - **Automatic** sampling can be easily adapted by the rotational stage and conveyor system.

Key embodiments of the invention (1/4) – Problem statement

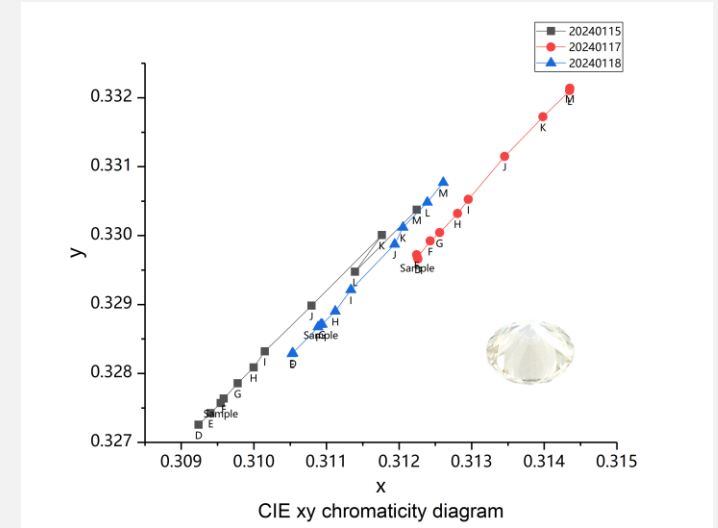
➤ Automated diamond color grading test on **pre-development prototype**

- Color grading procedure according to Sarine Color™:

Place the sample diamond in the



- Pre-determined database built by the procedures in **pre-development prototype**:



Results of master stones from D to M on different days

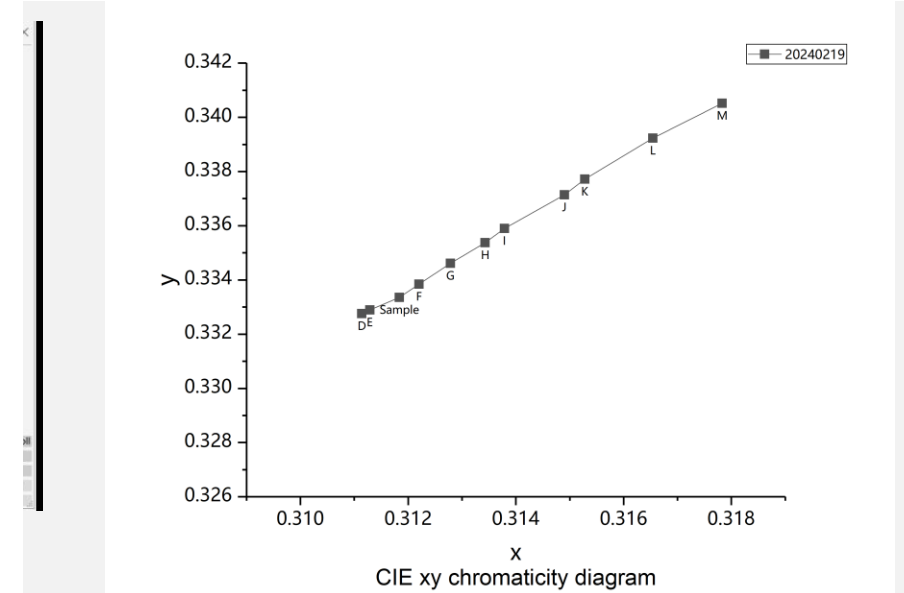
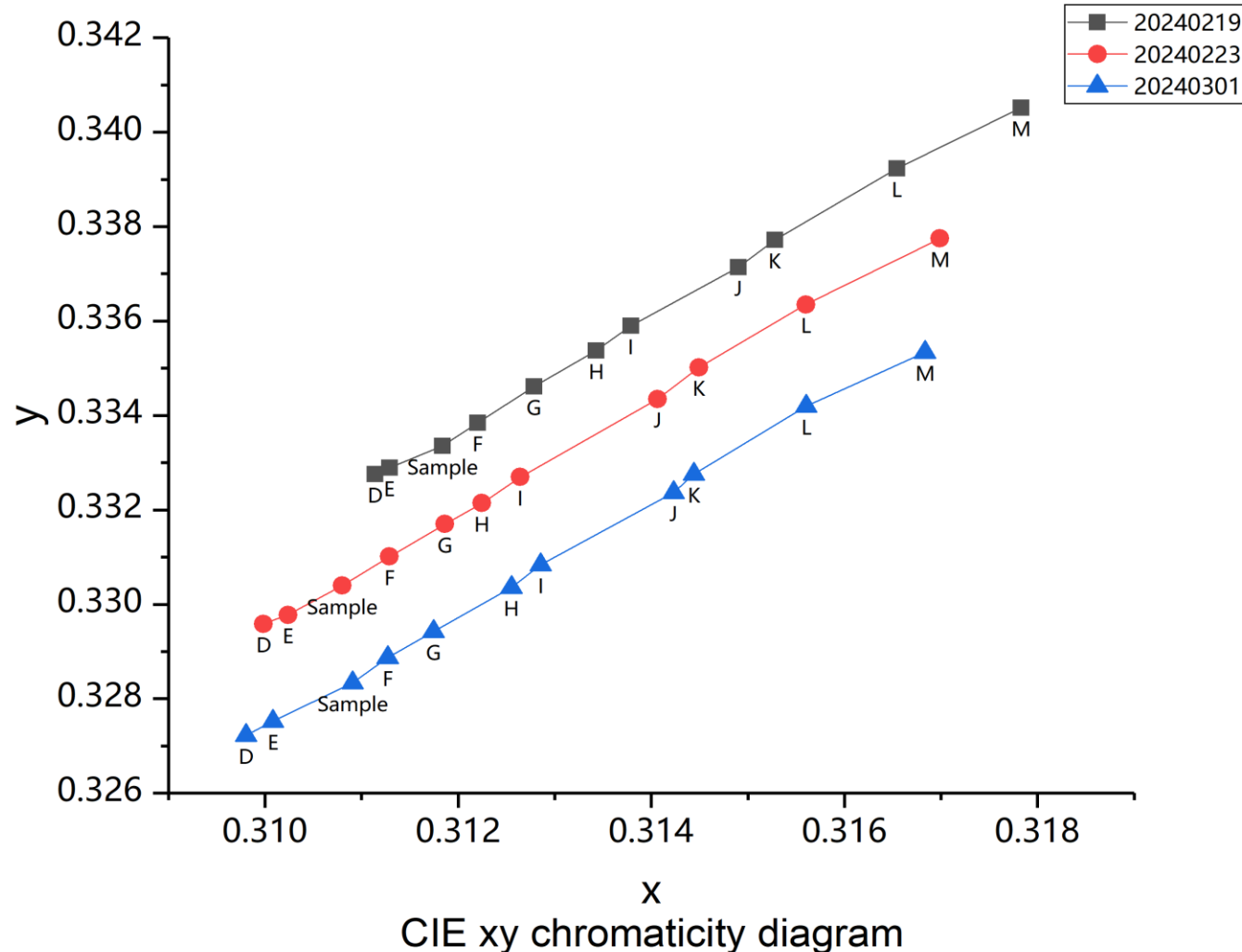
Problems in the results:

- Potential **errors** in the **relative sequence** of master stones within the range from D to M.
- Inability** to **replicate** the distance and slope between two adjacent grades in the entire baseline displayed by D to M master stones after each test.
- Significant **variance** in the range of values obtained from D to M master stone in different test.

Key embodiments of the invention (2/4) – Our solution

➤ Automated Diamond color grading test with Master Stones Set as an Internal Reference

- Color grading procedure in our invention: Using Master stone set for internal reference during sample testing



Results of sample diamond and master stones set on different days

Advantages in our invention:

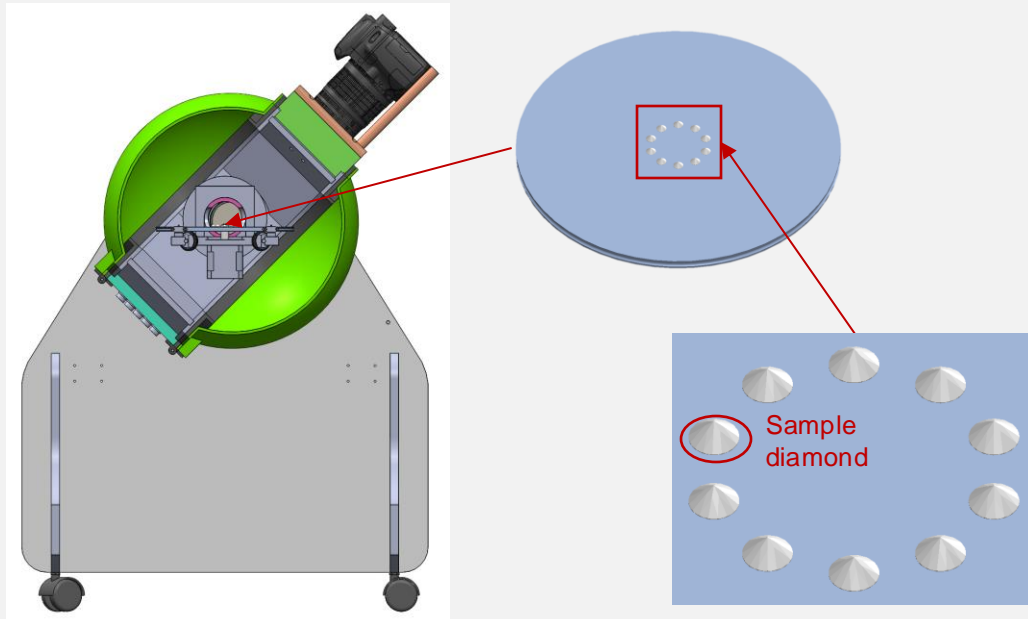
- It is not necessary to perform calibration before each test.
- The **relative sequence** of each master stone within the D to M range remains consistently **accurate**.
- After testing in different days, the distance and slope between two adjacent grades in the entire baseline by master stones from D to M is **replicable**.
- For sample testing, the results of sample diamond consistently shows the **accuracy under 0.5 grade** after each test.

Key embodiments of the invention (3/4) – Variation of different configuration

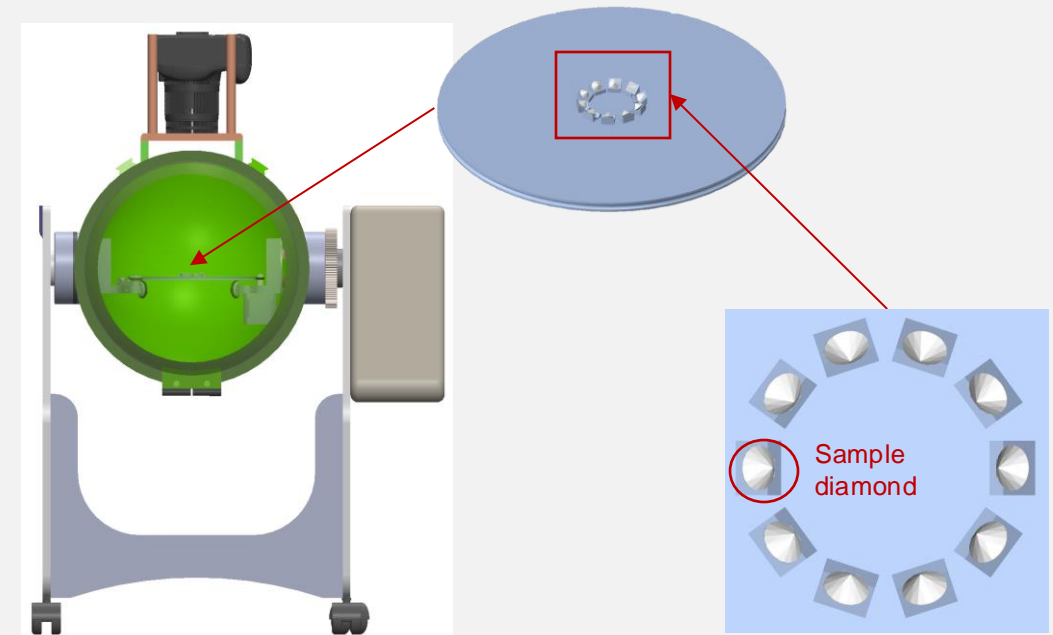
➤ An automatic system for diamond color grading evaluation

- Overall Arrangement: **unified placement plate**, step motor, broadband visible light LED, camera, control board, **conveyor system**, and **robotic arm**, and computational device are configured to make a continuous line detection system for high volume diamond color grading evaluation

◆ Sample plate for 45° viewing



◆ Sample plate for 90° viewing

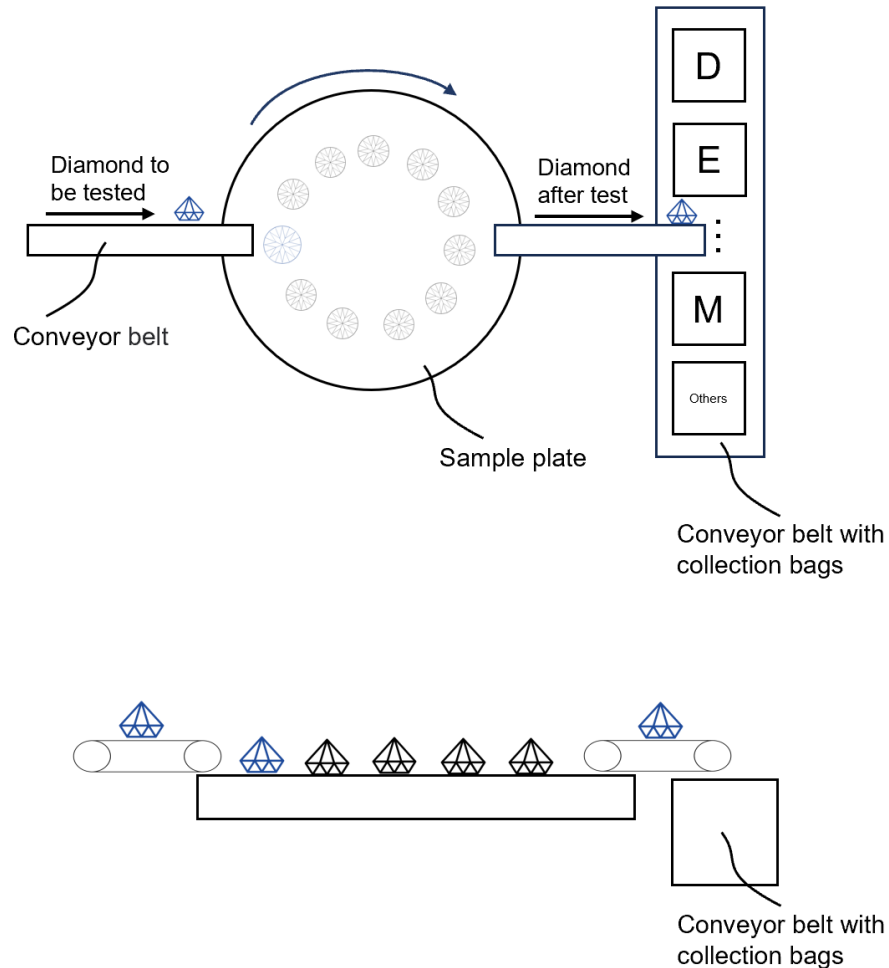


Key embodiments of the invention (4/4) – Variation of different configuration

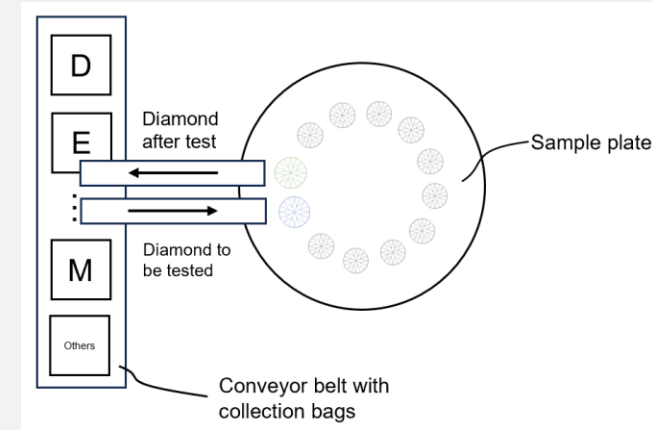
➤ A continuous line detection system for high volume diamond color grading evaluation

- Different configuration of diamond color grading on product line

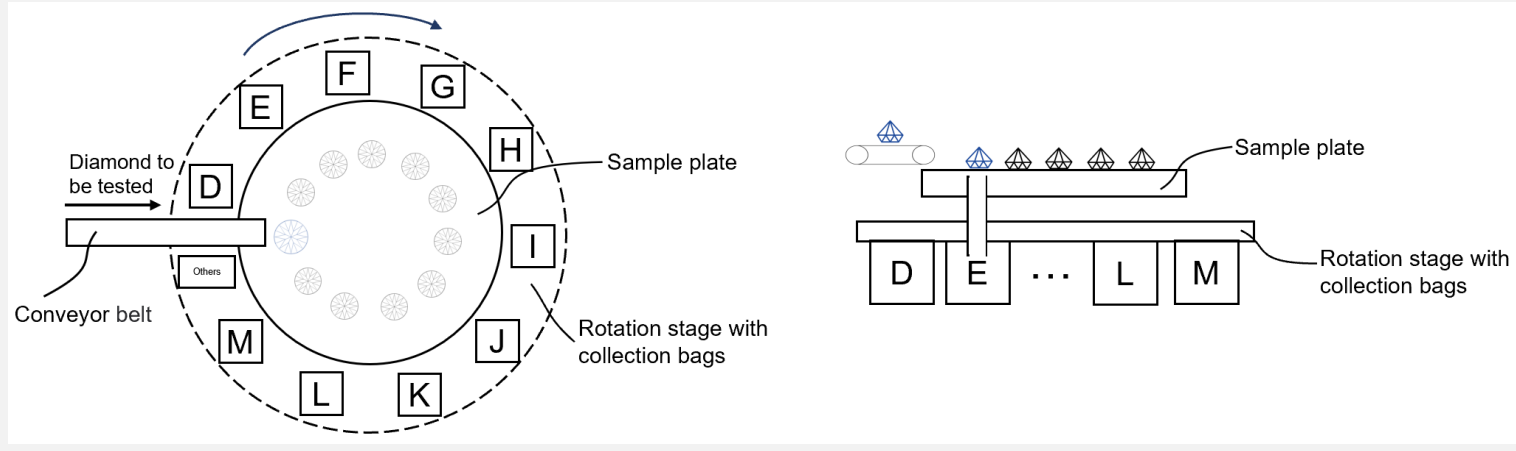
1.



2.



3.



Major claims and Inventorship detail per claim (1/2)

- Claim 1.** An automatic color grading system for more than one sample diamond comprising:
an enclosure, said enclosure containing a rotation system and an image capturing system, and a controller module.
the enclosure further comprising one or more sources of broadband visible light, the sources of broadband visible light being controllable by the controller module;
the enclosure further comprising one or more mounting structure and components including but not limited to fixtures for rotation system, image detector and controller;
a rotation system consisting of a plate, which is used for placing a set of master stones and one or more sample diamonds, and a set of drive mechanism;
the plate further would hold the sample diamonds next to the master stones instead of in the center of the plate;
the rotation system further would rotate n times which n stands for the total number of master stones and sample stone on the plate;
an image capturing system would capture n images of each stones when the stone rotated to the location of each fixture which the location is overlapped to the last one.
- Claim 2.** The image acquisition system of claim 1, wherein said the image detector is mounted on the fixture for viewing conditions under including but not limited to 0° , 45° , or 90° .
- Claim 3.** The image acquisition system of claim 1, wherein said the image detector captures a plurality of images of a set of master stones and a sample diamond.
- Claim 4.** The image acquisition system of claim 1, wherein said the image detector is set the parameter of white balance with the fixed value such as 6500K.
- Claim 5.** The encloser of claim 1, wherein controller module contains the electronic circuit boards.
- Claim 6.** The electronic circuit boards of claim 5 is connected to a computer, control the step motor, the image detector, and the broadband visible light.
- Claim 7.** A method for automatic diamond color grading comprising:
providing an enclosure, the enclosure including a plate for placing a set of master stones and a sample diamond on the plate and the plate being rotatable about a plate rotation axis by a rotation system;
the rotation system further can rotate $360/n$ degrees in each time and all diamonds will be captured the image at each same location after n times rotation;
the enclosure further comprising one or more sources of broadband visible light, the sources of broadband visible light being controllable by the controller module;
providing an image detector for capturing a plurality of images from one or more selected angle view;
providing an image processing device configured to process the plurality of images and to grade the sample diamonds using at least a part of the one or more images captured;
wherein the method further comprises: capturing by the image sensor, images of all mounted diamonds from one or more selected angles relative to the plate rotation axis;
- Claim 8.** The method of automatic diamond color grading of claim 7, further comprising the programmed image detector with fixed color temperature value in white balance setting.
- Claim 9.** The method of automatic diamond color grading of claim 7, further comprising the programmed rotation system wherein the plate can start rotation, rotate in the same angle for each time, and finish after 360° rotation.
- Claim 10.** The method of automatic diamond color grading of claim 7, further comprising the programmed image detector capturing an image after the plate rotated once.

Major claims and Inventorship detail per claim (1/2)

- Claim 11.** The method of automatic diamond color grading of claim 7, further comprising the program to control the broadband visible light.
- Claim 12.** The method of automatic diamond color grading of claim 7, wherein said all images are processed and calculate the average v values of CIE XYZ color space.
- Claim 13.** The method of image processing of claim 12, wherein all images are segmented into distinct regions and selected pixels with in said regions are used.
- Claim 14.** The method of automatic diamond color grading of claim 12, wherein said the x and y value in CIE XYZ color space are used for color grading evaluation.
- Claim 15.** The method of automatic diamond color grading of claim 14, wherein said the (x,y) values of all diamonds on the plate can be plotted in a linear curve and the point of sample diamond can be pointed between two adjacent points of master stones.
- Claim 16.** The method of automatic diamond color grading of claim 15, wherein the color of the sample stone is output as the lower level as the adjacent master stone.
- Claim 17. A method for continuously automatic diamond color grading comprising:**
replacing a sample diamond by an automated sampling system, capturing all images of the sample diamond after 360° rotation, processing and calculating the information in defined area and generating the report.
the procedure of replacing a sample further comprising feeding the sample on the sample plate, transporting the sample diamond and removing the sample diamond on the plate;
the automated sampling system further comprising a conveyor or a robotic arm and any other related accessories.

Claims	Contributor	Contribution	Contribution Percentage
Name of Inventor	WANG Yuelin	1-9, 15-17	50%
	WANG Ziqi	3, 10-16	30%
	ZHANG Chun	3, 6,7, 17	20%

Inventive steps:

- i) Use of **unified placement plate** with 10 tiny fixtures to hold the **master stone set** and a **sample diamond** to imitate color grading procedure in GIA's lab.
- ii) Use of **internal reference** to reduce the influence of **time, illumination**, and the **position** and **size** of the sample diamond.
- iii) Use of **conveyor system** and **robotic arms** to facilitate **sampling** of sample diamond.

Differences with the prior arts

Patent search

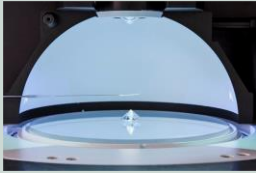


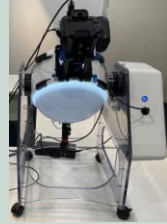
- 1) Search Engine : WIPS Global
- 2) Search strings (full text):
 String1 : (grading OR evaluating) AND (gemstone) AND (color OR color)
 String2 : (grading OR evaluating) AND (diamond) AND (color OR color)
 String3: (grading OR evaluating) AND (diamond) AND (color OR color) AND (master stone)
 Result : **121 + 360 +58 (43 + 219 + 45)** patent applications (families) were found.
- 3) **5 out of 539 patents were selected as the closest prior arts.**

Prior arts	US11892412B2 (2022)	US11435296B2 (2022)	CN109991230B (2022)	CN110132972B (2019)	CN106840404B (2017)	This invention																																												
Features of similar prior arts	Manually rotatable stage for mounting gemstones. Take single diamond in each test.	Modulate the light as input. Provide output indicative of the transmittance spectrum . Compared the spectrum to the fixed reference values .	Using integrating spheres to control lighting conditions. Output based on correlation thresholds of predetermined criteria . Acquiring optical images of the diamond table and the pavilion.	Daylight-approximating light source. Creating a virtual mask of color image. Comparing color scores to predetermined values of reference gemstones.	Placing the diamond sample in a fixed V-shaped groove . Color coordinates x, y of the under-tested sample is measured.	Master stones set with sample diamond , without using predetermined calibration datasets. Automatically high-volume test , including the infeed/outfeed, rotation of platform and color image capture.																																												
Algorithm					<table border="1"> <thead> <tr> <th></th> <th>x</th> <th>y</th> <th>指数</th> </tr> </thead> <tbody> <tr> <td>(D, E)</td> <td>0.0023</td> <td>0.0032</td> <td>0.00395</td> </tr> <tr> <td>(E, F)</td> <td>0.0021</td> <td>0.0032</td> <td>0.00377</td> </tr> <tr> <td>(F, G)</td> <td>0.0021</td> <td>0.0033</td> <td>0.00377</td> </tr> <tr> <td>(G, H)</td> <td>0.0009</td> <td>0.0017</td> <td>0.00190</td> </tr> <tr> <td>(H, I)</td> <td>0.0034</td> <td>0.0047</td> <td>0.00582</td> </tr> <tr> <td>(I, J)</td> <td>0.0012</td> <td>0.0016</td> <td>0.00189</td> </tr> <tr> <td>(J, K)</td> <td>0.0021</td> <td>0.0030</td> <td>0.00366</td> </tr> <tr> <td>(K, L)</td> <td>0.0024</td> <td>0.0036</td> <td>0.00431</td> </tr> <tr> <td>(L, M)</td> <td>0.0026</td> <td>0.0034</td> <td>0.00433</td> </tr> <tr> <td>(M, N)</td> <td>0.0031</td> <td>0.0044</td> <td>0.00542</td> </tr> </tbody> </table>		x	y	指数	(D, E)	0.0023	0.0032	0.00395	(E, F)	0.0021	0.0032	0.00377	(F, G)	0.0021	0.0033	0.00377	(G, H)	0.0009	0.0017	0.00190	(H, I)	0.0034	0.0047	0.00582	(I, J)	0.0012	0.0016	0.00189	(J, K)	0.0021	0.0030	0.00366	(K, L)	0.0024	0.0036	0.00431	(L, M)	0.0026	0.0034	0.00433	(M, N)	0.0031	0.0044	0.00542	Calculate the selected area and pixel value in all diamonds under Color coordinates x, y. Use the leftmost master stones grade of the sample diamond as the output grade.
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Closest prior art

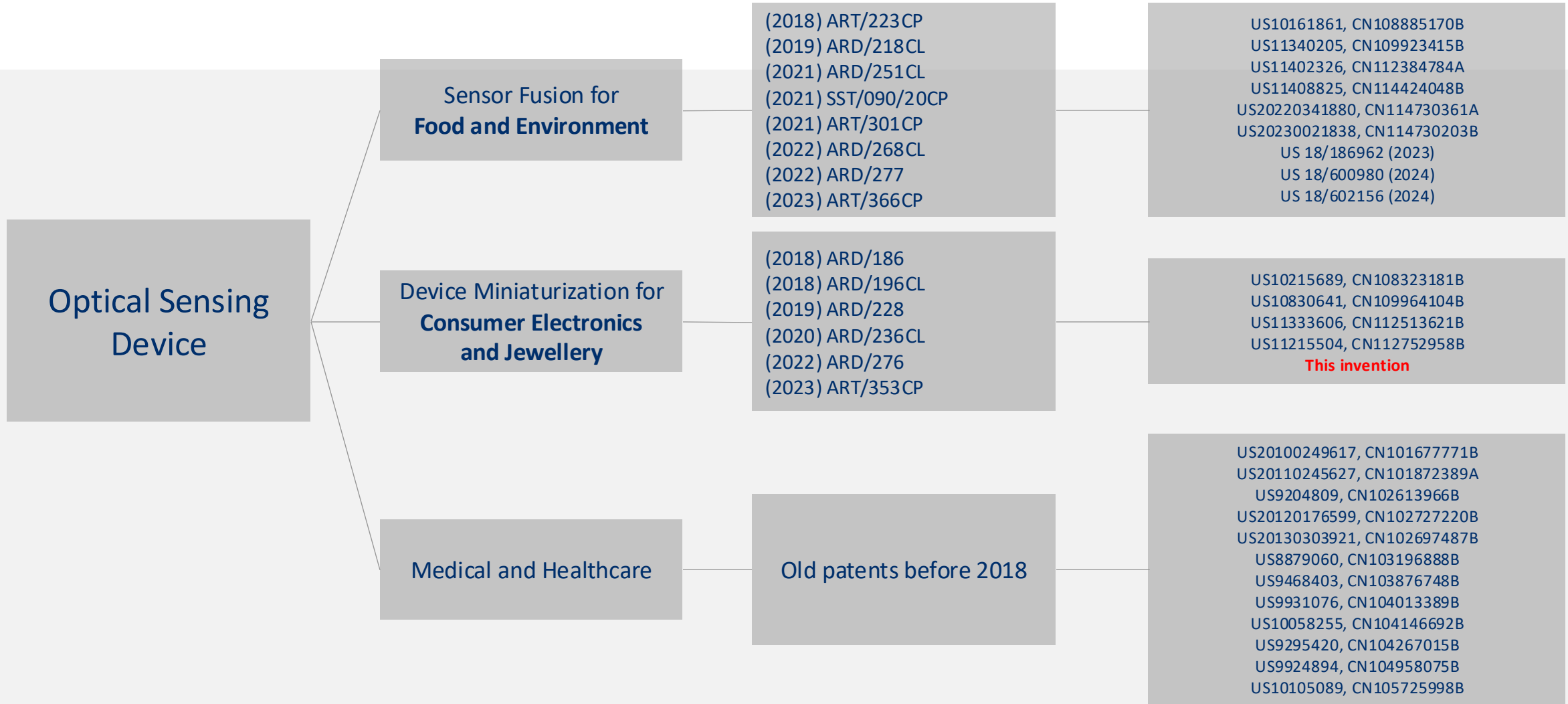
Differences with the prior arts

Patents and Pre-developments

Prior arts	<u>US11892412B2/ Sarine Color (2022)</u>	<u>VARNA-D (2019)</u>	<u>DiaColor</u>	<u>US11435296B2 (2022)</u>	<u>CN1 09991230B (2022)</u>	<u>CN1 10132972 (2019)</u>	<u>CN1 06840404B (2017)</u>	<u>US7388656B2 (2008)</u>	This invention
Commercial product				×	×	×	×	×	 Prototype
CT between 5500-6500K	√	√	√	×	√	√	√	√	√
45° viewing	√	×	×	×	√	√	×	√	√
Rotational average of measurement	√	×	×	√	√	√	×	×	√
Analysis color in CIE XYZ colorspace	√	×	×	×	×	×	√	√	√
Internal master stones reference	×	×	×	×	×	×	×	×	√

Closest prior art

Patent Portfolio



Business Value**

1. What are your inventions key differentiation and impact in the value chain of the associated potential applications? (Please note that this refers to the invention's immediate benefits and impact in the industry and not the big picture. E.g. An NB-IoT IC design will benefit the IoT equipment manufacturer to create a low cost and power consumption IoT product to make smart city implementation cost effective)

The color grading holds pivotal importance in the diamond industry as it directly impacts a gemstone's perceived quality and market value. The conventional diamond color grading is performed by **qualified staff** only. The continuous line for automatic diamond color grading offers a plethora of benefits, such as improved precision and uniformity in grading processes. This not only enhances **operational efficiency** in the marketplace but also significantly **curtails labor expenses**. Moreover, the accuracy of automatic color grading ensures even the **tiny diamonds** are assessed reliably, guaranteeing extensive quality assurance.

2. Who would your potential customers in the next step up in the value chain of the potential applications and what kind of product will they produce using your inventions?

The invention could be used by **jewelry manufacture** or **trading companies**. Professional users will have the direct needs to **evaluate the color grading** of diamond and distribution **without the certification** by International Institutes. This invention will help them with faster and more accurate detection with continuously automatic evaluation, instead of professional technician or oversea labs. Jewelry manufactures and traders will determine the moderate price of high-volume diamonds.

3. Any estimation in the potential market size in coming 5 years?

The global diamond market size is expected to reach USD 123.83 billion by 2030, expanding at a CAGR of 3.2% from 2023 to 2030.

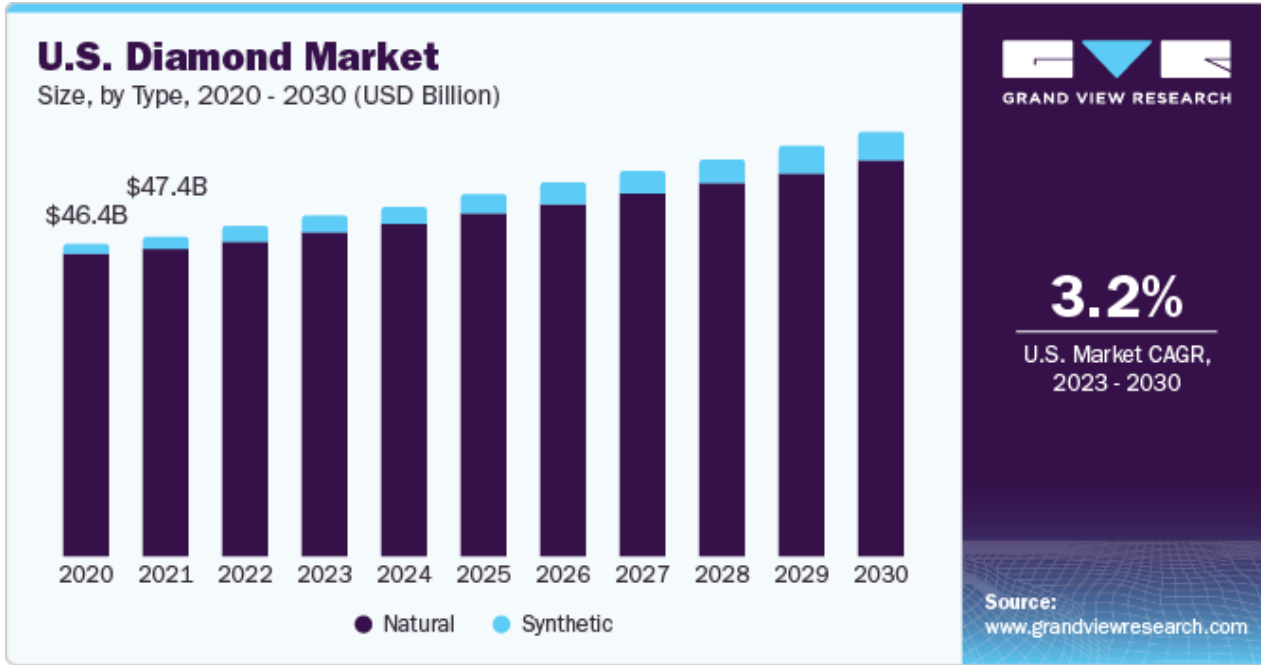
4. What is the status of the commercial discussions regarding your invention? Any deals signed or in progress and please provide details.

We will further investigate and connect to the local **jewelry market**. We have collaborated with Sunlin Jewellery Equipment (HK) Group Co., Ltd. Currently, we are collaborated with the vendor of **Chow Tai Fook**, carrying out trials using our automatic diamond color grading equipment for diamonds inspections.

5. Which ITF project's deliverable(s) is(are) related to current invention? Please quote the ITF project code with details of the deliverable(s).

This invention is directly related to **deliverable 1 and 2** (A prototype of all-round optical system for the inspection of jewelry samples) for **ART 353CP**, All-round Optical System for Smart Jewelry Inspections.

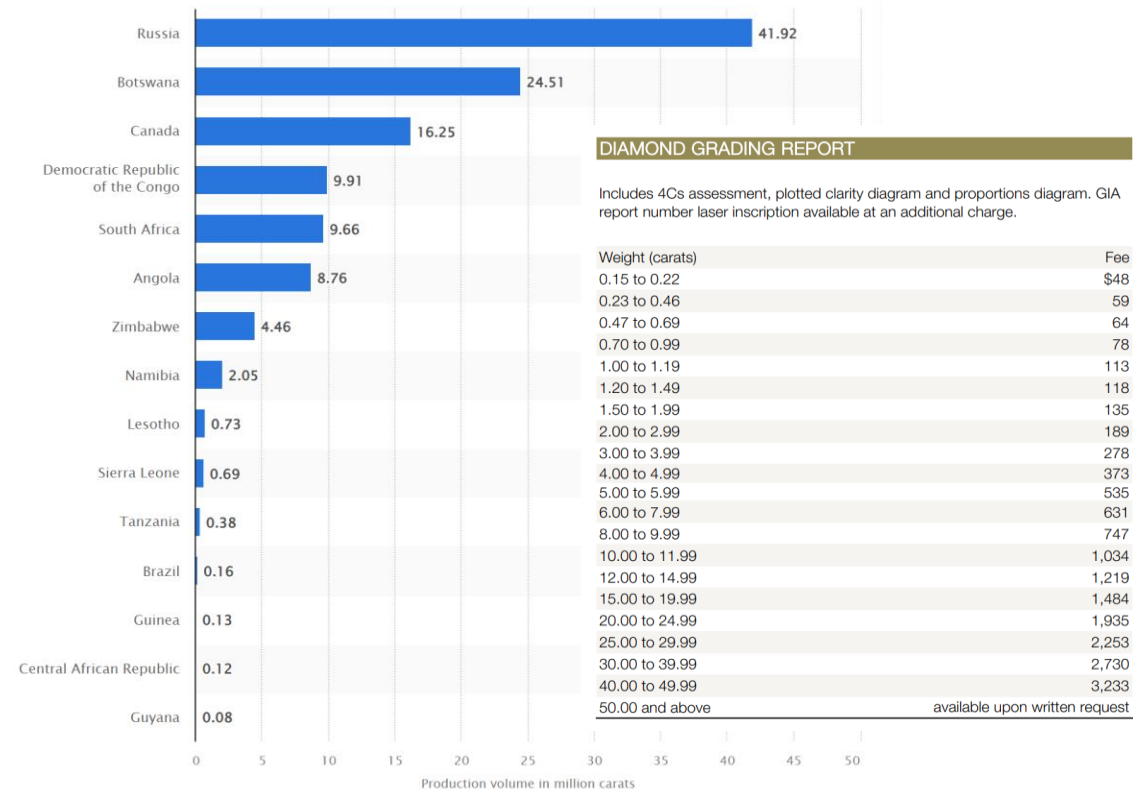
Business Value**



Published by [Statista Research Department](https://www.statista.com), Oct 30, 2023

Production volume of diamonds worldwide in 2022, by country

(in million carats)



Potential Collaborators:

香港珠寶學院及香港寶石鑑定所

AGIL 亞洲寶石學院及鑑定所有限公司



周大福
CHOW TAI FOOK

TSL | 謝瑞麟
the artisan of love

周生生
(how Sang Sang)

六福珠寶
LUKFOOK JEWELLERY

It is estimated that **50 to 60 million polished diamonds** have been produced. According to GIA's Fee Schedules, there is an annual expenditure of at least **USD 600 million** dedicated to color grading.

Which Country to File

Project Number, Name: ART 353CP, All-round Optical System for Smart Jewelry Inspections

Project Period: 19/01/2023 to 18/05/2024

- Filing a non-provisional patent application in US**
- Filing a provisional patent application in US**
- Filing an invention patent application in China**
- Filing an utility model patent application in China**
- Filing a patent application in Taiwan**
- Filing a PCT patent application**
- Filing a patent application in HK**
- Others**

Q&A in domain review

- Please list the questions asked by all the reviewers in the domain review and give corresponding answer.

Thank You



www.astri.org | TECH FOR IMPACT

Name: WANG Yuelin

Email: yuelinwang@astri.org

Contact: 34062652

Date:

Supplemental information

- Lower end (D to M) color grade diamonds are typically used as jewelry and ornaments

GIA	CIBJO/IDC						Scan.D.N	
	English	German	French	Italian				
D	Exceptional white + D	Hochfeines Weiss + D	Blanc exceptionnel + D	Bianco extra eccezionale + D			River	D
E	Exceptional white E	Hochfeines Weiss E	Blanc exceptionnel E	Bianco extra eccezionale E			River	E
F	Rare white + F	Feines Weiss + F	Blanc extra + F	Bianco extra + F			Top Wesselton	F
G	Rare white G	Feines Weiss G	Blanc extra G	Bianco extra G			Top Wesselton	G
H	White H	Weiss H	Blanc H	Bianco H			Wesselton	H
I	Slightly tinted white I	Leicht getöntes Weiss I	Blanc nuancé I	Bianco sfumato I			Top Crystal	I
J	Slightly tinted white J	Leicht getöntes Weiss J	Blanc nuancé J	Bianco sfumato J			Crystal	J
K	Tinted white K	Getöntes Weiss K	Légèrement teinté K	Bianco leggermente colorito K			Top Cape	K
L	Tinted white L	Getöntes Weiss L	Légèrement teinté L	Bianco leggermente colorito L			Cape	L
M	Tinted M	Getönt M	Teinté M	Colorito M			Cape	M
N	N	N	N	N			Cape	N
O	O	O	O	O			Cape	O
P	P	P	P	P			Cape	P
Q	Q	Q	Q	Q			Cape	Q
R	R	R	R	R			Cape	R
S	S	S	S	S			Cape	S
T	T	T	T	T			Cape	T
U	U	U	U	U			Cape	U
V	V	V	V	V			Cape	V
W	W	W	W	W			Cape	W
X	X	X	X	X			Cape	X
Y	Y	Y	Y	Y			Cape	Y
Z	Z	Z	Z	Z			Cape	Z

Table 1 – Corresponding Terms for Colour Grades

Supplemental information

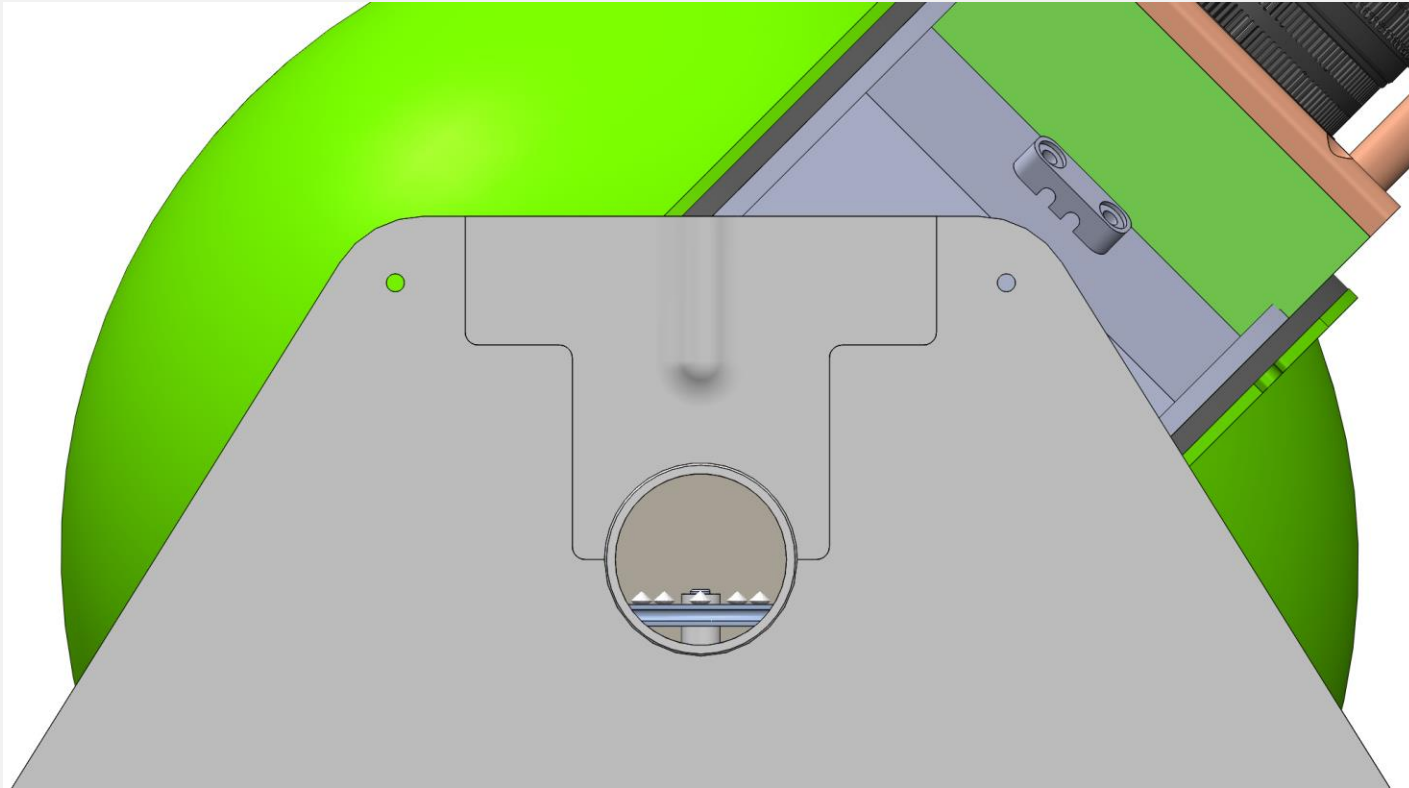
➤ GIA's comments on the master stones size for manual color grading

Members of the trade decide the best size for the diamonds in their set of master stones, based on their typical stock (understanding that GIA will not grade diamonds under 0.25 ct for master stones). If, for example, a manufacturer or jeweler typically works with half-carat diamonds, the master stones should also be approximately half a carat. Over the years, we have found that sets larger than one carat are not necessary, as masters in the one-carat range can accommodate comparisons to larger diamonds. At the laboratory, we have compared masters of this size to diamonds 50 ct and more. When such diamonds have been observed on more than one occasion, we have

According to standards set by GIA, we designed different sample plates for diamonds in different size. Moreover, we can provide the color grading results of diamonds under 0.3ct for reference.

Supplemental information

- Mechanical design for automatic easily



Conveyor system can transport the sample diamonds through the side hole of our machine.