OFFICE COLOR SCIENCE developed new color matching system applied anisotropic color appearance model and image processing calculation. In measurement dialog, operator measure reflectance and image by BYK multi-angle spectrophotometer. CI-Navigator System calculates Metallic and Pearlescent Paint Formulation by reflectance and Image information.
Metallic and Pearlescent Color such like Automotive Exterior Color needing high level human experience and quite difficult. Before developing Formulation System, Office Color Science had studied and considered deeply about Color Model and Optics Property about Coatings. And we decided, Formulation system have to calculate 4 Category Materials, Each Category has different Optical Property and Structure.

Paint Film Structure of Metallic and Pearlescent Color

1. Absorption Pigment
2. Metal Flake
3. Pearlescent
4. Flop Control Agent
Absorption Pigment

Absorption Pigment has Scattering and absorbing Coefficient by Kubelka-Munk Theory. These two coefficient are related with Chemical or molecular structure and particle size.

Automotive Color needing so many kind of Absorption Pigment, and these two factor are related highlight and shade Spectrum. Especially, Scattering Coefficient is very important to calculate highlight and shade color. CI-Navigator are applied Absolute two constancy method.

Metallic Effect Material

Metallic Effect Materials are mostly Metal Flake such as Al, Cu, etc., and no transparency. Basic Optical is same as miller, incident light are reflected to Specula direction.

In this case, Kubelka-Munk model and Duncan color mixing theory are mismatched and can not apply. CI-Navigator was developed special optics and color matching model.
These four images are Silver Dollar type Aluminum Flake observation photograph by Laser Con-focal Microscope. This method can be get 3 dimension orientation information of Effect Material in Coating Layer.

Upper side two images are pure Aluminum over dark coating, left side is Color Image and right side is 3 dimension orientation image. And lower two images are pure Aluminum mixed with carbon black paint. Each particles color are related with orientation and z-axis position.

Pearlescent Effect Materials has complex optical property. Core Material is Mica and coated oxide Metal, such like TiO2, SnO2, Cu, etc., and interference color and transparency.

Of coarse, Kubelca-Munk model and Duncan color mixing theory are mismatched and can not apply. CI-Navigator was developed special optics and color matching model.
These four images are Pearlescent Material Merck Xiralic T60-24 SW Steller Green observation photograph by Laser Con-focal Microscope. This method can be get 3 dimension orientation information of Effect Material in Coating Layer. Upper side two images are over dark coating, left side is Color Image and right side is 3 dimension orientation image. And lower two images are coating pure Xiralic mixed with carbon black. Each particles color are related with orientation and z-axis position.

Core: Mica, Al₂O₃, etc

TiO₂, SnO₂, Fe₂O₃

Fe₂O₃

SnO₂

TiO₂

Ti₁₋ₓOₓ, FeTiO₂, CoTiO₂, Carbon, etc

Mostly Pearlescent Material composed by core and coated layer different refractive index material, for example mica and oxide metal. Coating layer is very thin, and occurred interference color.
Pearlescent Material has transparent, then there are quite difference color between over bright and over dark coatings.

Flop Control Agent are applied to adjust flop feel. There are two type, one is orientation controller such as Silica or Wax material, and the other is scattering controller such as TiO2 or Micro-TiO2.
Measuring Method of Gonio Apparent Color

BYK-Mac

6 Angle System

BYK-Mac Optics

BYK-Mac (BYK-Gardner) has a Monochrome CCD Sensor that can sense 15 deg., 45 deg., 75 deg., and Diffuse Illuminant.
Solid Color has almost same reflectance profile in each geometry. Highlight and shade are almost same level and shape. It is very low flop property.

In the case of Metallic color, highlight and shade reflectance levels are different. But highlight and shade reflectance spectrum profile are not same level and profile. Especially, highlight color and shade has opposite color over bright coat.

Pearlescent color has quite complex optical property. Highlight and shade reflectance spectrum profile are not same level and profile. Especially, highlight color and shade has opposite color over bright coat.

### Why metallic and pearlescent color are required Multi-Angle Spectrophotometer Measuring?

### Color Matching Theory of Metallic and Pearlescent Color
Characteristics of Metallic and Pearlescent Color

Color with Feel.......  
Measure by Multi-Angle Spectrophotometer

Color with Texture.......  
Measure by Imaging Devices

Color Information
Measured by Multi-Angle Spectrophotometer

Image Information
Measured by Imaging Devices

Color Matching Theory applied
Color and Image Information
CCD Image Processing for Metallic and Pearlescent Coatings

Applied Fractal Dimension

D = 2.6696  n = 0
D = 2.5097  n = 1
D = 2.3274  n = 5
D = 2.1391  n = 20
D = 2.1195  n = 30

Computer Color Matching System for Metallic and Pearlescent
**CI-Navigator Purpose**

- **Laboratory Use**
  - High Accurate Color Matching with Image Control
  - Create Database
  - 3-Dimension Visualize to Communicate with Customer Designer

- **Production Use**
  - Batch Correction
  - QC

- **Body Shop Use**
  - CCM, Search and Correction
  - 3-Dimension Visualize to Customer Full body Repair Presentation

**CI-Navigator available Spectrophotometers**

BYK-Mac
Color and Image Matching System

Spectrophotometer with Imaging Device

Micro Scope
Laser Con-focal Microscope

BYK-Mac

CI-Navigator Function
Formulation System relate with Data Base

Ordinary Case, Body Shop user know the Color Number.

System have data base and store the Color, Image and Formulation Data.

Customer can use these information and System calculate Correct Formulation.

Of course these Data can apply for Self-Learning and improve Color accuracy.
Data Base Dialog

Data Base Search by Color, Code, etc.

Measuring Function

Measure Function can apply Evaluation and QC Work
Color and Image Matching System

Quality Control Dialog

Color Search Dialog
Sean Change Function

Top Coat (Pearlescent)  
Base Coat (Color Base)

Multi-Layered Structure Simulation
Object Control
Object Control can change Oval shape proportion and surface condition such as pealing, reflection intensity.

Lighting Control
These control function are included Parallel and direct, or spot lighting, Ambient, Diffuse, and Spot lighting intensity.

View Control
View point and Oval Object Direction can change freely with indicator.

Object Control
Object Control can change Oval shape proportion and surface condition such as pealing, reflection intensity.

Specification -1

Formulation Calculation
Measure: up to 20 Angle Reflectance/ Up to 4 Geometry Image Processing with Self-Learning Function
Color Matching Object:
Absorption Pigment, Metallic Pigment, Pearlescent Pigment, Flop Controller
Matching Type: Isometric/Metameric Color Matching
Combination Mode: Manual/ Automatic/ Full Automatic
Maximum Combination Number:
Absorption Pigment 6
Metallic Pigment 3
Pearlescent Pigment 3
Flop Controller 3
CCM Mode:
Metallic-Pearlescent 2-Coat Color
Metallic-Pearlscent 3-Coat Color
Candy Tone Color
Solid Color
Correction Calculation: Remake/ Batch Correction (Labo and Production Use.)

Simulation Function
Reflectance Simulation
Real Color Simulation on White/ Black/ Measured Substrate
Image Parameter Simulation
CIELAB Parameter to Reflectance Creation Function
BRDF Out-put relate with 3D rendering system and Light Viewer Function
### Specification -2

#### Primary Data Base
- **Absorption Pigment**: 50-200
- **Metallic Pigment**: 50-200
- **Pearlescent Pigment**: 50-200
- **Flop Controller**: 50

#### Data Base
- Data Base Function can store and register the following items:
  - Measured or simulated Reflectance
  - Measured or simulated Image Parameter
  - Measured actual Image
  - Header Information
- 5 terms (Such like Color Code, Production Code, Car Maker, etc.)

- Formulation
- Included following Function:
  - 3 Dimension Distribution Display
  - Self Learning Accuracy Check Function

#### Data Measure
- Spectrophotometer:
  - X-Rite MA68II, MA98, etc.
  - BYK Gardner BYK Mac, BYK 3 Angle etc.
  - Konica Minolta CM512m3
  - Murakami GCMS 3B, GCMS 4
- (Up to 10,000 Angles one time measuring, included Normal and GCMS Coordinate Converter)