GPU TECHNOLOGY CONFERENCE

March 26-29, 2018 | Silicon Valley

Sharing Physically Based Materials Between Renderers with MDL

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PRESENTED BY NVIDIA.

Agenda

Introduction to NVIDIA Material Definition Language MDL

Matching the appearance of a single material within different rendering techniques

Defining physically-based materials

Measured materials

MDL ecosystem

Become part of the ecosystem

Introduction

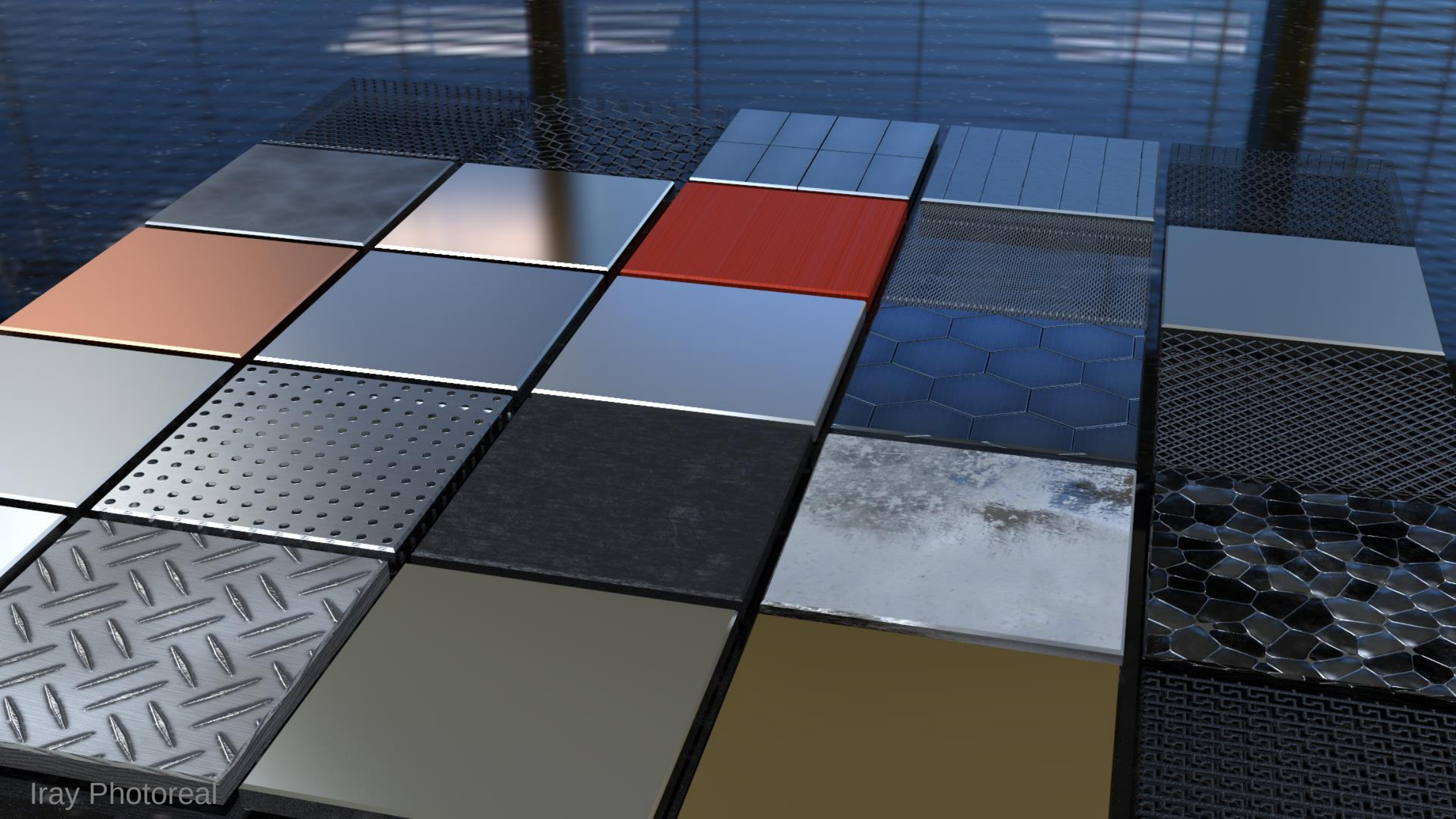
What is NVIDIA MDL?

The **NVIDIA Material Definition Language (MDL)**

is technology developed by NVIDIA

to define **physically-based** materials

for physically-based rendering solutions.


Iray Photoreal


Iray Photoreal


B TZ 2012
D
Iray Photoreal

courtesy Harley Davidson

Photographer: Simon Puschmann/Rendering and Retouching: [zerone]


diamond
emerald
aquamarine
iolite
morganite
tanzanite
ametrine
tourmaline
topaz
silver
turquoise
peridot
sapphire
amethyst
ruby
citrine
garnet
alexandrite
gold
pearl
zircon
jade
opal
onyx
NVIDIA vMaterials with Iray Photoreal


Iray Photoreal

Matching the appearance of a single material within different rendering techniques

One Scene for Different Rendering Modes

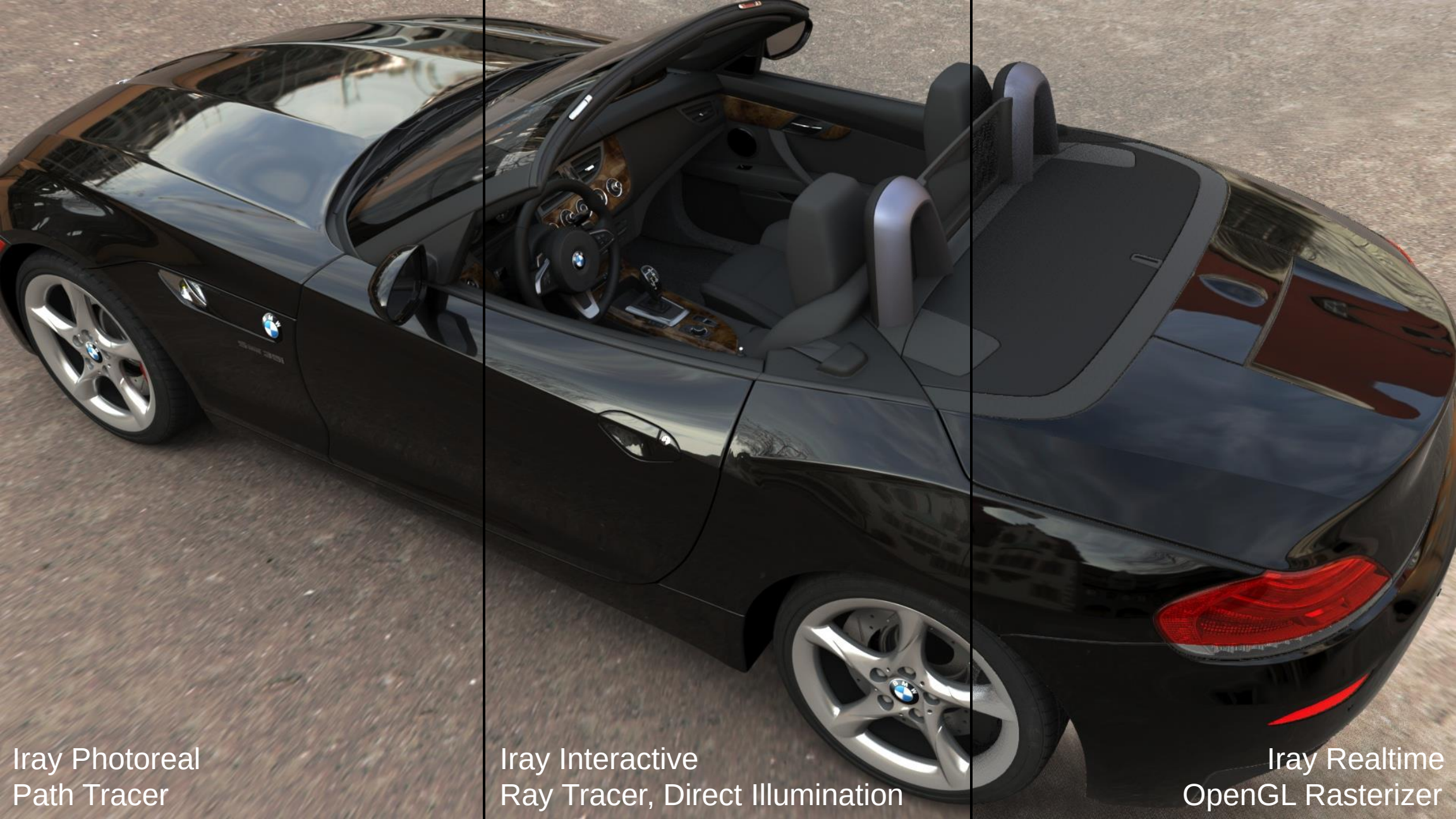
Realtime Rasterizer

Interactive Raytracer

Pathtracer

Share Scene Database and MDL materials for a consistent look

Switching modes with 1 call with no scene modifications


Iray Photoreal
Path Tracer
Iray Interactive
Ray Tracer, Direct Illumination
Iray Realtime
OpenGL Rasterizer

Traditional Shading Language Parts

Texturing

- Texture lookups
- Procedurals
- Uv-transforms
- Projectors
- Noise functions
- Math functions

Material Definition

- Glossy reflection
- Transparency
- Translucency

Material Implementation

- Light loops / trace N rays
- OIT / ray-continuation
- Ray marching

MDL

Procedural Programming Language

- Texture lookups
- Procedurals
- Uv-transforms
- Projectors
- Noise functions
- Math functions

Declarative Material Definition

- Glossy reflection
- Transparency
- Translucency

Renderer

Rasterizer

Light loops / OIT

Raytracer

Trace N rays

Pathtracer

Ray-marching

MDL

Procedural Programming Language → **Declarative Material Definition**

Renderer

Rasterizer

Light loops / OIT

Raytracer

Trace N rays

Pathtracer

Ray-marching

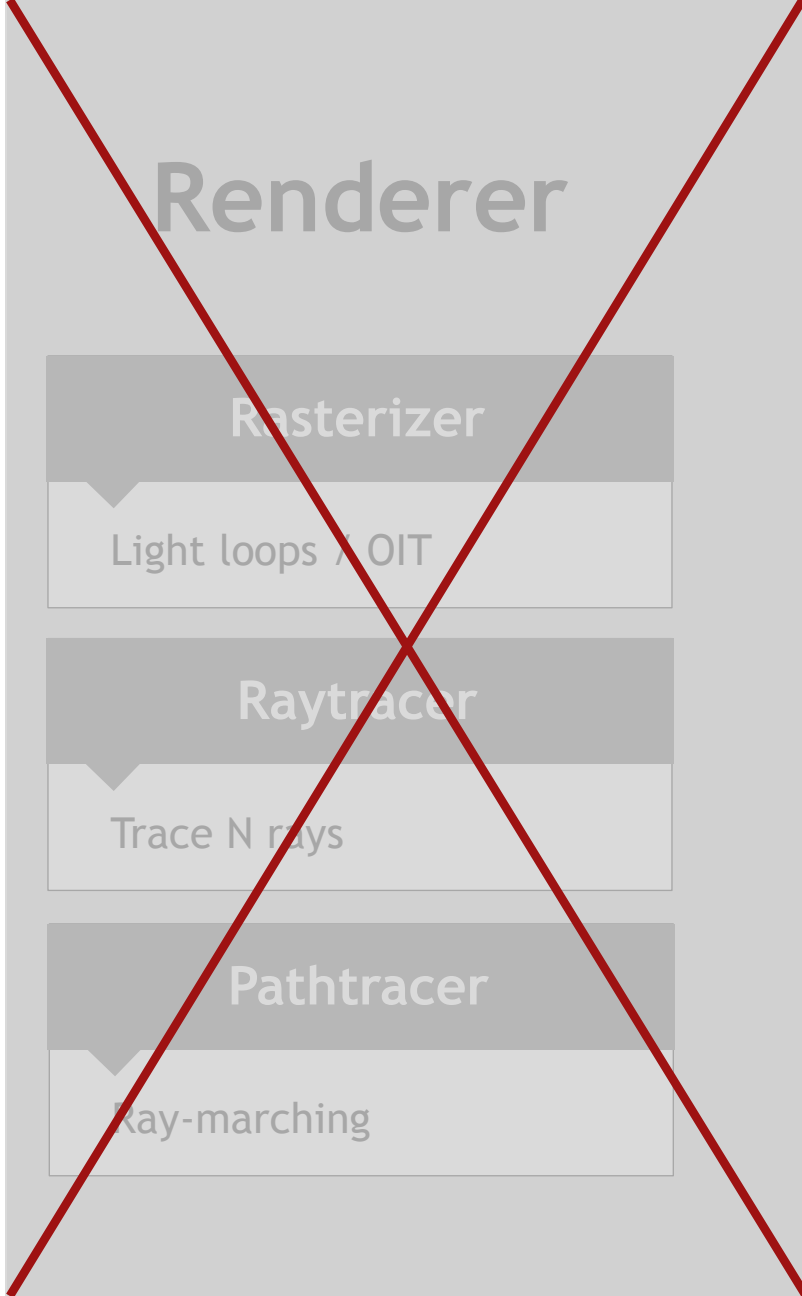
MDL

Procedural Programming Language → **Declarative Material Definition**

MDL is not a Shading Language

MDL defines what to compute, **not** how to compute it

- no programmable shading
- no light loops or access to illumination
- no trace call
- no sampling
- no camera dependence

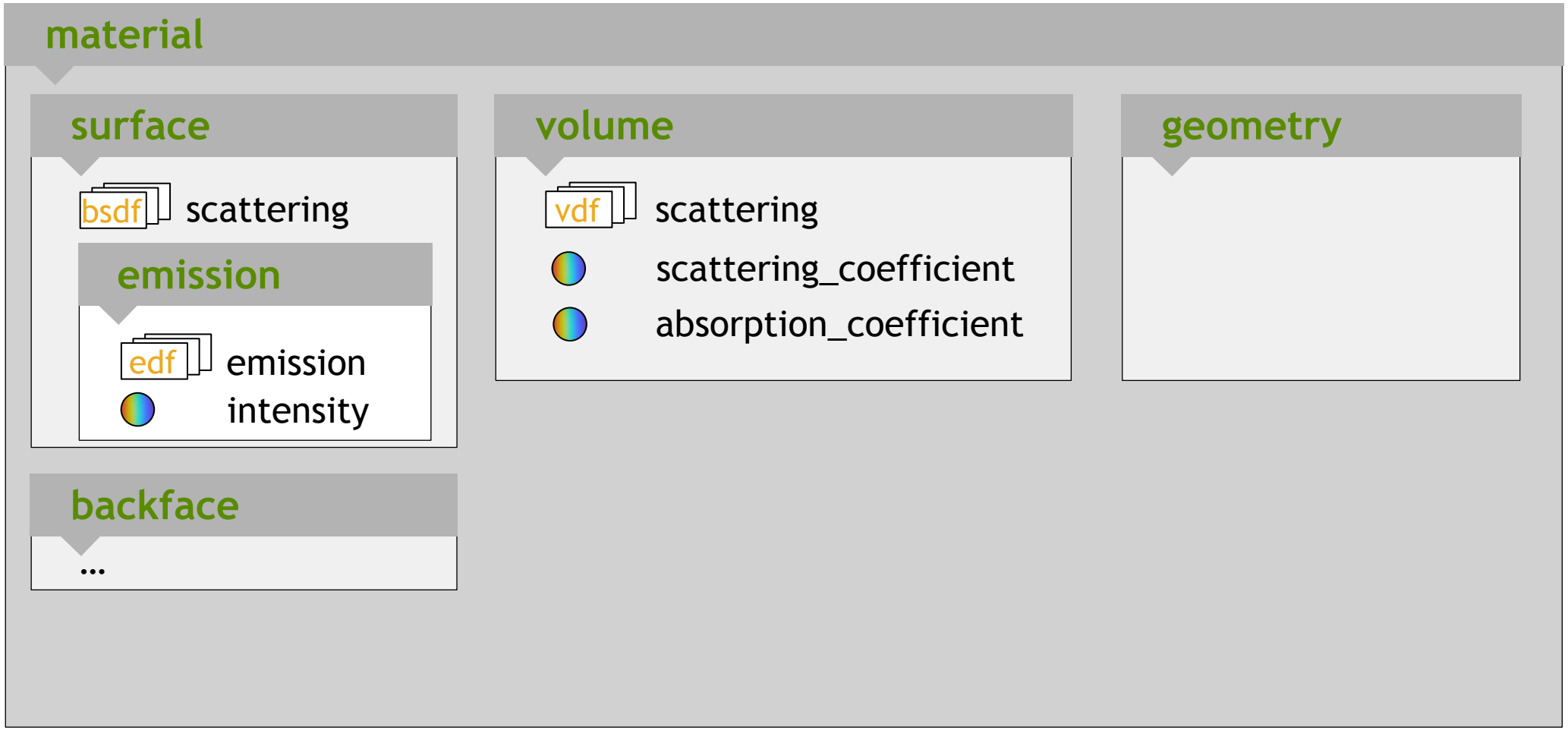


MDL Material Model

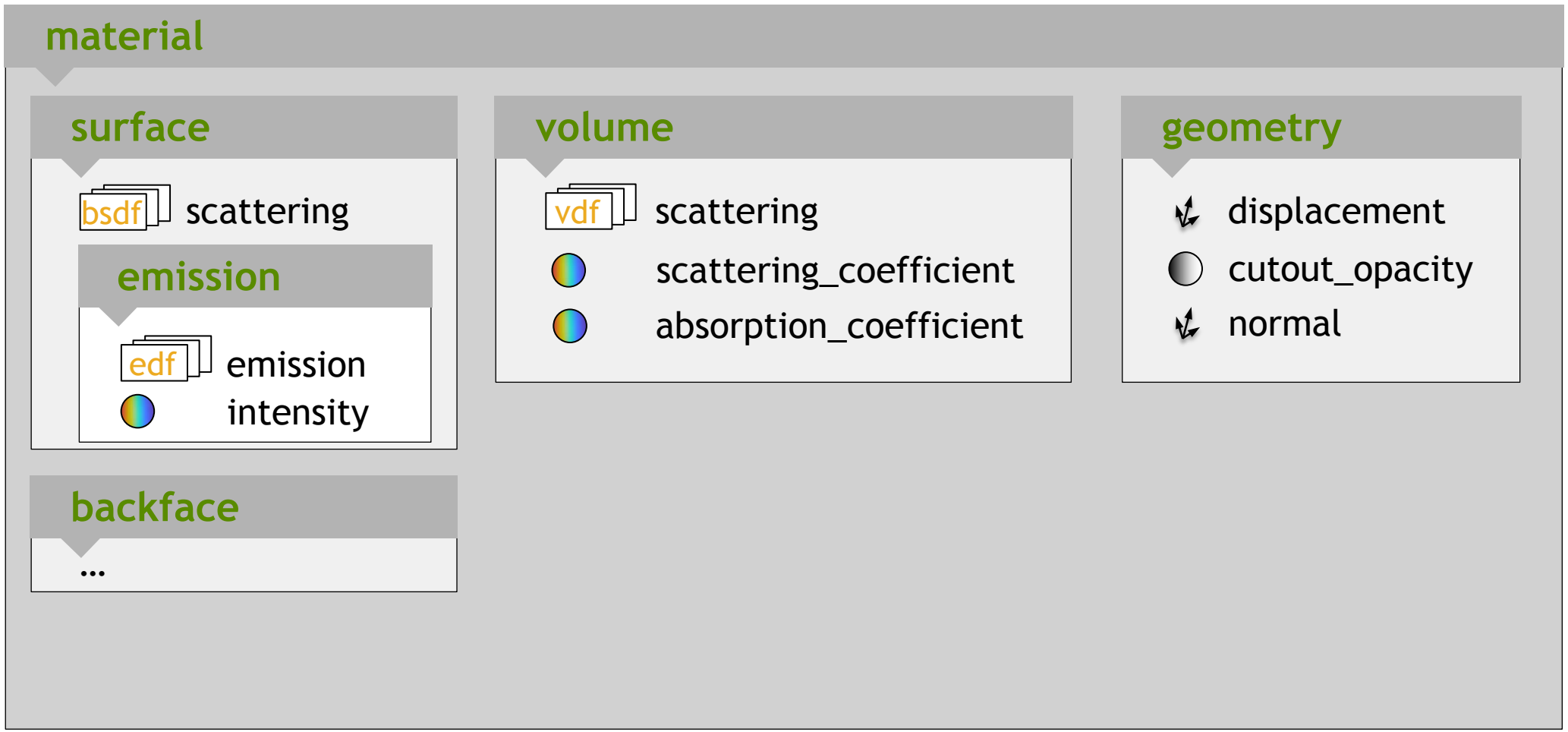
MDL Material Model

MDL Material Model

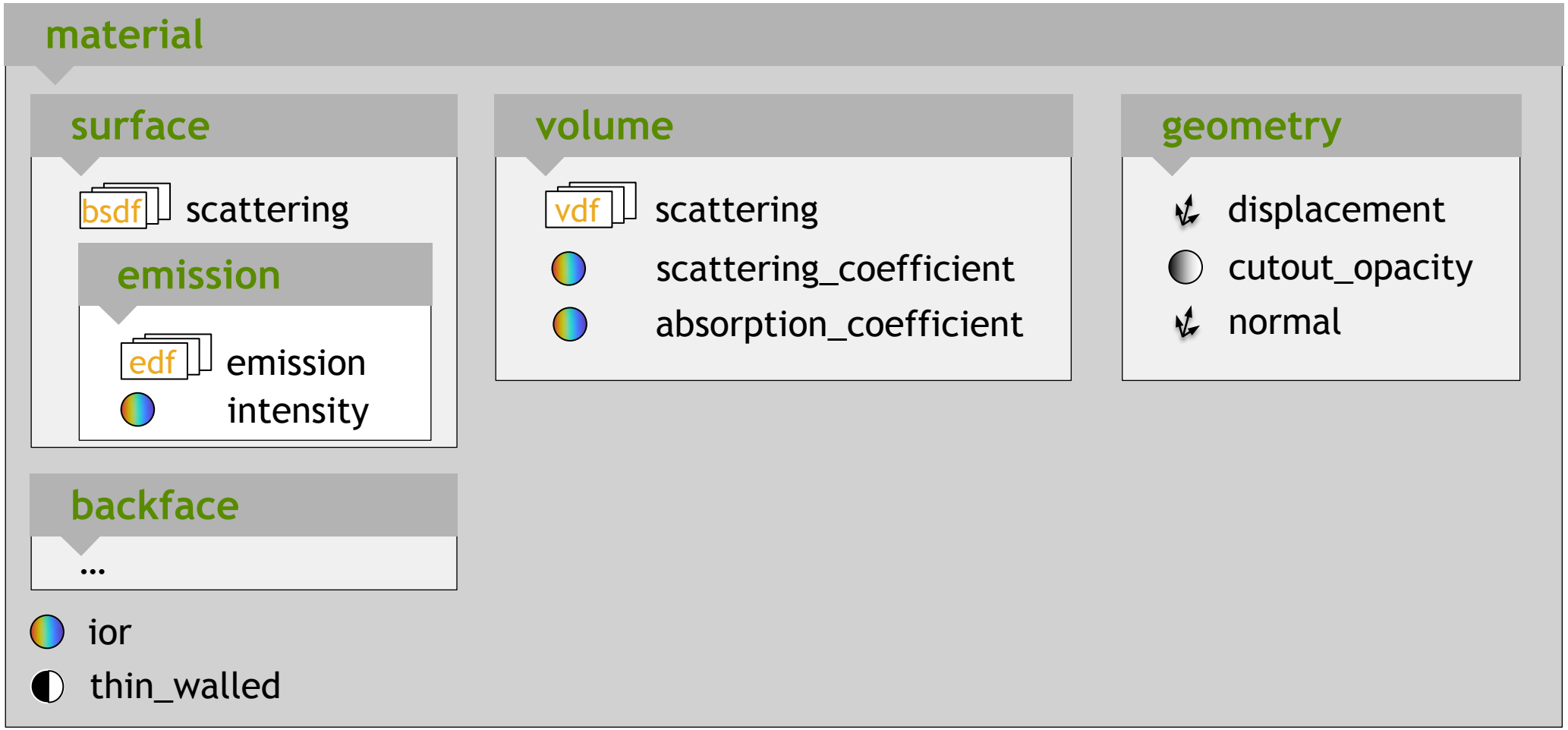
MDL Material Model



MDL Material Model



MDL Material Model

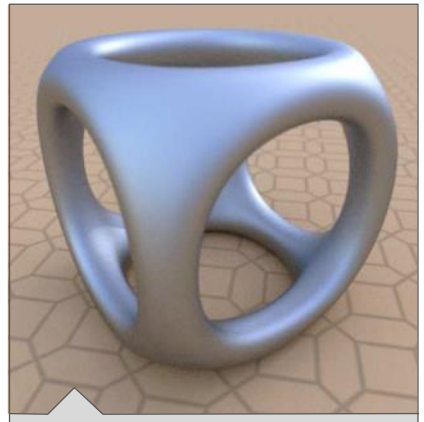


MDL Elemental Distribution Functions

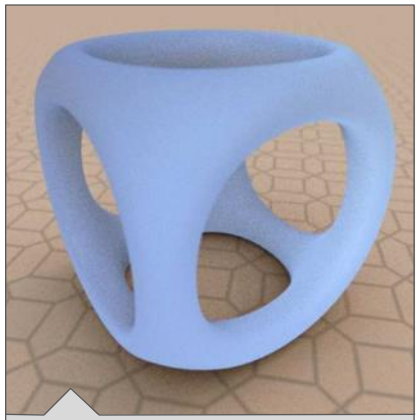
Bidirectional
Scattering
Distribution
Functions

Diffuse Reflection

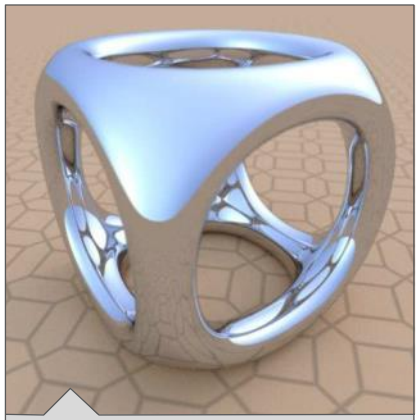
Diffuse Transmission



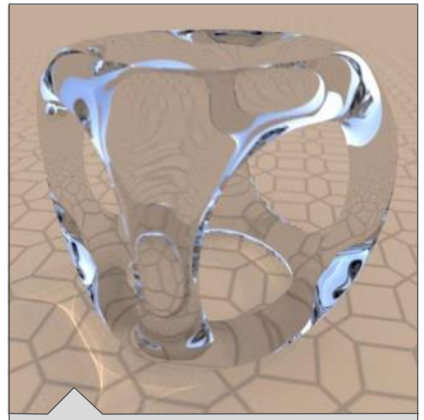
Glossy (various)



Backscatter Glossy



Specular Reflection



Spec. Refl.+Transm.

Measured BSDF

MDL Elemental Distribution Functions

Emissive
Distribution
Functions

Diffuse

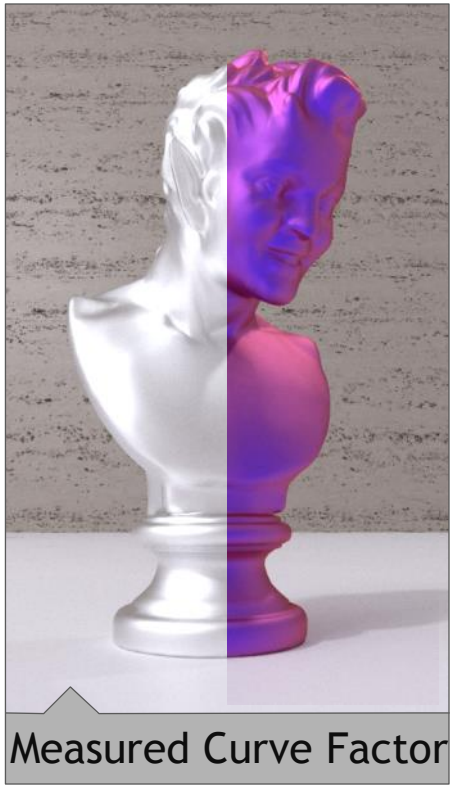
Spot

IES Profile

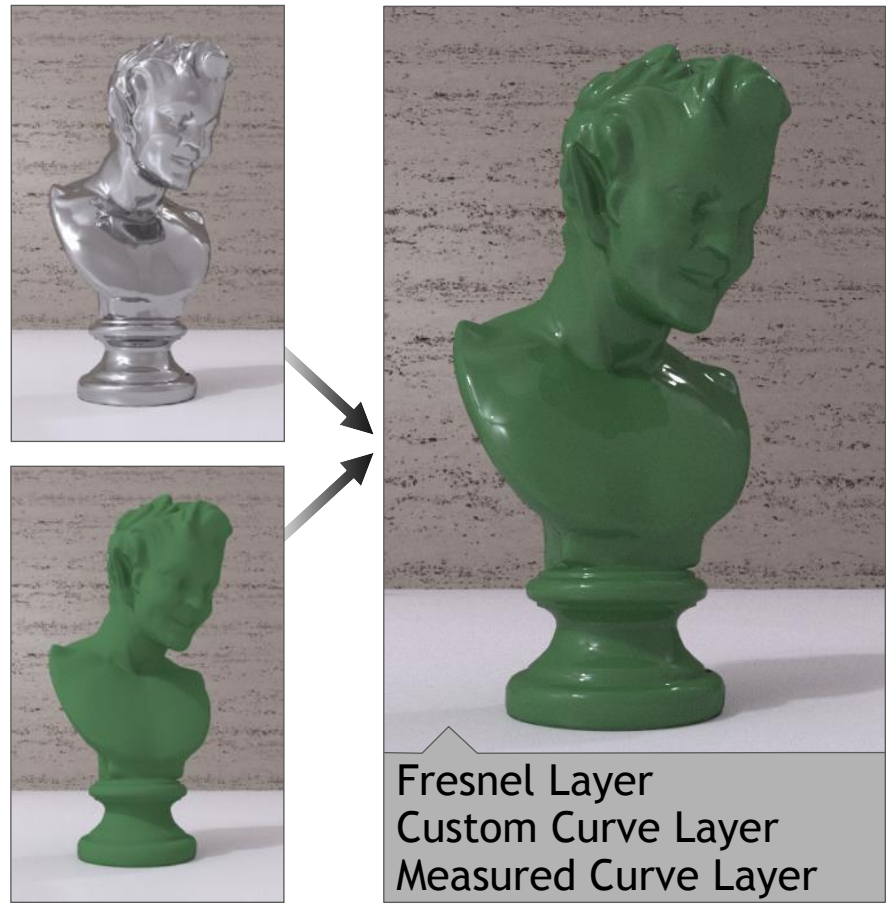
Volume
Distribution
Functions

Henyey-Greenstein

MDL Distribution Function Modifiers

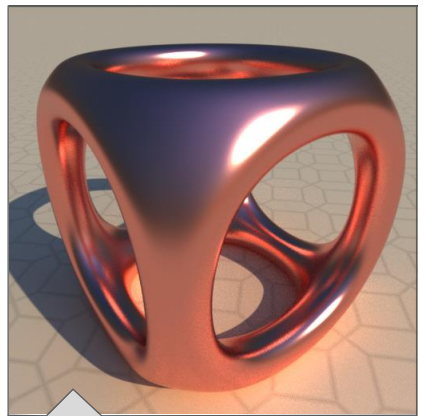


MDL Distribution Functions Combiners

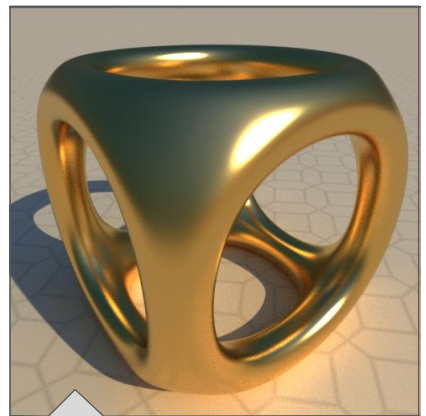


MDL 1.4: New BSDF

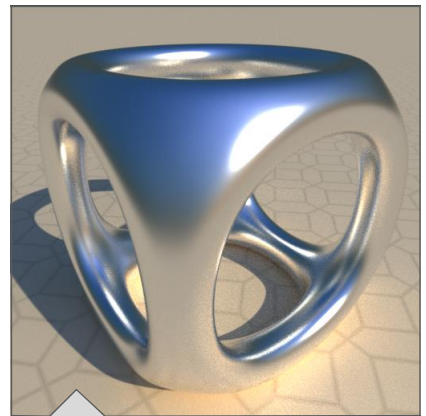
Modifier:
Complex ior factor



Copper

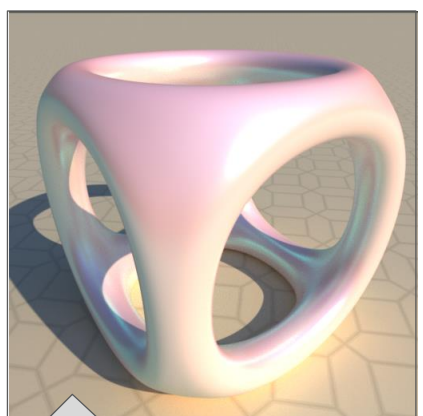


Gold



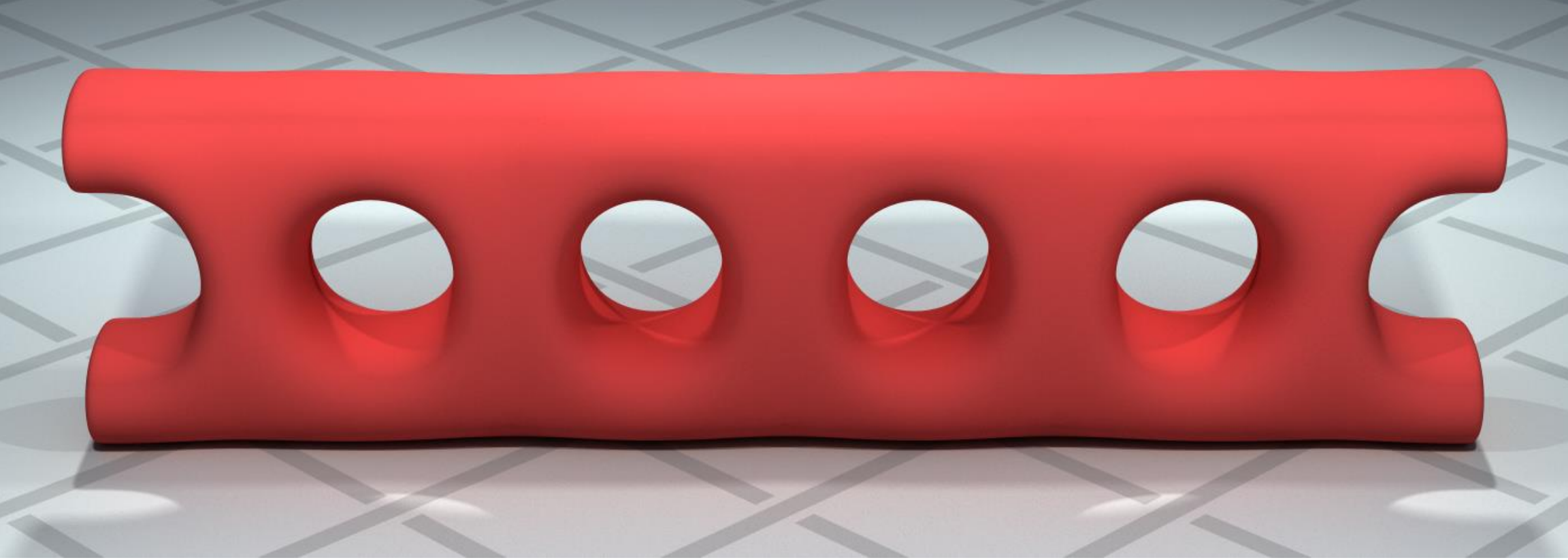
Silver

Combiners:
All weights can be color now

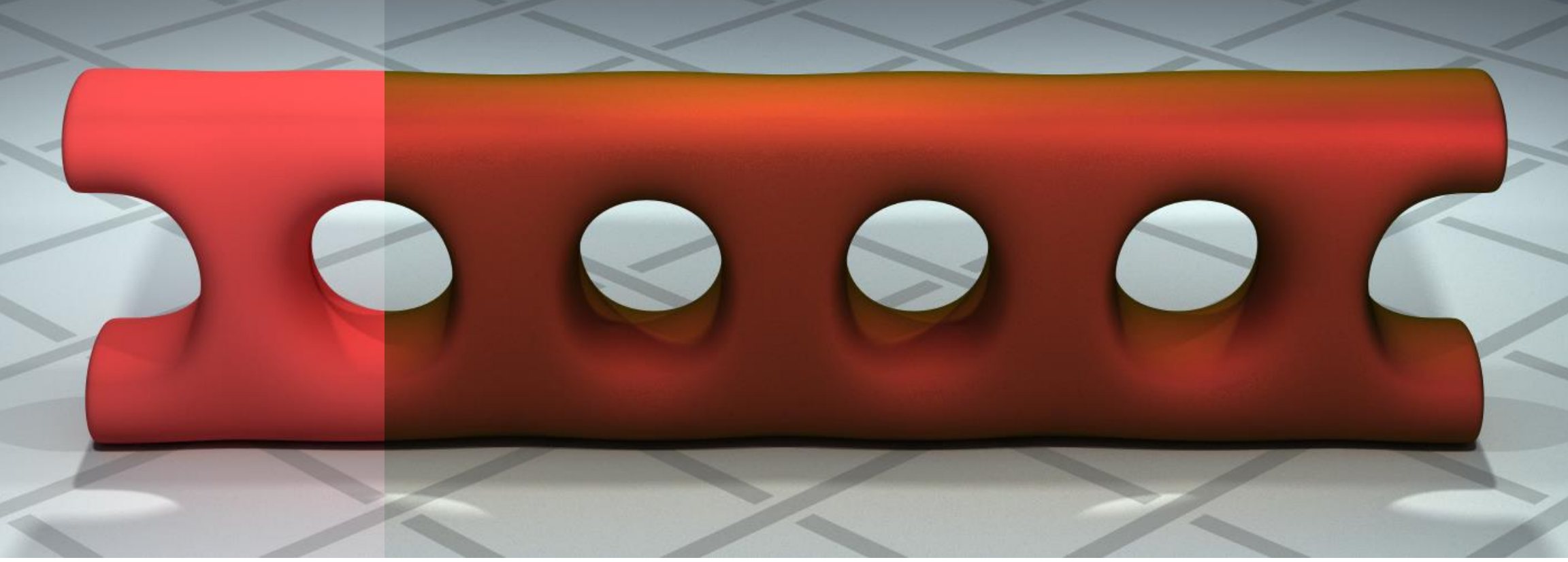


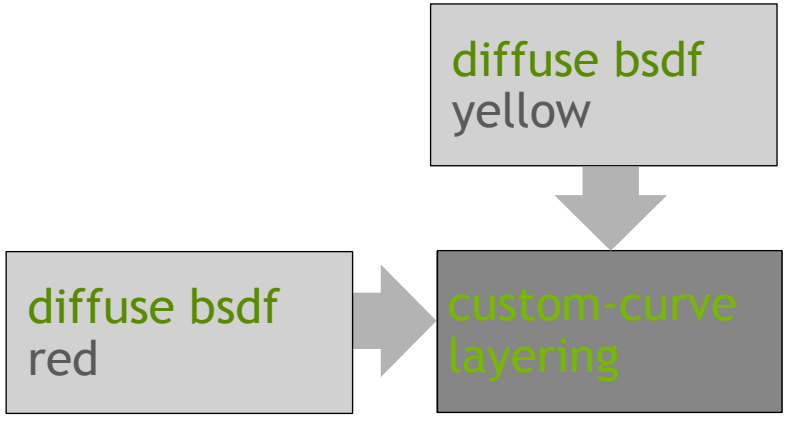
Custom curve layer

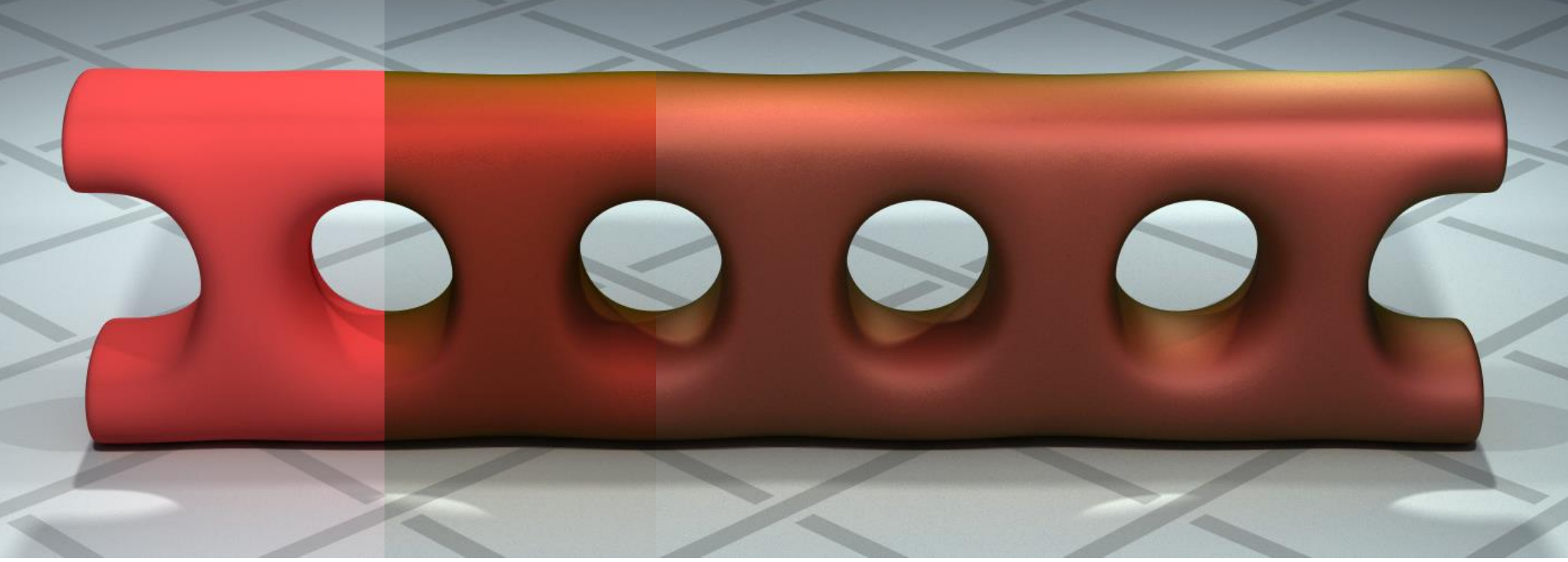
MDL Layered Material Example

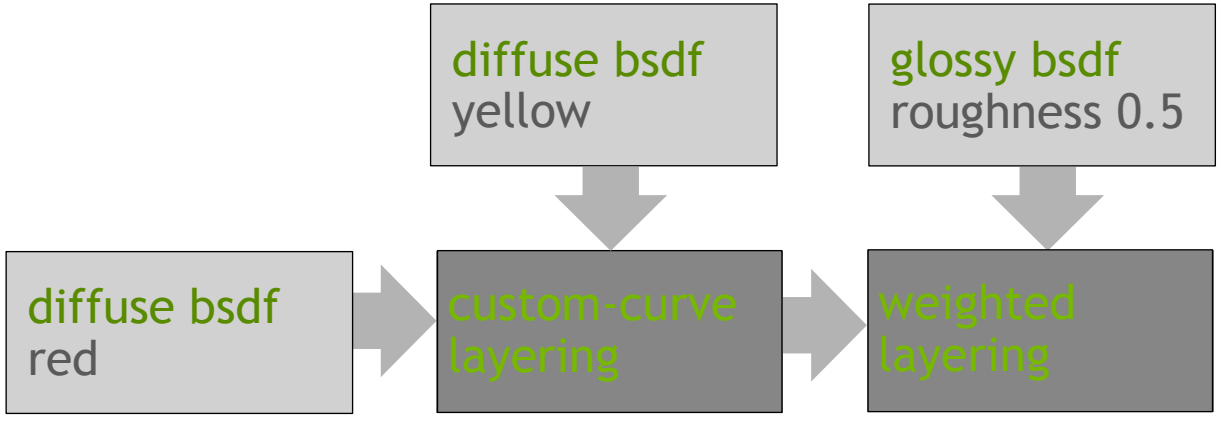


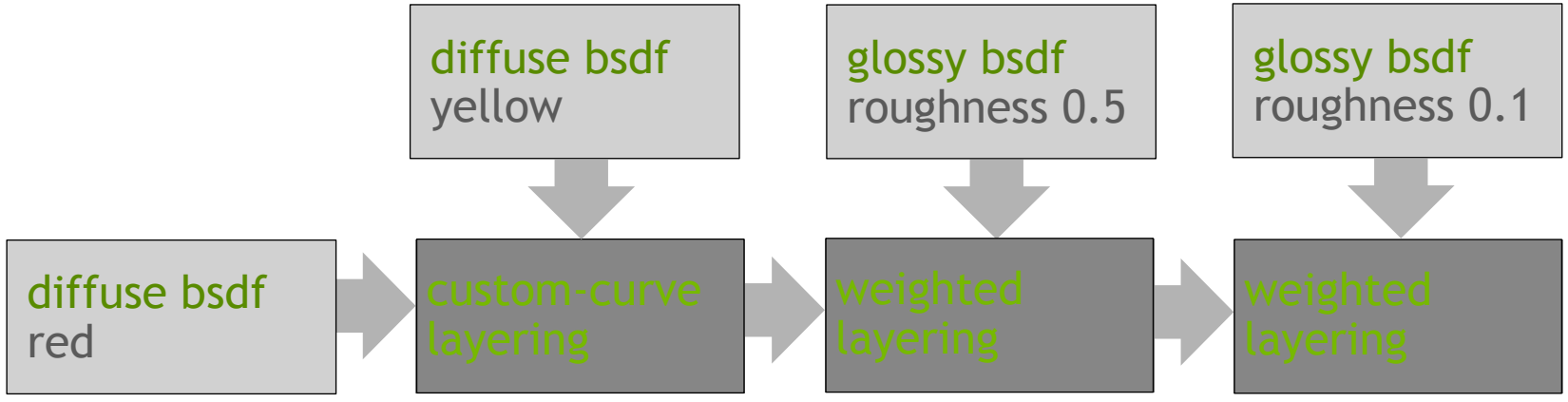
diffuse bsdf
red

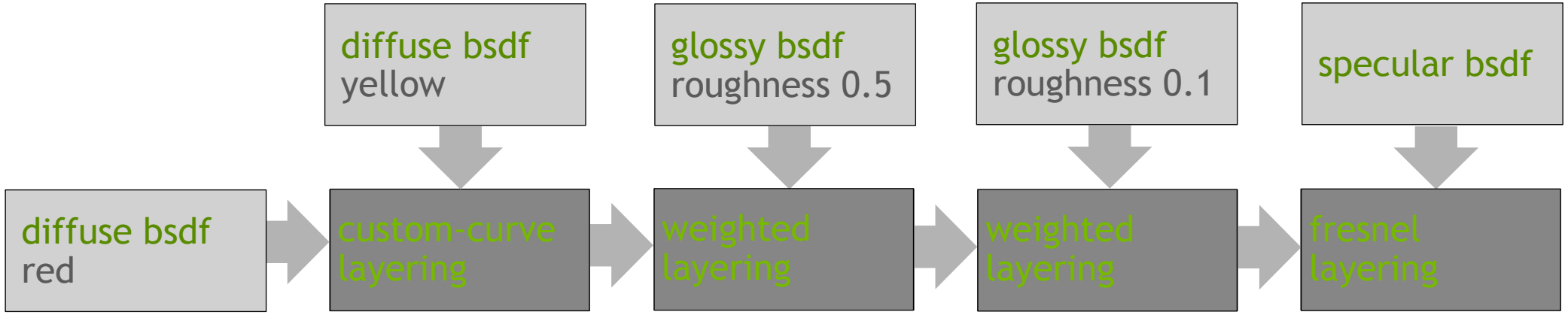



diffuse bsdf
yellow
diffuse bsdf
red
custom-curve
layering




diffuse bsdf
yellow
glossy bsdf
roughness 0.5
diffuse bsdf
red
custom-curve
layering
weighted
layering


diffuse bsdf
yellow
glossy bsdf
roughness 0.5
glossy bsdf
roughness 0.1
diffuse bsdf
red
custom-curve
layering
weighted
layering
weighted
layering


diffuse bsdf
yellow
glossy bsdf
roughness 0.5
glossy bsdf
roughness 0.1
specular bsdf
diffuse bsdf
red
custom-curve
layering
weighted
layering
weighted
layering
fresnel
layering

Defining physically-based materials with source code

Defining a Material Using MDL

MDL is a ‘C’ like language. The material viewed as a struct

```
struct material {
    bool                thin_walled;
    material_surface    surface;
    material_surface    backface;
    color               ior;
    material_volume     volume;
    material_geometry   geometry;
};
```

Defining a Material Using MDL

MDL is a ‘C’ like language. The material and its components viewed as a struct

```
struct material {
    bool                    thin_walled;
    material_surface        surface;
    material_surface        backface;
    color                   ior;
    material_volume         volume;
    material_geometry       geometry;
};

struct material_surface {
    bsdf                    scattering;
    material_emission       emission;
};
```

Defining a Material Using MDL

MDL is a ‘C’ like language. The material and its components viewed as a struct

```
struct material {
    bool              thin_walled   = false;
    material_surface  surface       = material_surface();
    material_surface  backface      = material_surface();
    color             ior           = color(1.0);
    material_volume   volume        = material_volume();
    material_geometry geometry      = material_geometry();
};

struct material_surface {
    bsdf              scattering    = bsdf();
    material_emission emission      = material_emission();
};
```

Defining a Material Using MDL

Material struct is already fully defined

```
material();
```

Defining a Material Using MDL

Material struct is already fully defined

```
material();
```

Defining a Material Using MDL

Creating new materials

```
material name    ( material-parameters )
    = material   ( material-arguments );
```

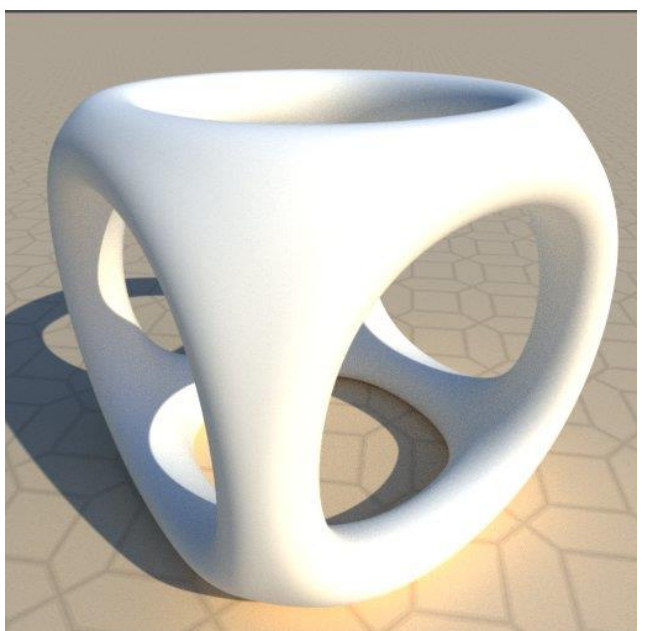
Defining a Material Using MDL

Creating new materials

```
material mymaterial  ( )
    = material       ( );
```

Defining a Material Using MDL

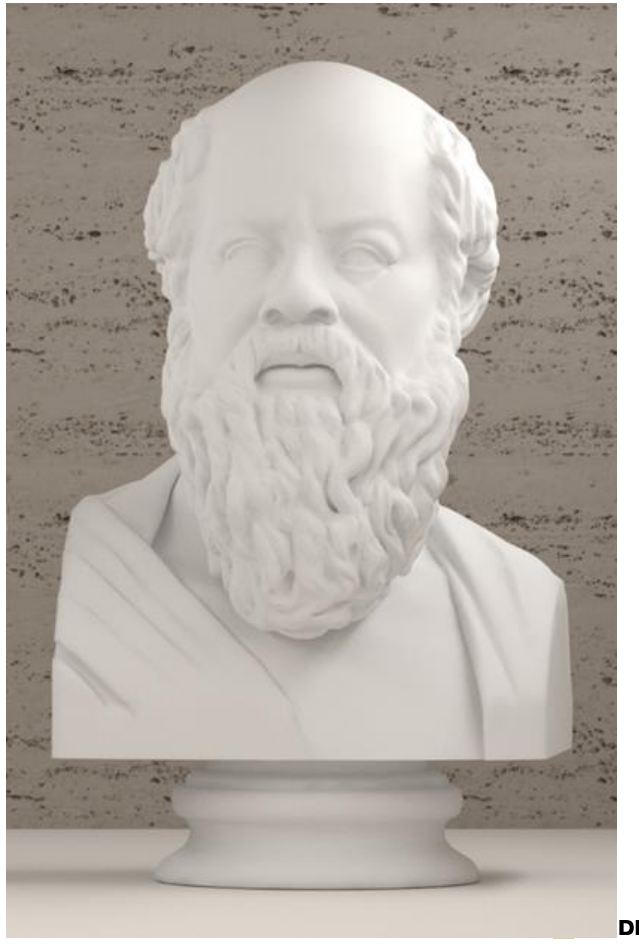
```
material plaster( )
    = material(
        surface: material_surface(
            scattering: df::diffuse_reflection_bsdf()
        )
    );
```



Defining a Material Using MDL

New materials can have parameters

```
material plaster ( color plaster_color = color(.7))
    = material(
        surface: material_surface (
            scattering: df::diffuse_reflection_bsdf (
                tint: plaster_color
            )
        )
    );
```



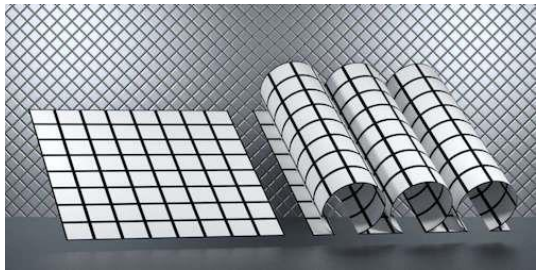
Defining a Material Using MDL

Create complex materials by layering

```
material plastic(
    color diffuse_color = color(.15,0.4,0.0),
    float roughness = 0.05
) = material(
    surface: material_surface(
        scattering: df::fresnel_layer (
            ior: color(1.5),
            layer: df::simple_glossy_bsdf (
                roughness_u: glossy_roughness
            ),
            base: df::diffuse_reflection_bsdf (
                tint: diffuse_color )
        )
    )
);
```

MDL Handbook

www.mdlhandbook.com



Added displacement since 2017

Cloth example

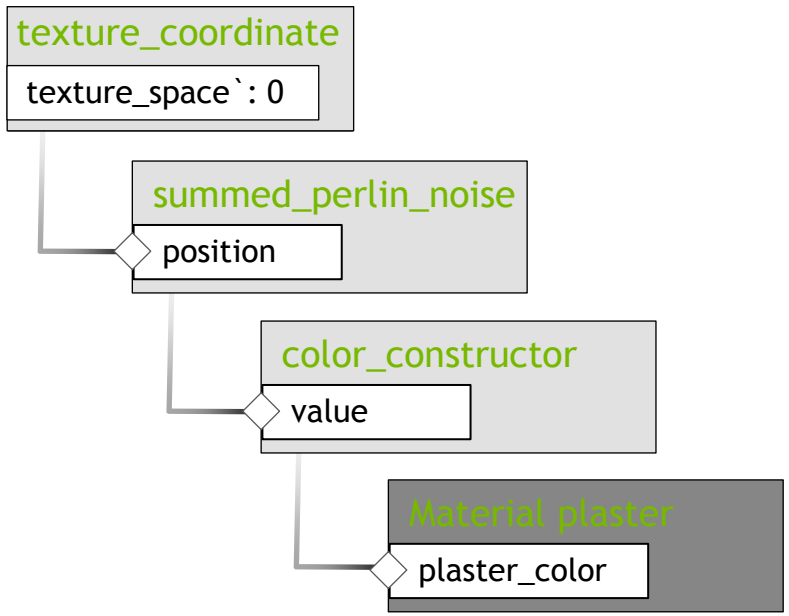
4 anisotropic glossy highlights + translucency

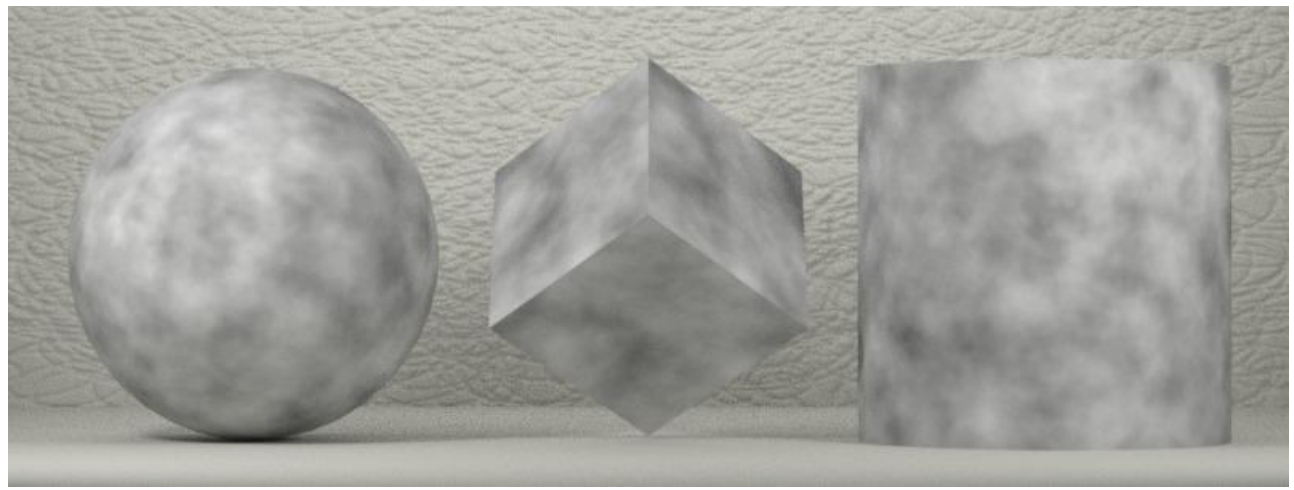
MDL Procedural Programming Language

C-like language for function definitions

Function results feed into material and function parameters

“Shader graphs” are equivalent to function call graphs





Defining a Function Using MDL

MDL is ‘C’ like

```
type-of-return-value function-name ( parameters )
{
    statements
}
```

Defining a Function Using MDL

Function access render state through standard modules

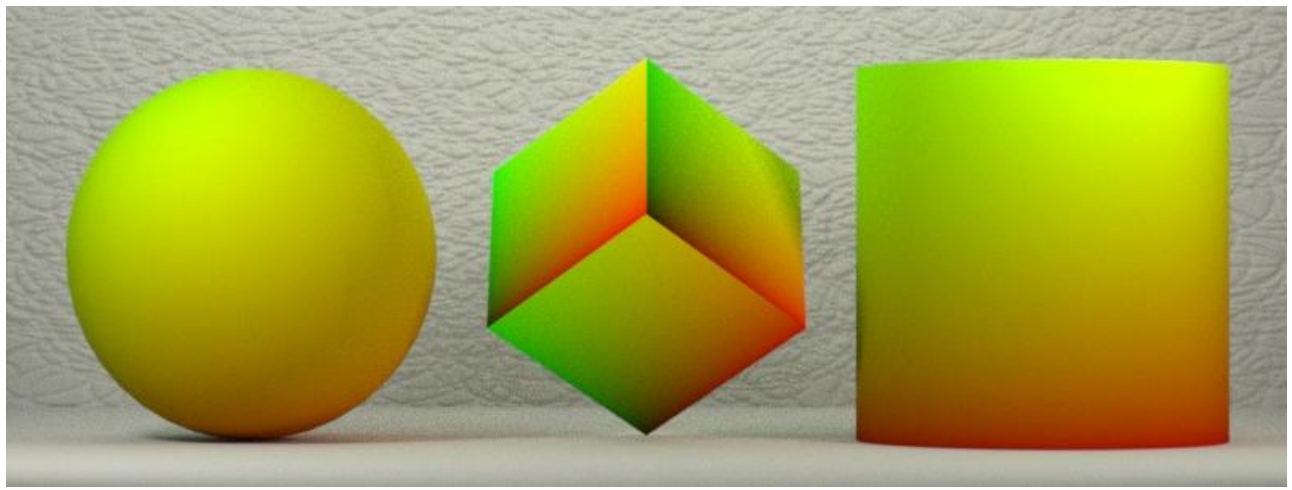
```
color uv_as_color()
{
	return color( state::texture_coordinate(0) );
}
```

Defining a Function Using MDL

Use functions to drive BSDF or material parameters

```
color uv_as_color()
{
        return color(state::texture_coordinate(0));
}

material uv_as_color_material_v2()
= plaster( plaster_color: uv_as_color() )
```



Defining a Function Using MDL

Functions allow control flow like loops, switches, conditionals

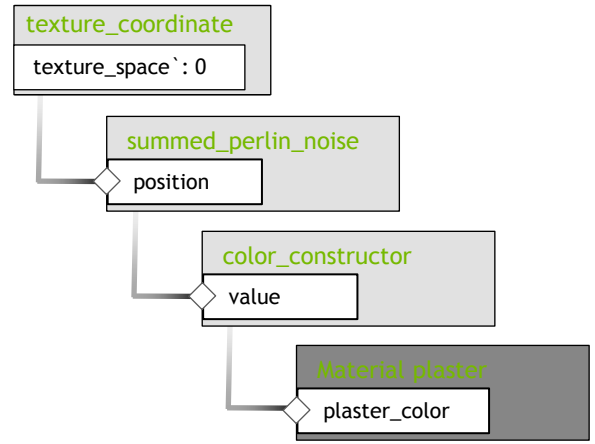
```
float summed_perlin_noise (
     float3 point,
     int level_count=4,
     float level_scale=0.5,
     float point_scale=2.0,
     bool turbulence=false)
{
     float scale = 0.5, noise_sum = 0.0;
     float3 level_point = point;
     for (int i = 0; i < level_count; i++)
     {
          float noise_value = perlin_noise(level_point);
          if (turbulence)
               noise_value = math::abs(noise_value);
          else noise_value = 0.5 + 0.5 * noise_value;
          noise_sum += noise_value * scale;
          scale *= level_scale;
          level_point *= point_scale;
     }
     return noise_sum;
}
```

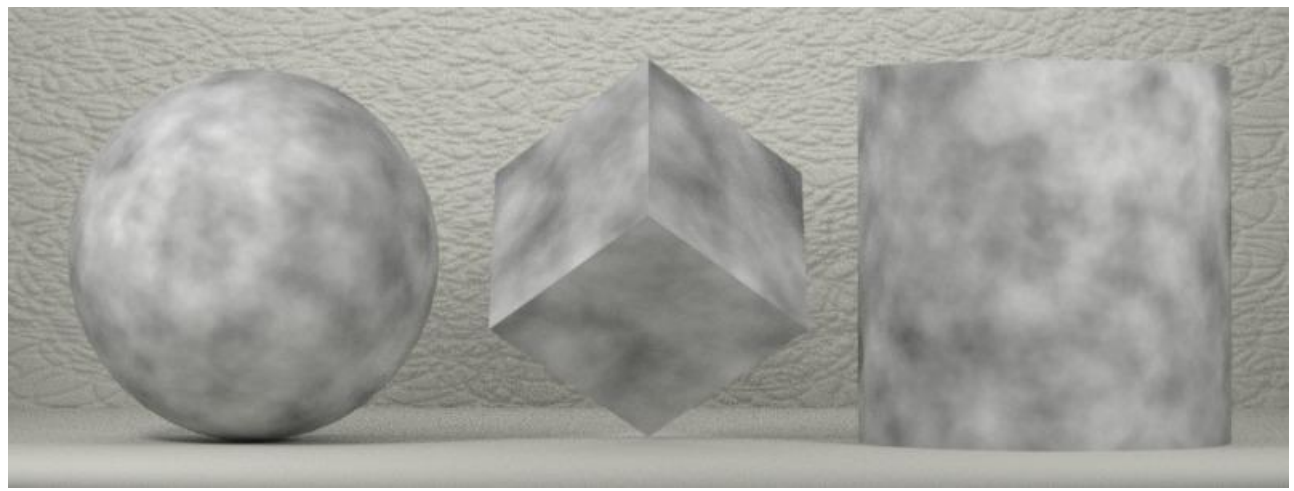
MDL Handbook

Defining a Function Using MDL

Call graph of functions substitute shader graphs

```
material perlin_noise_material()
= plaster(
    plaster_color: color(
        summed_perlin_noise(
            point: state::texture_coordinate(0)
        )
    )
)
```





MDL Module System

MDL is program code

MDL is a programming language allowing dependencies among modules and materials

```
import nvidia::vMaterials::Design::Metal::chrome::*;
```

We use search paths to resolve imports

MDL Module System

MDL is program code

MDL is a programming language allowing dependencies among modules and materials

```
import nvidia::vMaterials::Design::Metal::chrome::*;
```

We use search paths to resolve imports

C:\Users\Jan\Documents\mdl\nvidia\vMaterials\Design\Metal\chrome.mdl

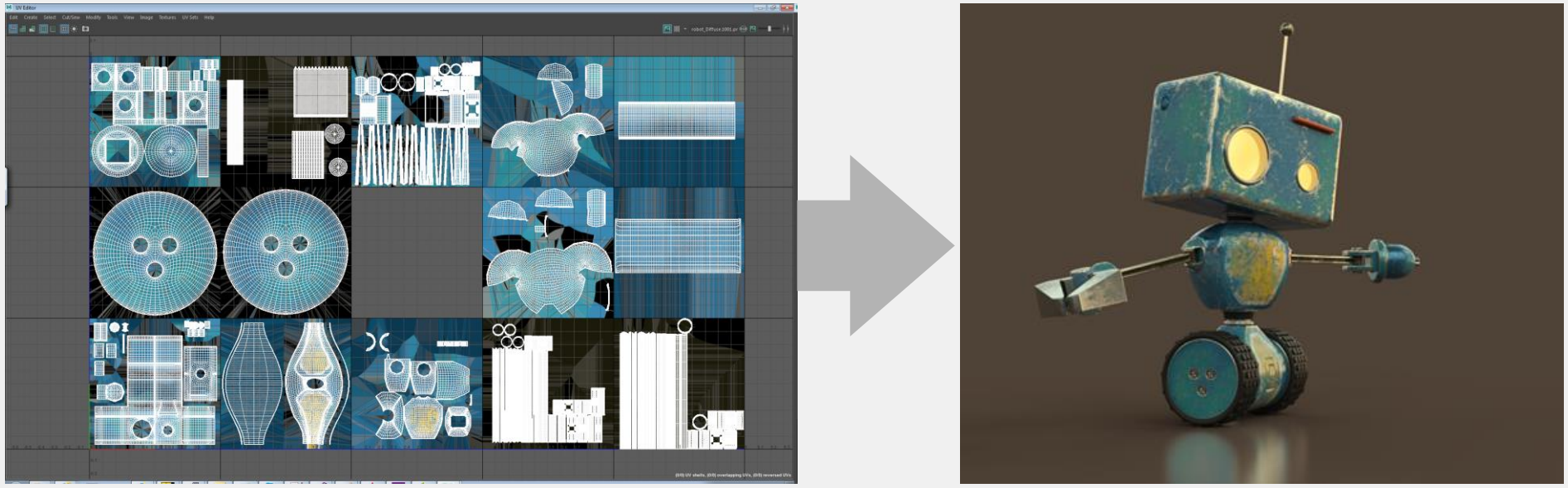
search path

MDL package space

nvidia::vMaterials::Design::Metal::chrome

UDIM and uv-tiles

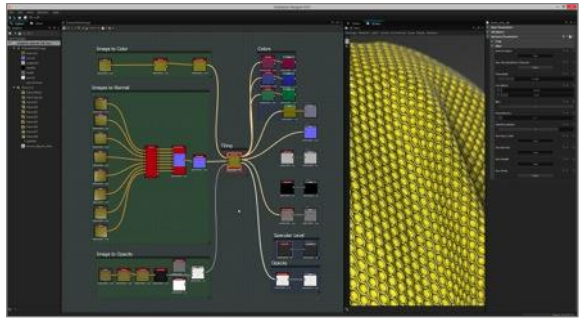
New in MDL 1.4



UDIM texture layout in Autodesk Maya, rendering in Iray

Additional MDL Benefits

Measured Materials

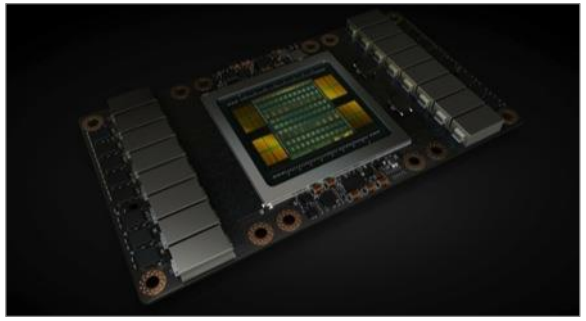


Spatially Varying BRDF

AxF from X-Rite

Measure Isotropic BSDF

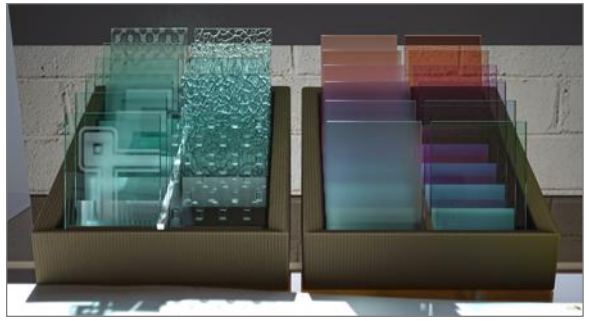
Designed for Parallelism



Little data dependencies

Side-effect free functions

Material Catalogs



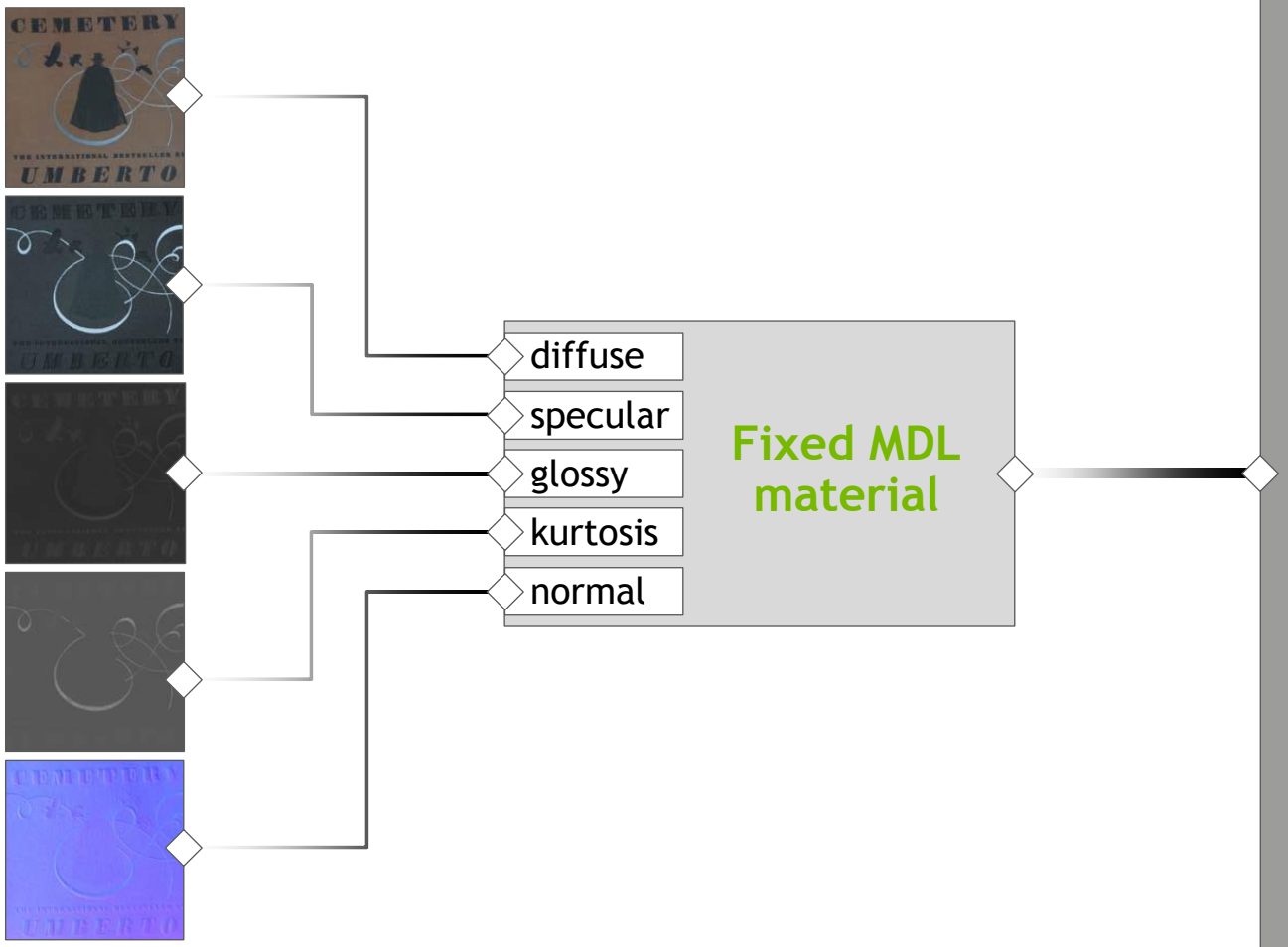
Modules and packages

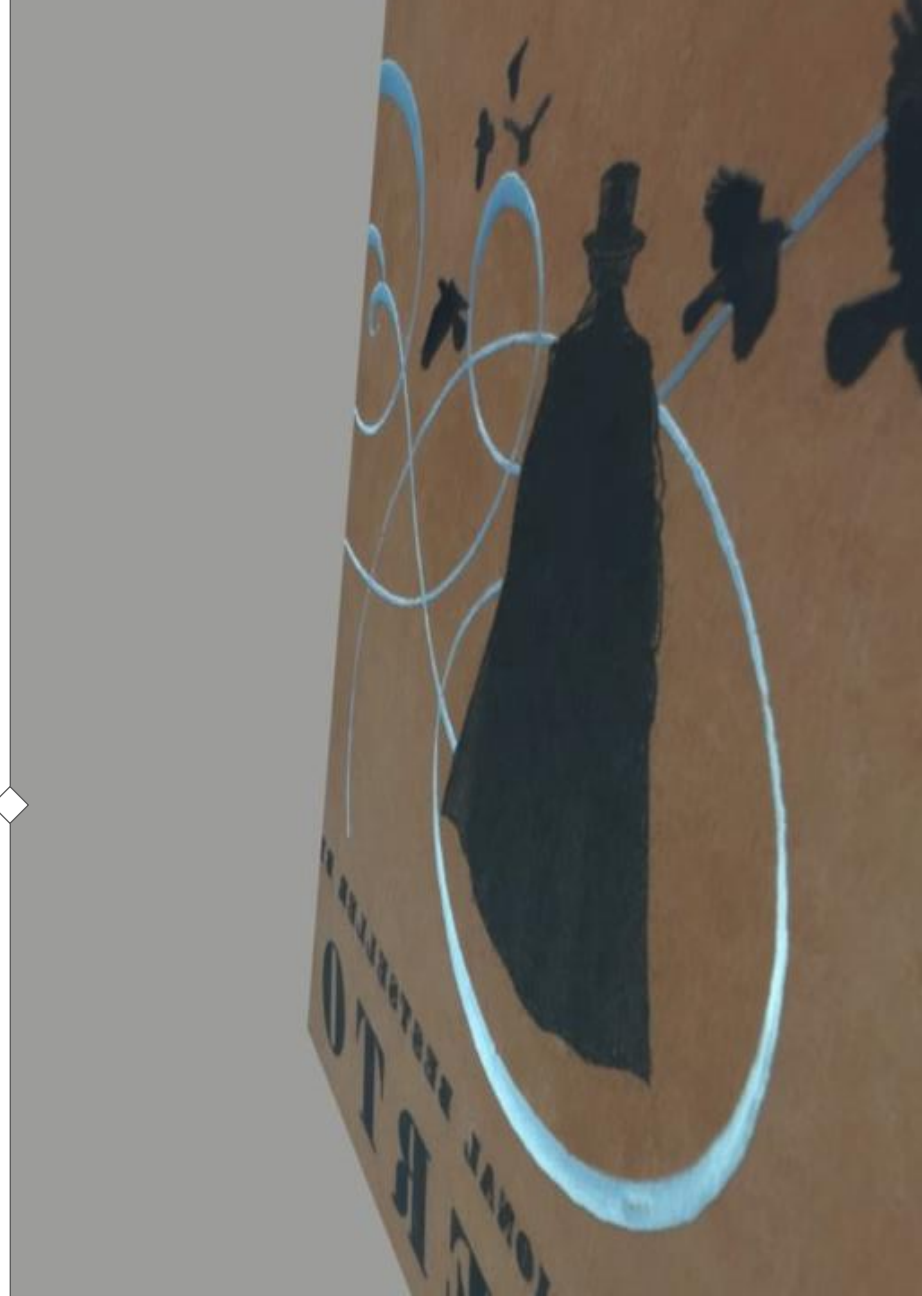
Archives

Measured materials

Spatially Varying (SV)BRDF

Set of textures for an analytic material model

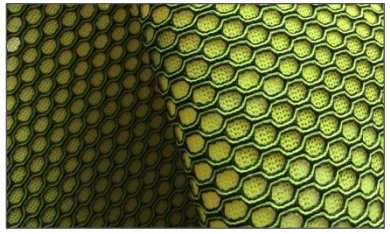




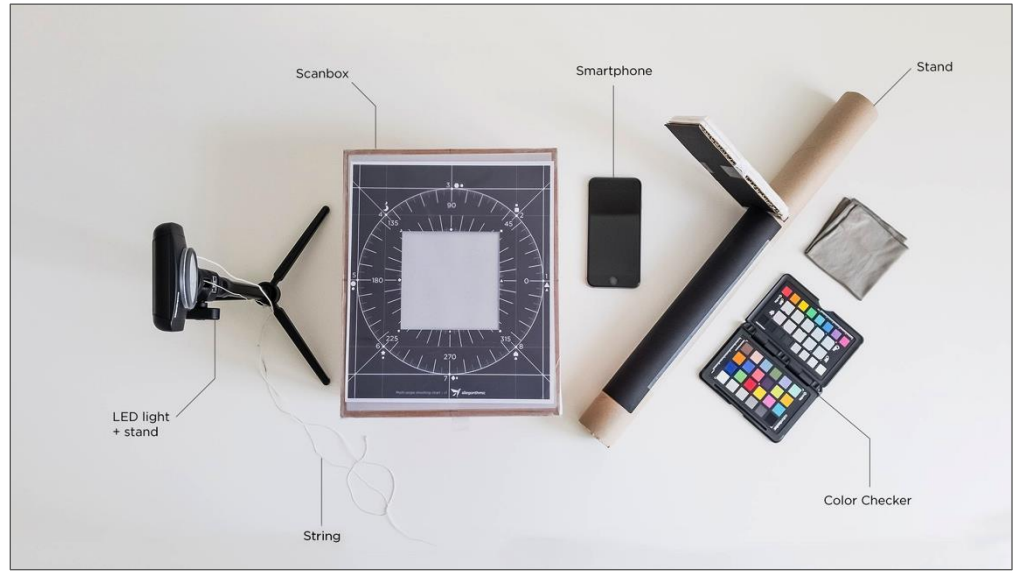
Spatially Varying (SV)BRDF

Allegorithmic: Substance Designer

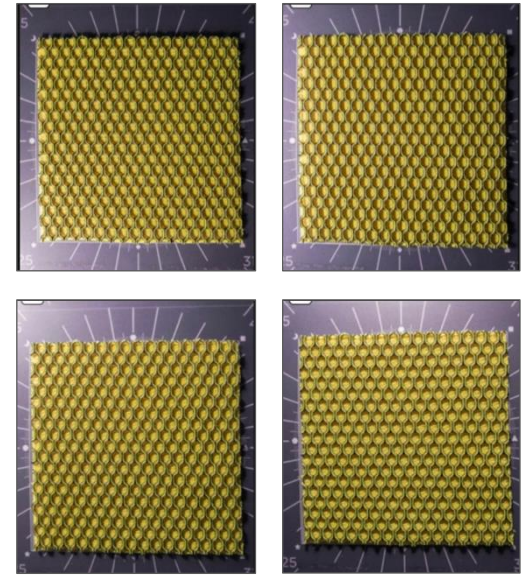
Sample



Simple acquisition method



Raw measurements

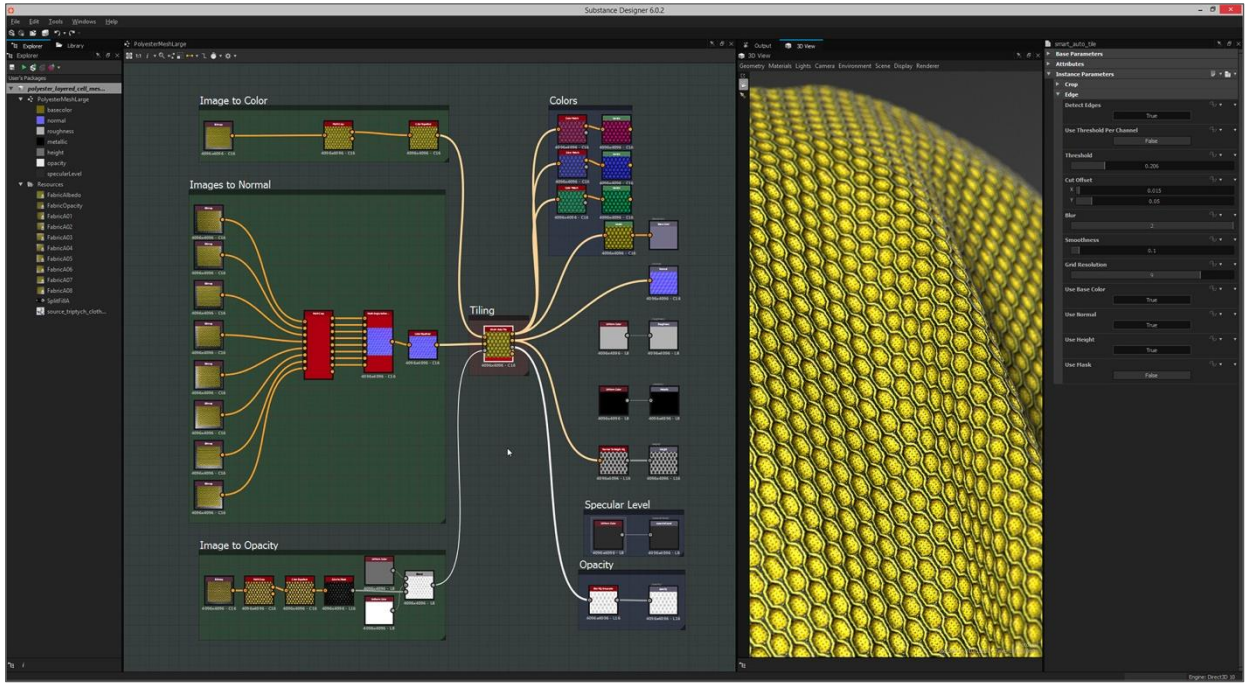


Images courtesy of Allegorithmic

Spatially Varying (SV)BRDF

Allegorithmic: Substance Designer

Postprocessing with Substance Designer: crop, repair, tile

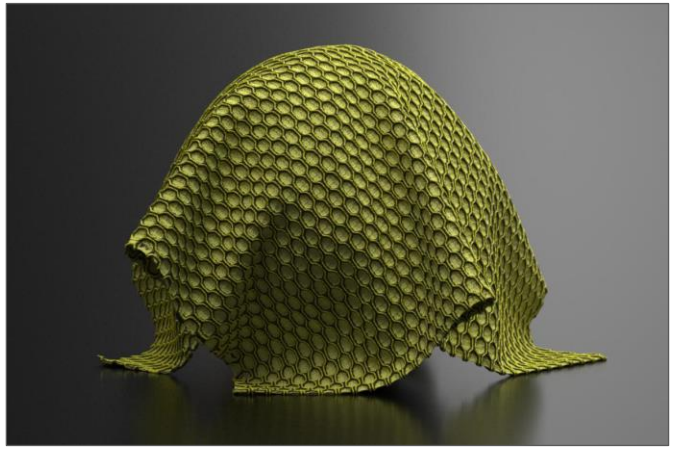


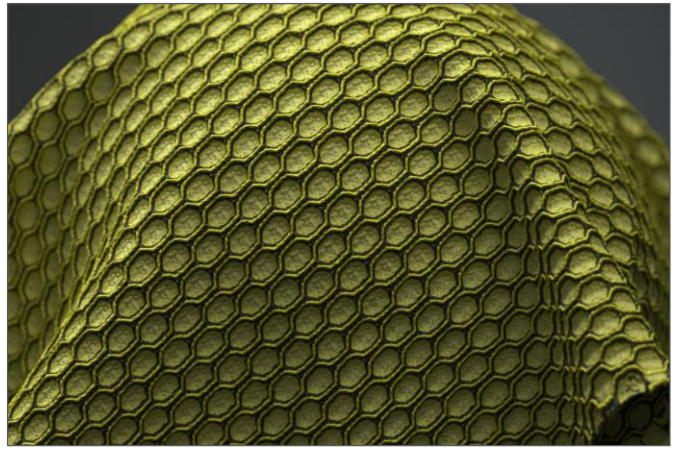
Images courtesy of Allegorithmic

Spatially Varying (SV)BRDF

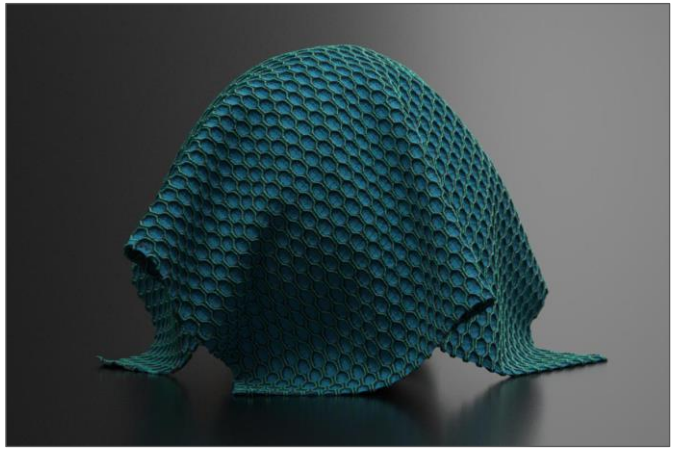
Allegorithmic: Substance Designer

Render with Iray and export to MDL





Easy modifications



Images courtesy of Allegorithmic

Spatially Varying (SV)BRDF

X-Rite: TAC 7, Pantora, AxF file format

Sample

TAC 7

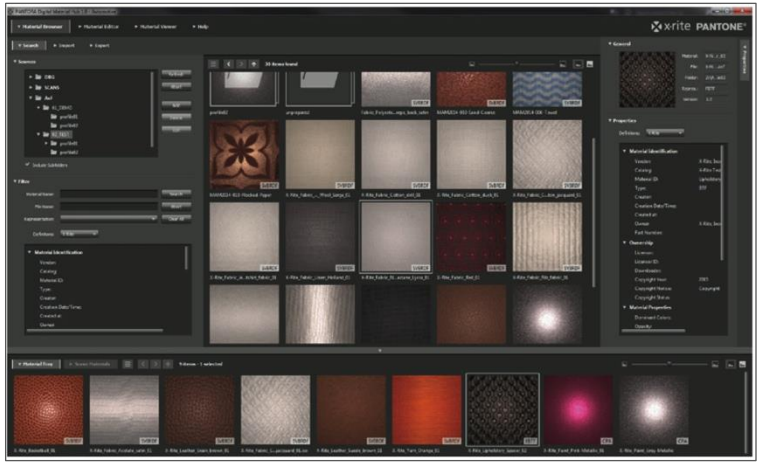
Virtual Lightbooth

Images courtesy of X-Rite

Spatially Varying (SV)BRDF

X-Rite: TAC 7, Pantora, AxF file format

Pantora

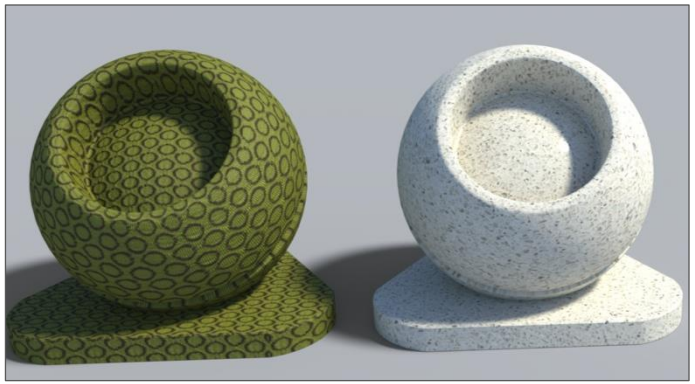


Images courtesy of X-Rite

Spatially Varying (SV)BRDF

X-Rite: TAC 7, Pantora, AxF file format

AxF file format importer to Iray and MDL



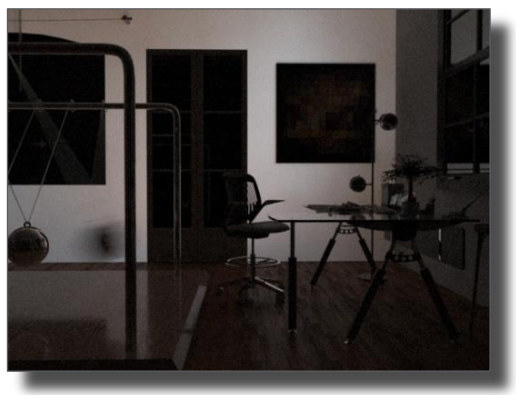
Added dirt with MDL layers

Substance Designer combines AxF and MDL

Images courtesy of X-Rite

Light Path Expressions

Paths that interact with wall



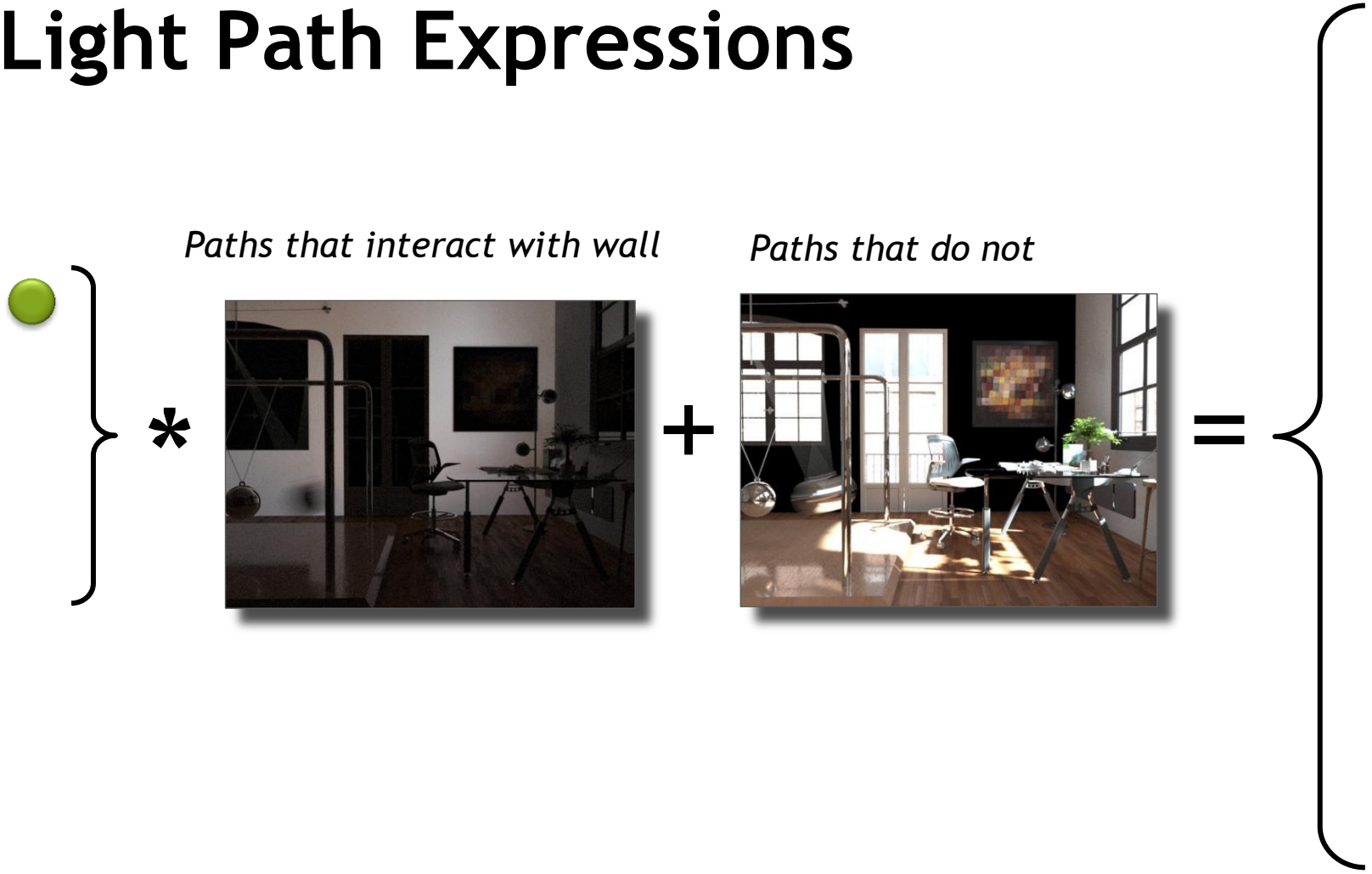
+

Paths that do not

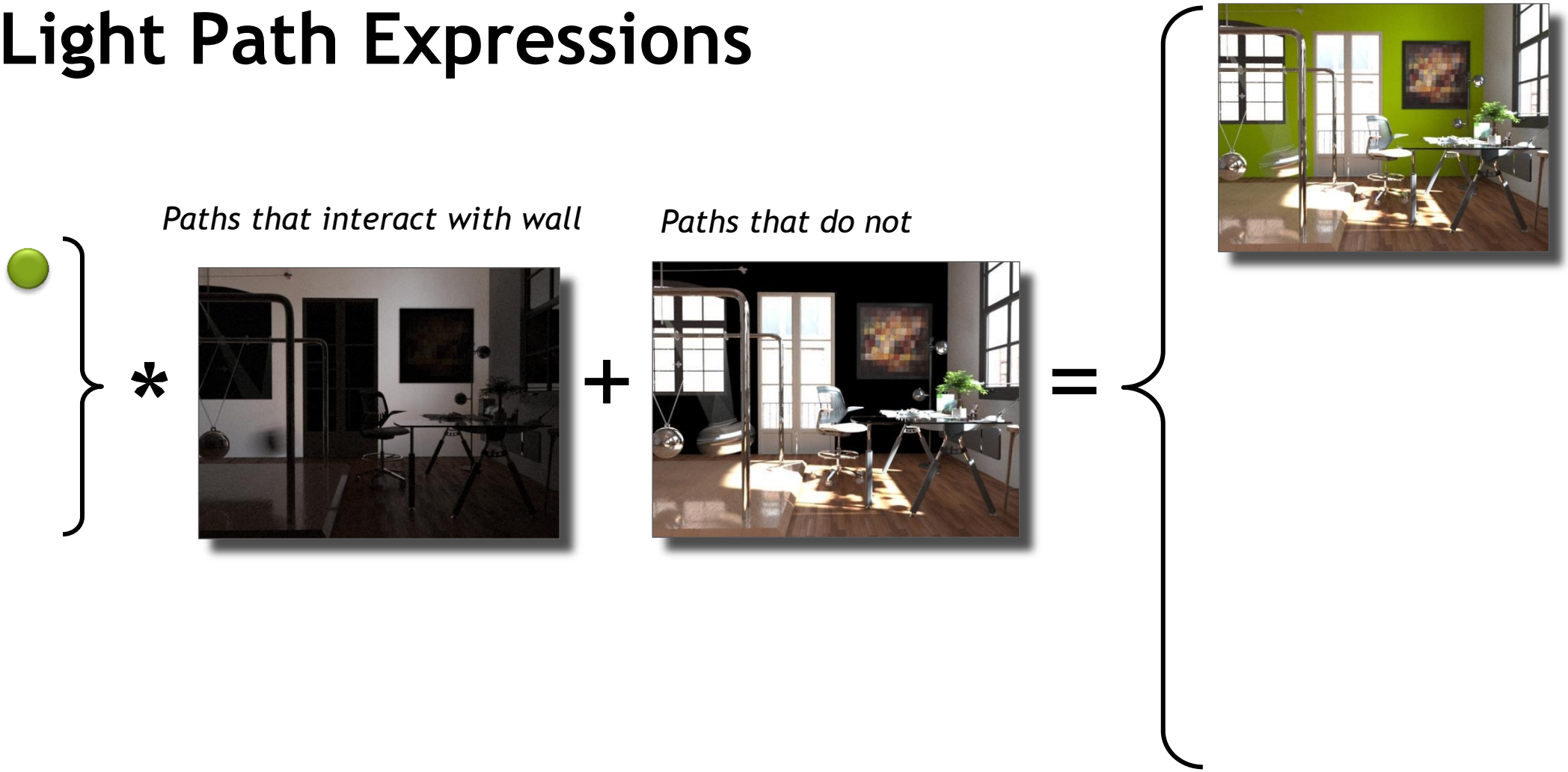
Light Path Expressions

Paths that interact with wall

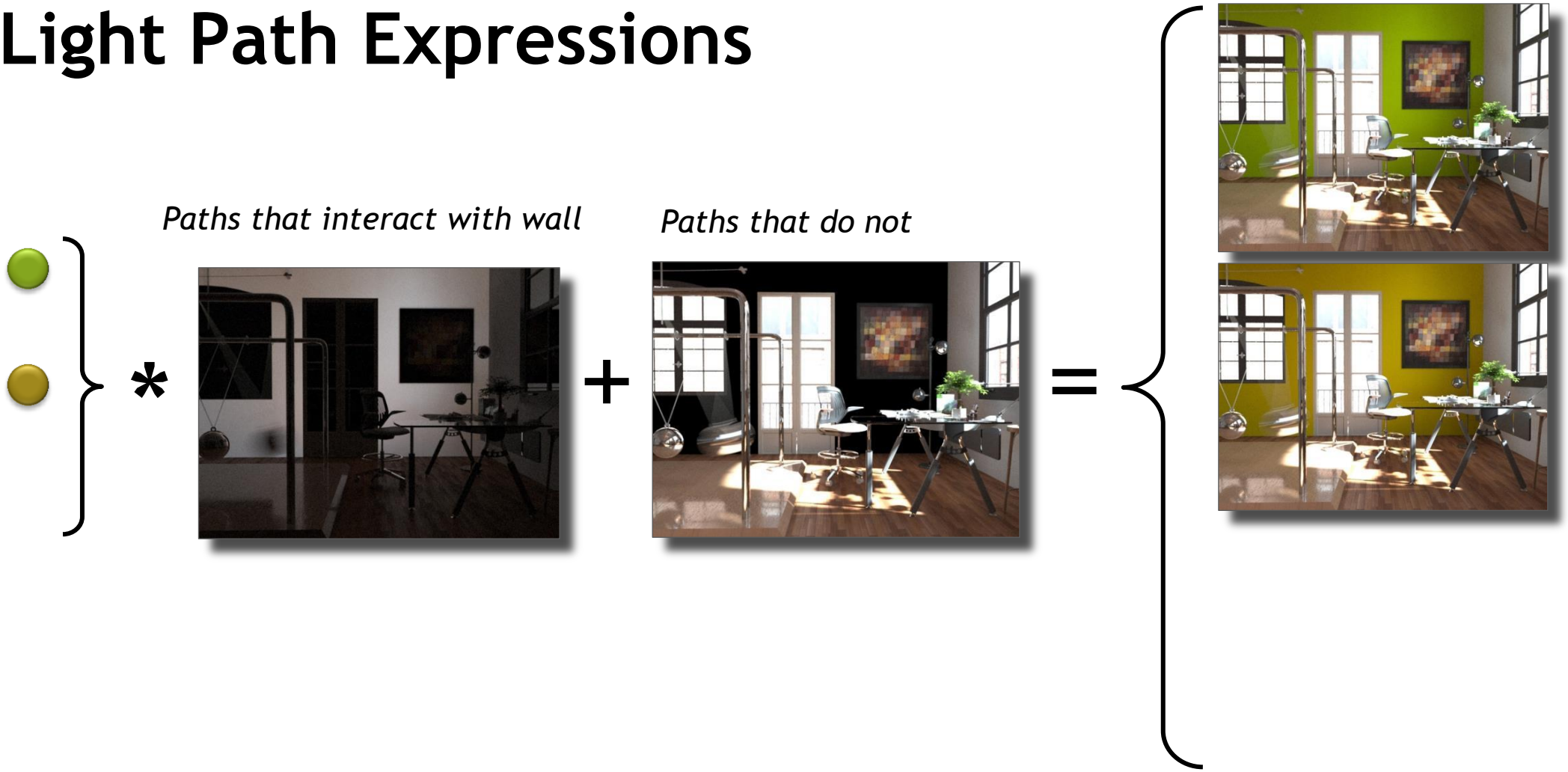
Paths that do not



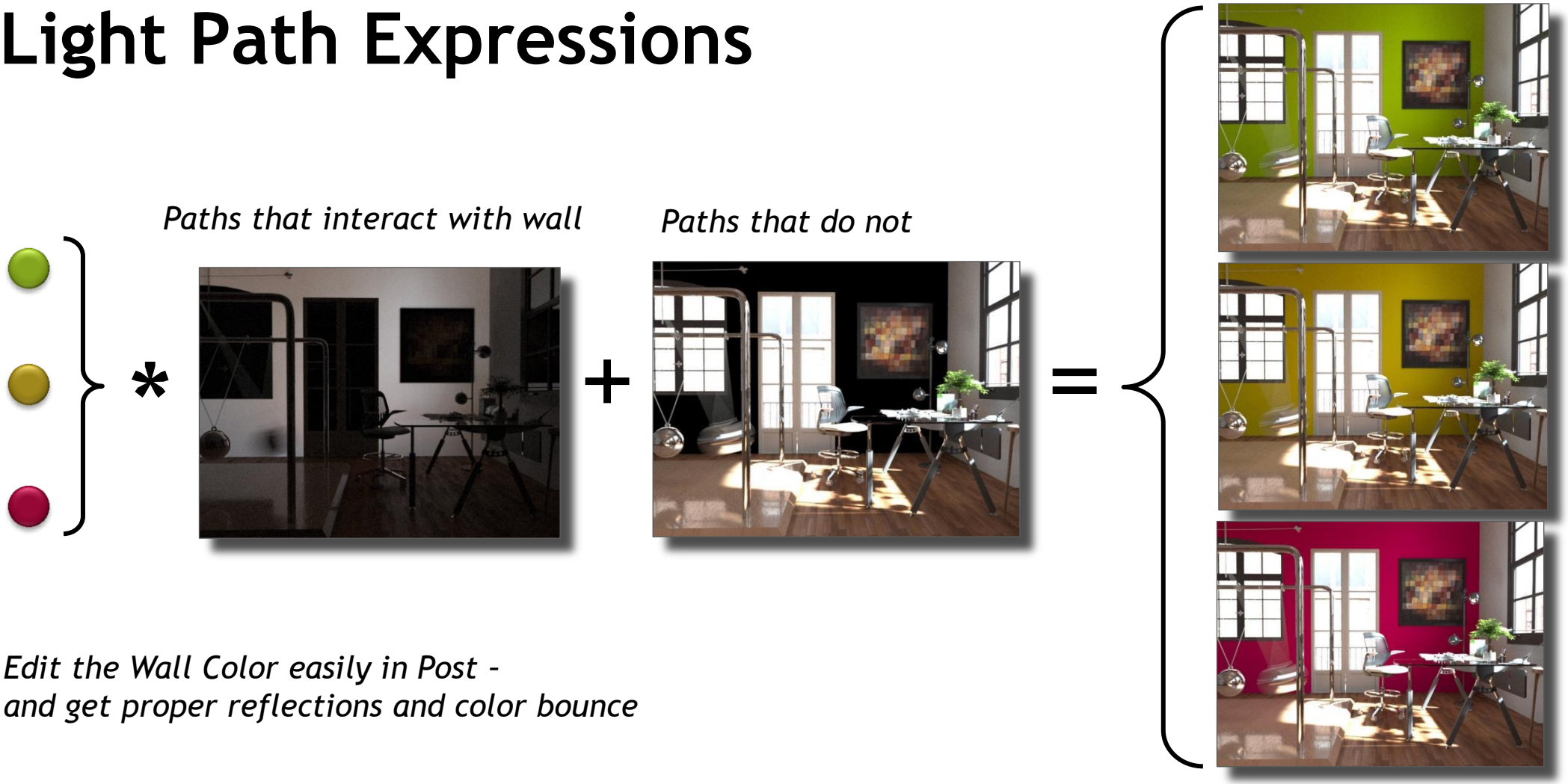
Light Path Expressions



Light Path Expressions



Light Path Expressions

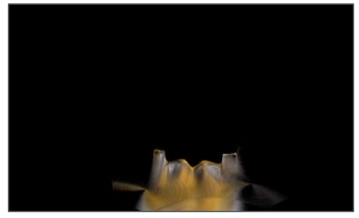


Edit the Wall Color easily in Post -
and get proper reflections and color bounce

MDL Complements Light Path Expressions

LPEs can select individual DF components

Light falling onto the ground without first passing through the glass



Caustics cast by the glass

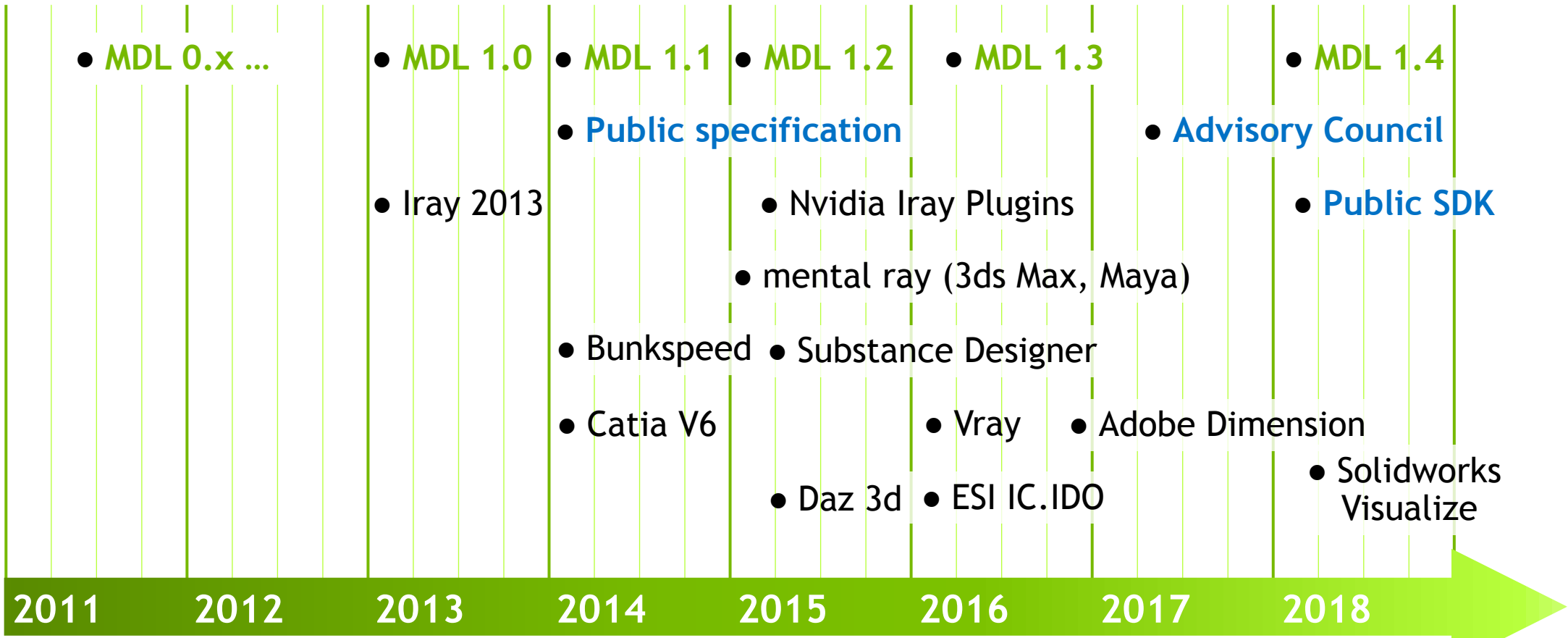
Specular reflections on the glass

Specular reflections on the ice cube

All remaining interactions

MDL ecosystem

MDL – Past, Present and Future



MDL Advisory Council

Companies sharing our vision of MDL

Joint direction of MDL and the MDL eco system

Include expertise other companies have gained in the field and with MDL

NVIDIA Iray

Shipping integrally within commercial products

DASSAULT SYSTEMES

Catia V6 and Industrial Designer

allegorithmic

Substance Designer & Painter

DAZ 3D

DAZ Studio

LUMISCAPHE

Patchwork 3D

SOLIDWORKS

Visualize

SIEMENS PLM

NX 11

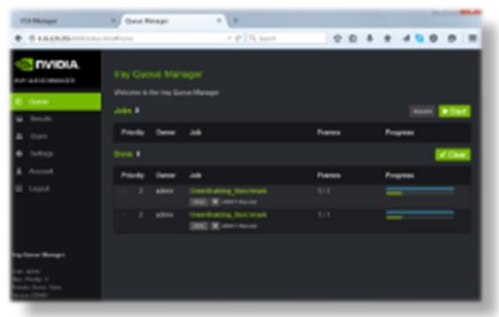
migenius

SketchUp

Iray Plugin Solutions

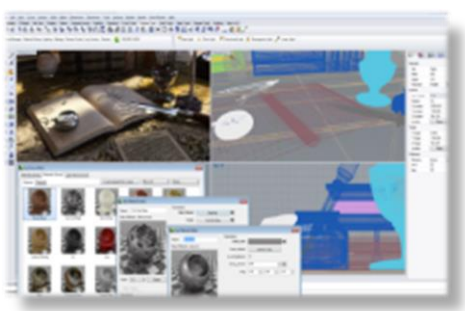
www.irayplugins.com

Iray for 3ds Max



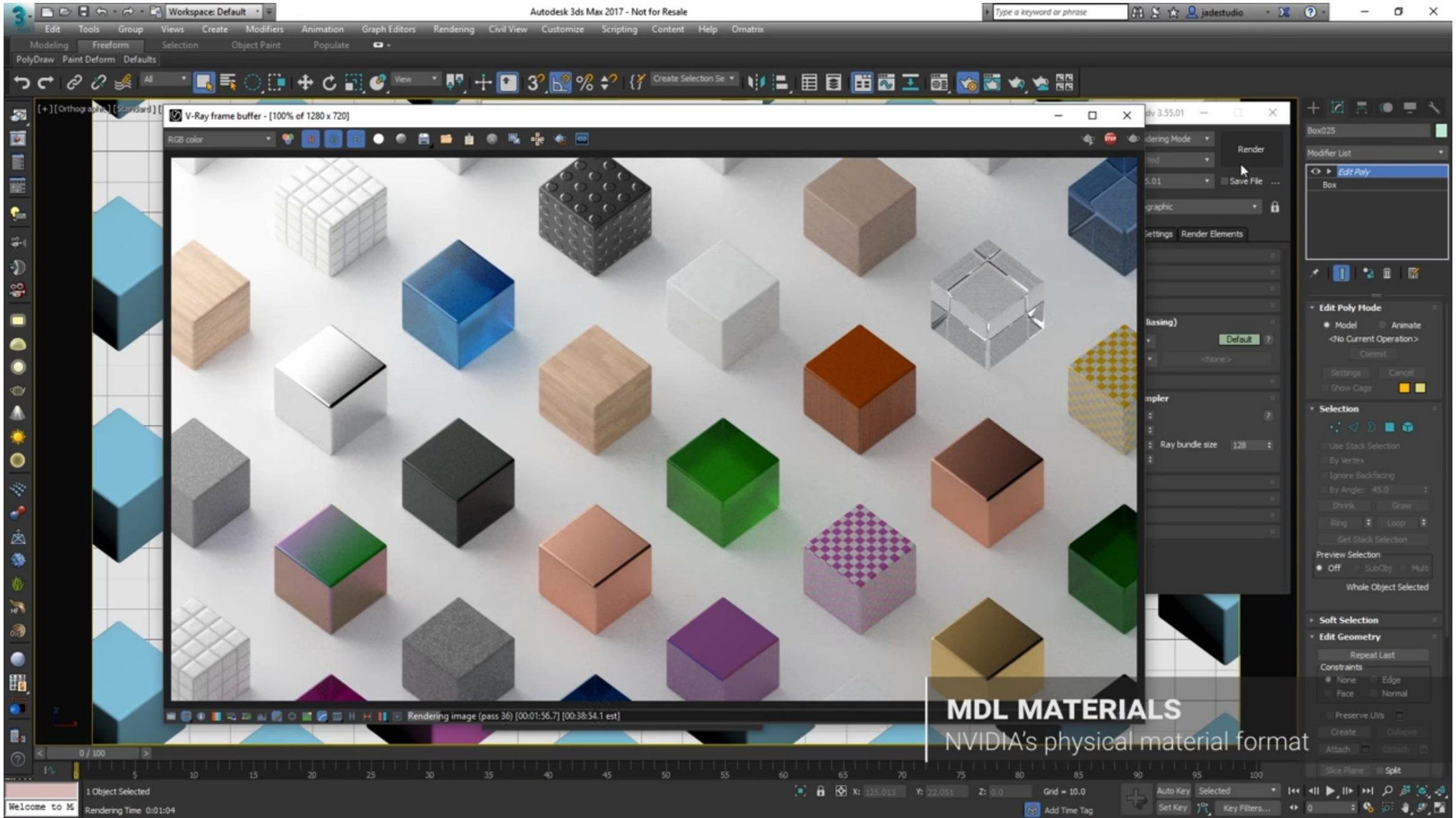
Iray Server

Iray for Maya



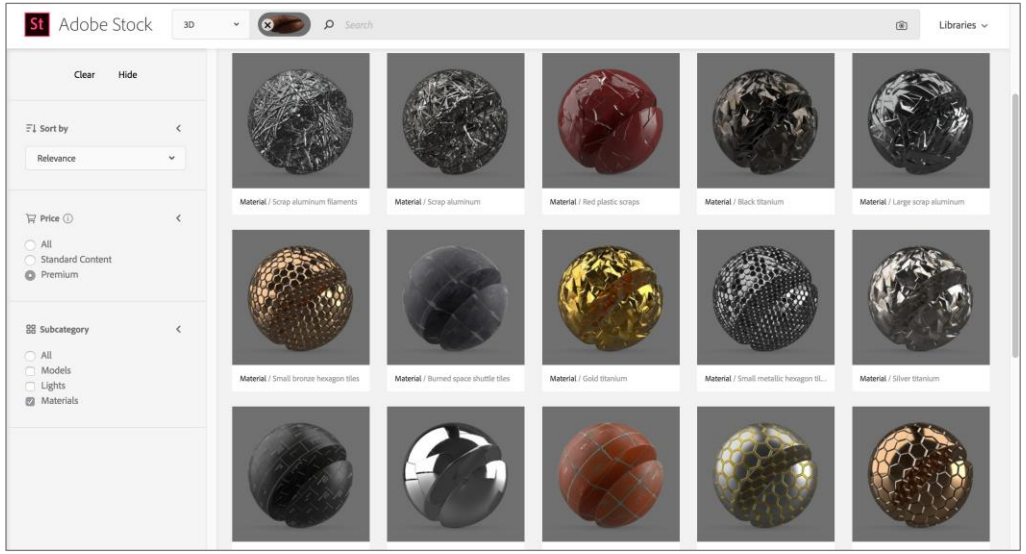
Iray for Rhino

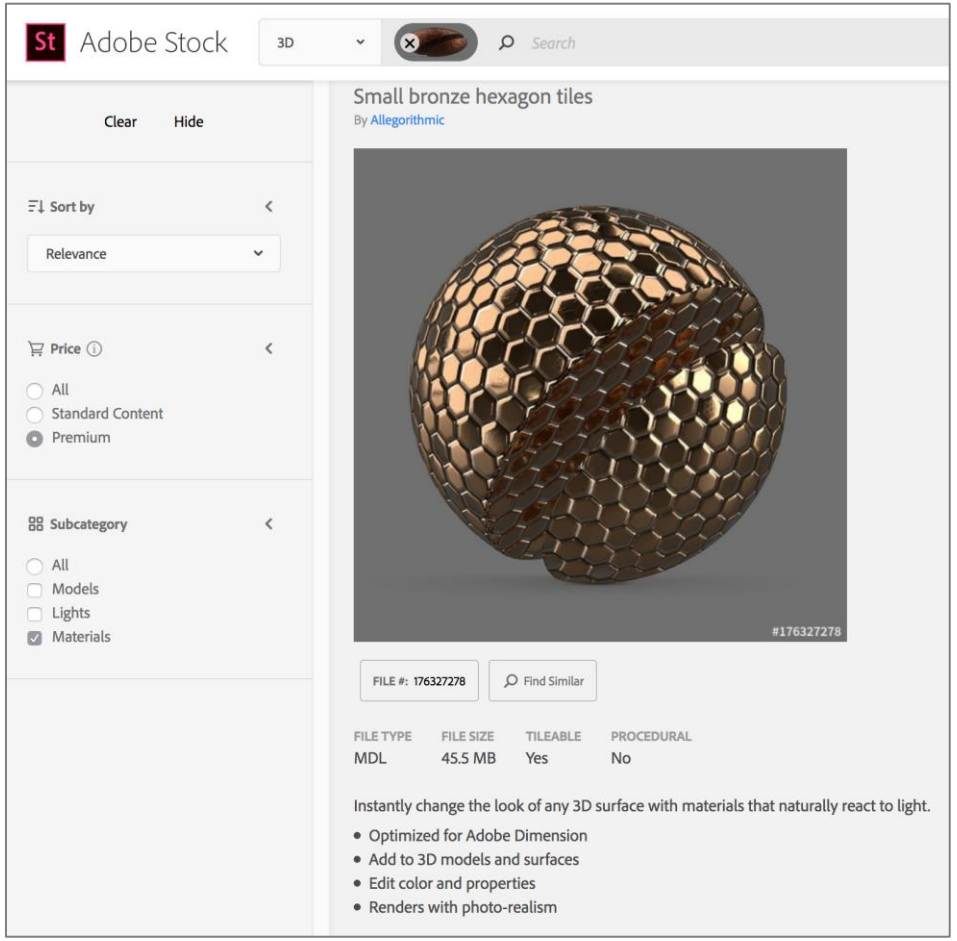
MDL in VRAY


Autodesk 3ds Max 2017 - Not for Resale
V-Ray frame buffer - [100% of 1280 x 720]
Rendering image (pass 36) [00:01:56.7] [00:38:54.1 est]
MDL MATERIALS
NVIDIA's physical material format

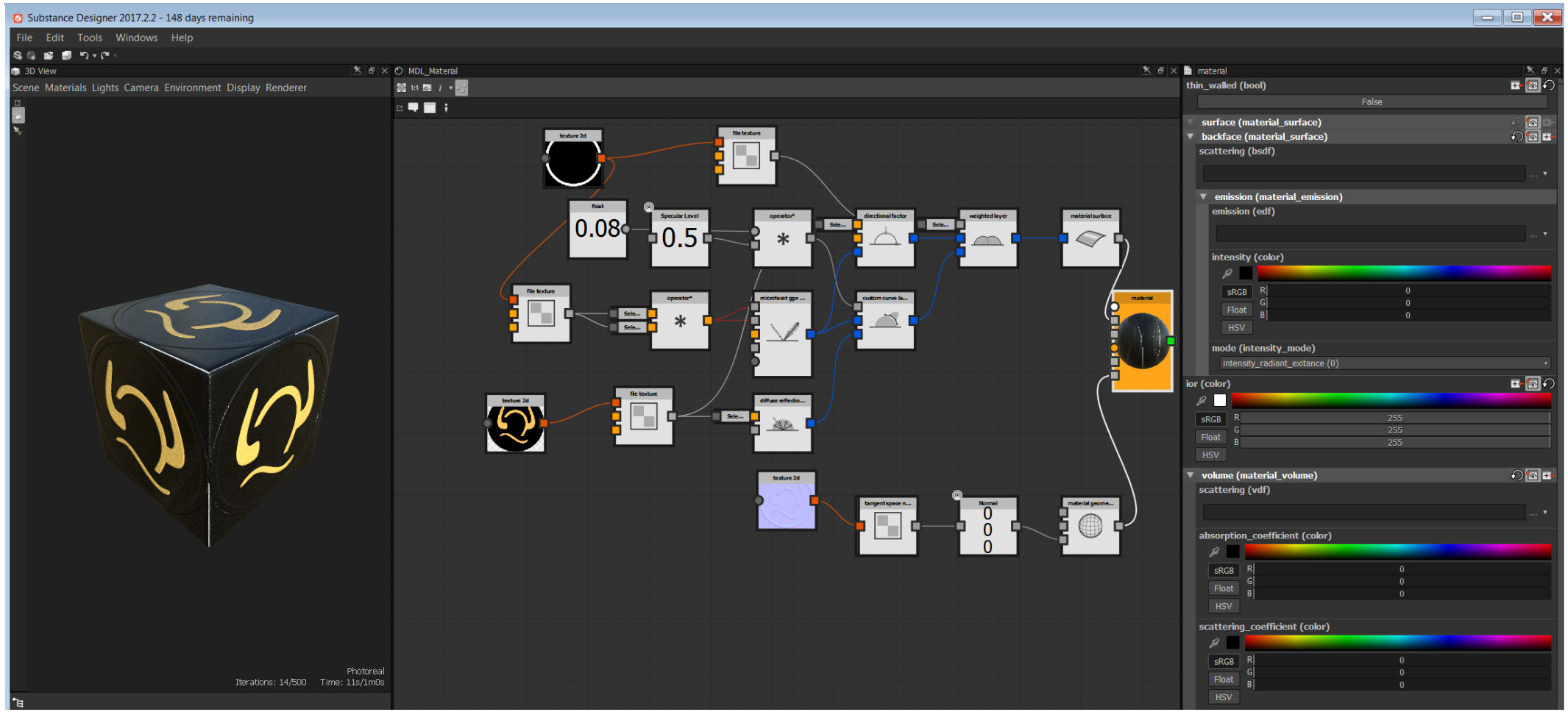
MDL Adobe Dimension and Adobe Stock

http://www.adobe.com/products/dimension.html

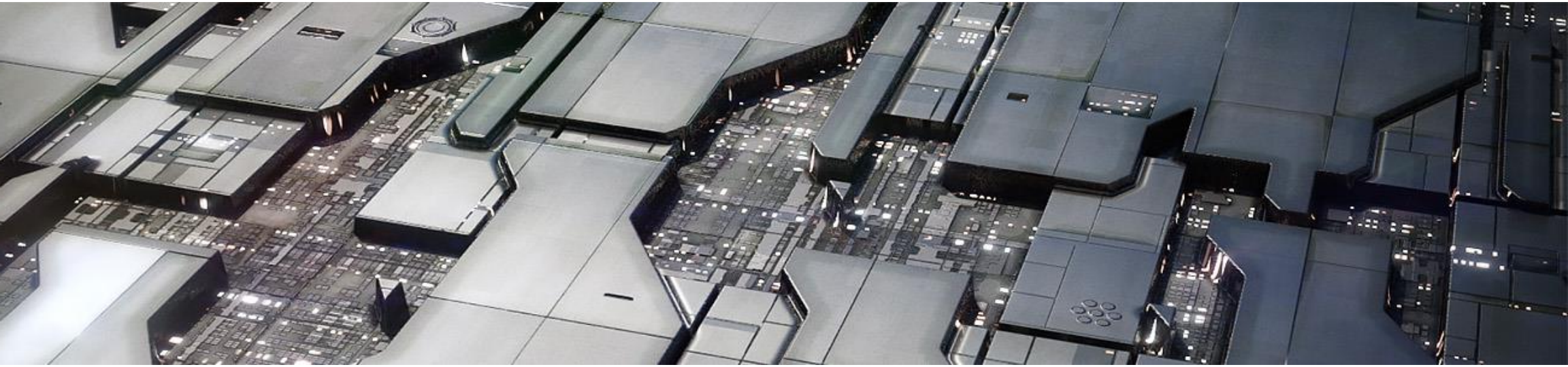




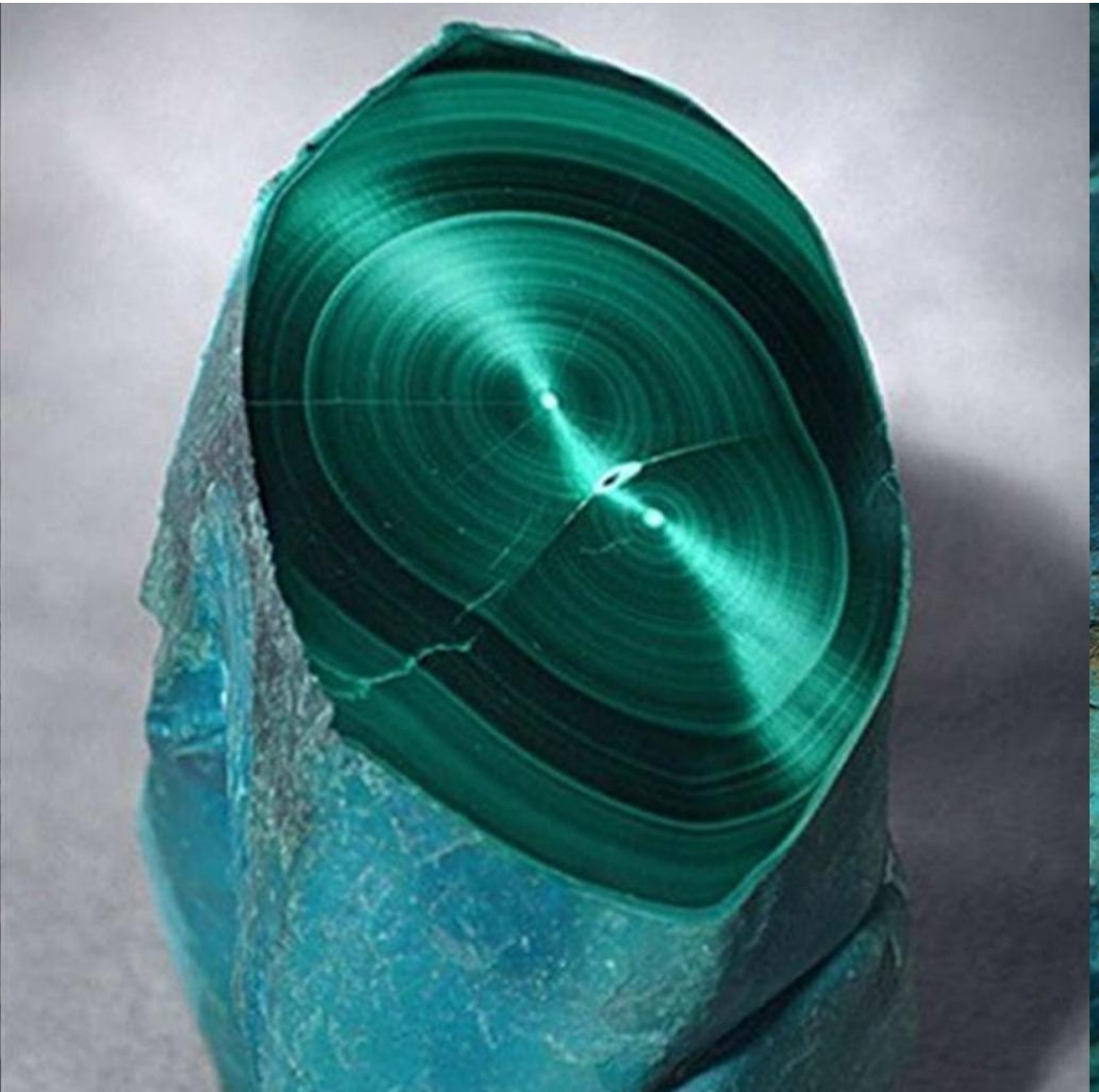
MDL in Substance Designer

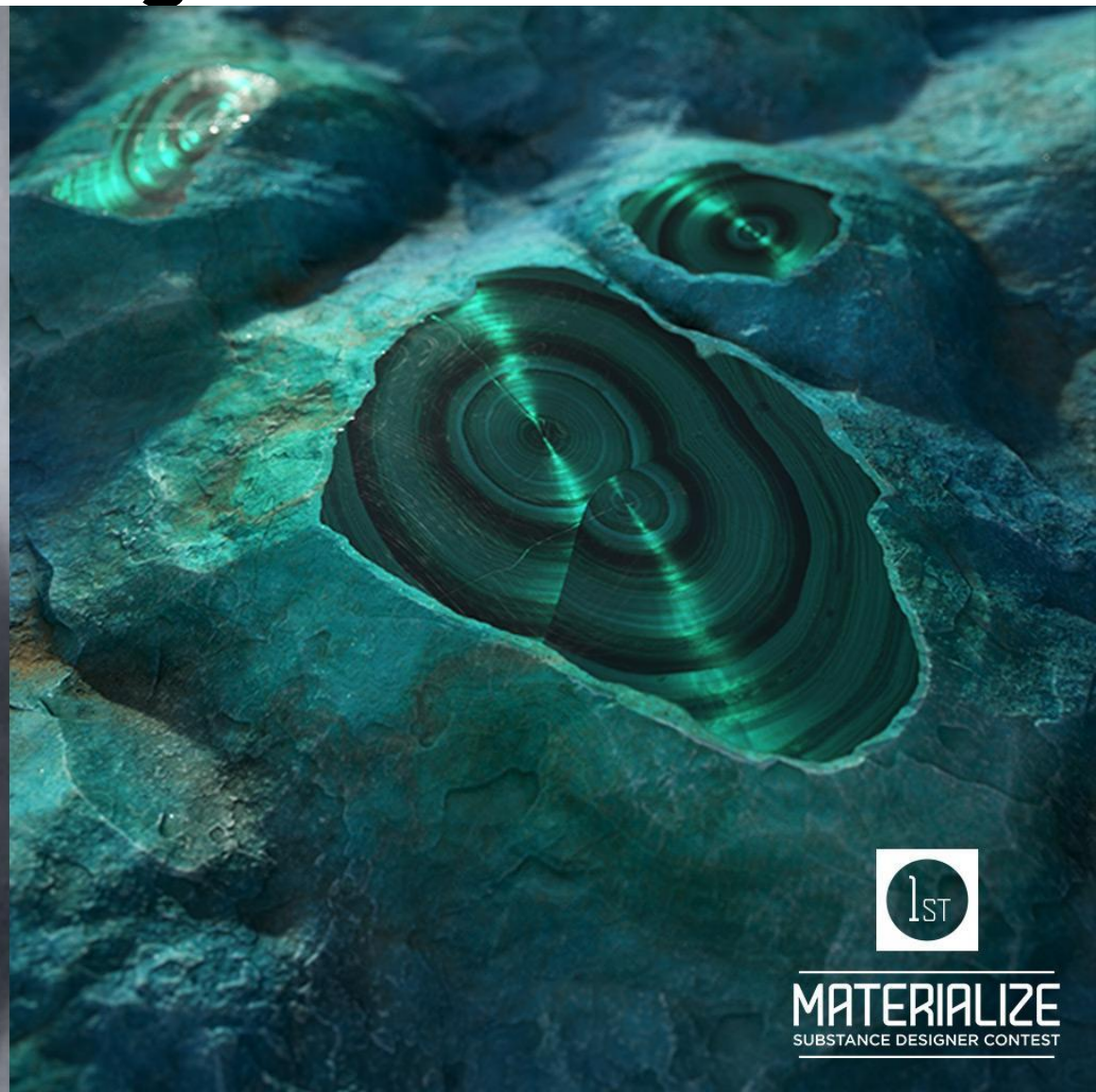


MDL in Substance Designer



MDL in Substance Designer

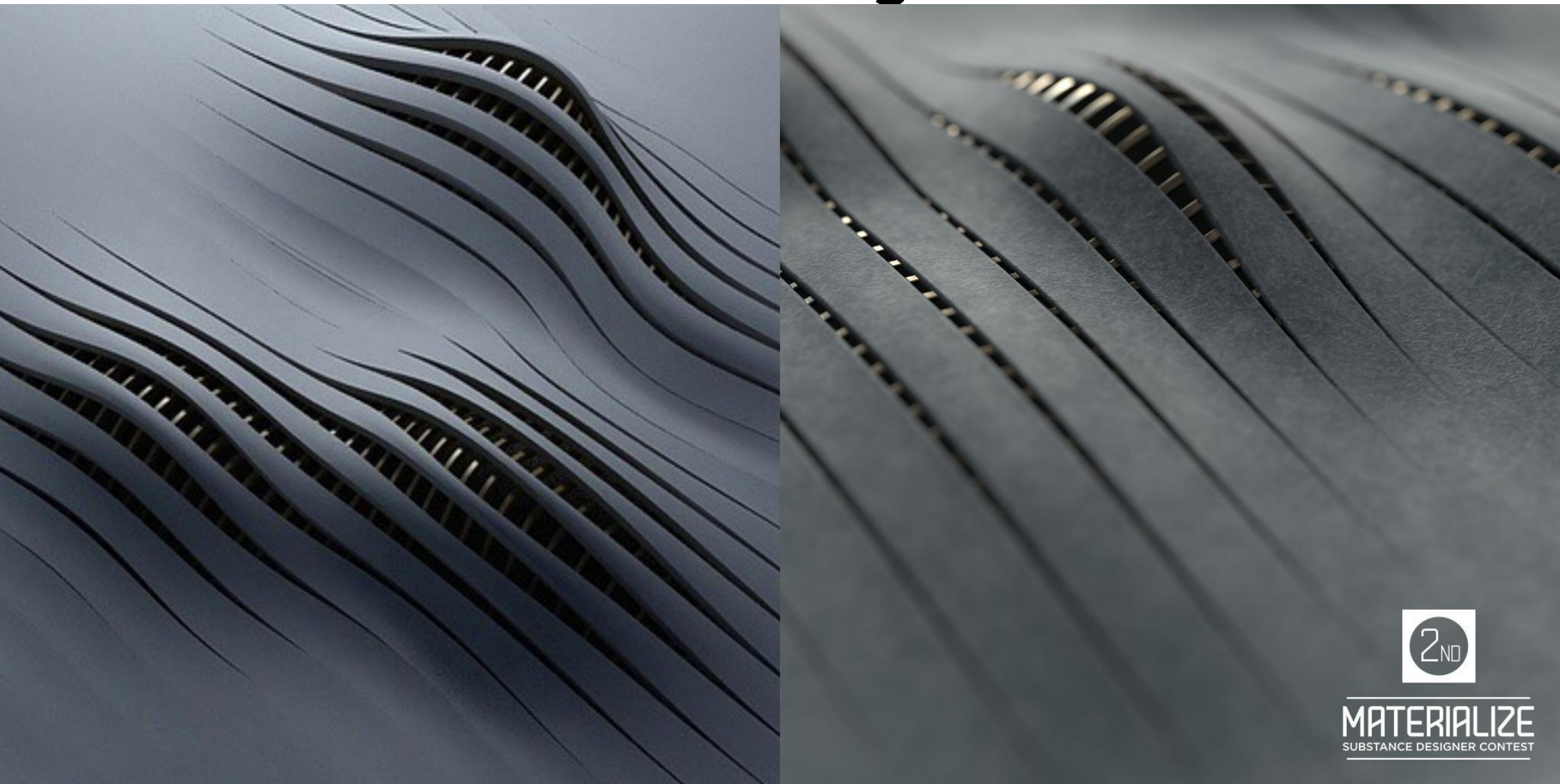




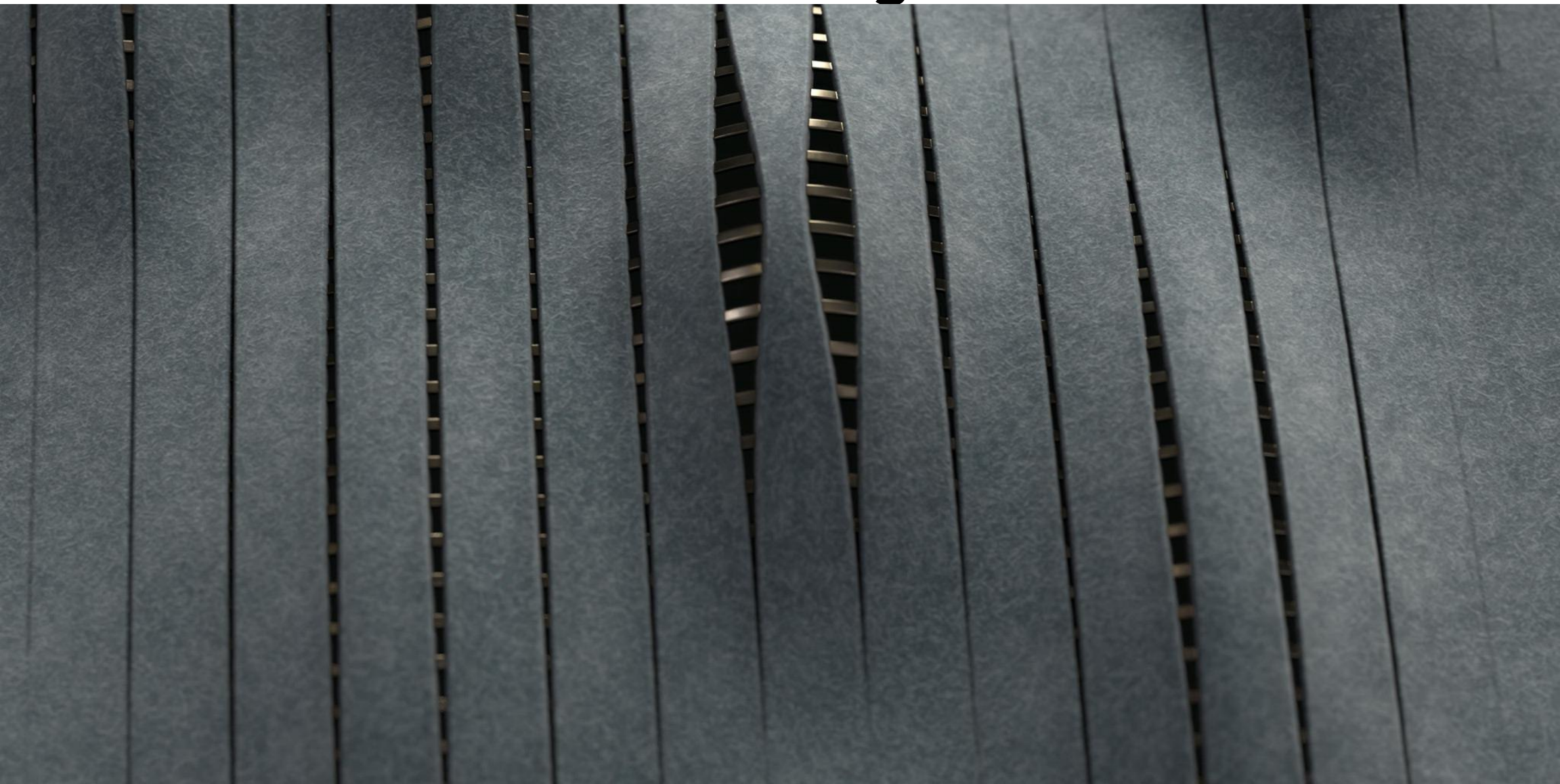
Mark Foreman Malachite with Chrysocolla

SUBSTANCE DESIGNER

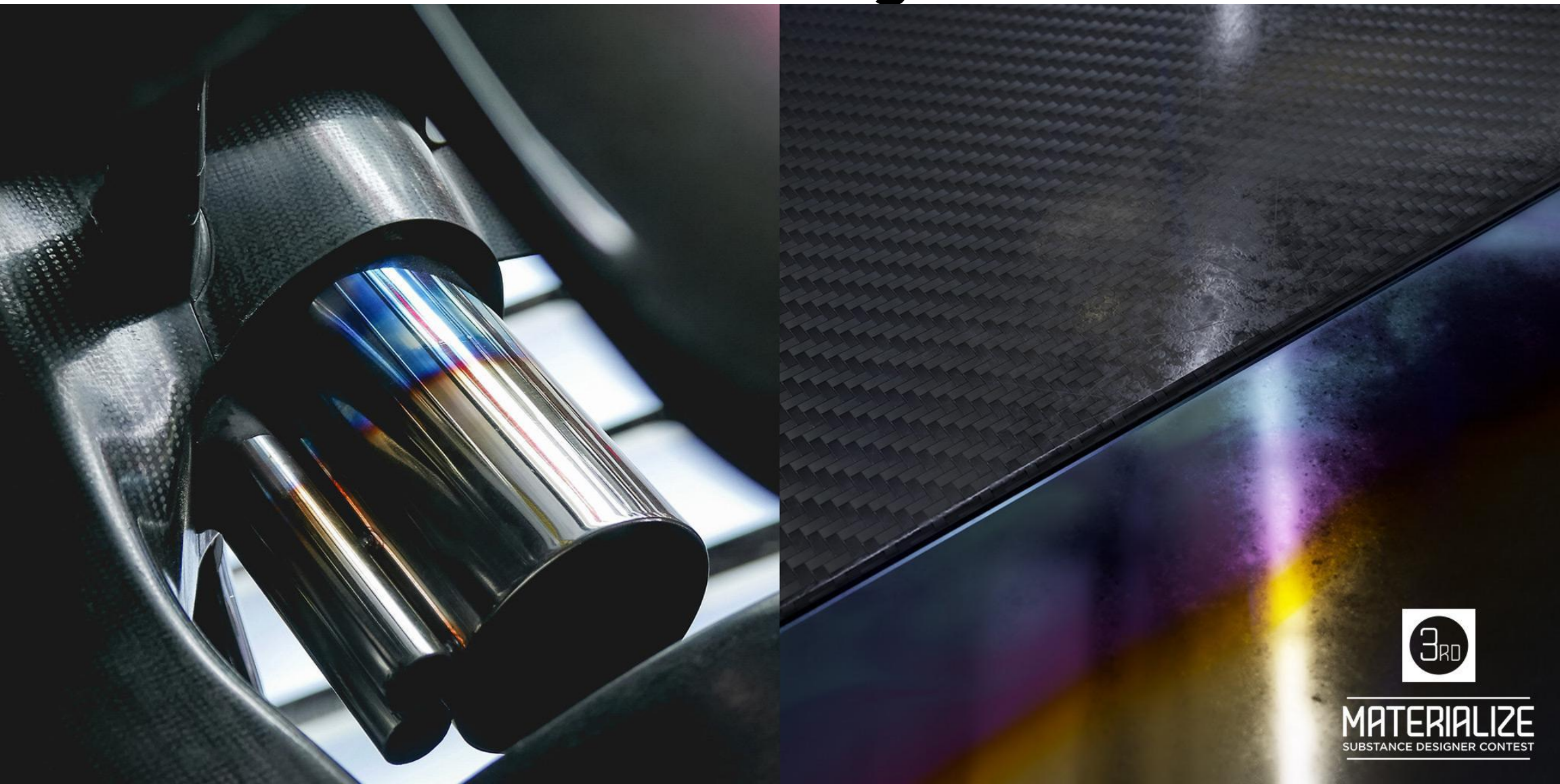
MDL in Substance Designer



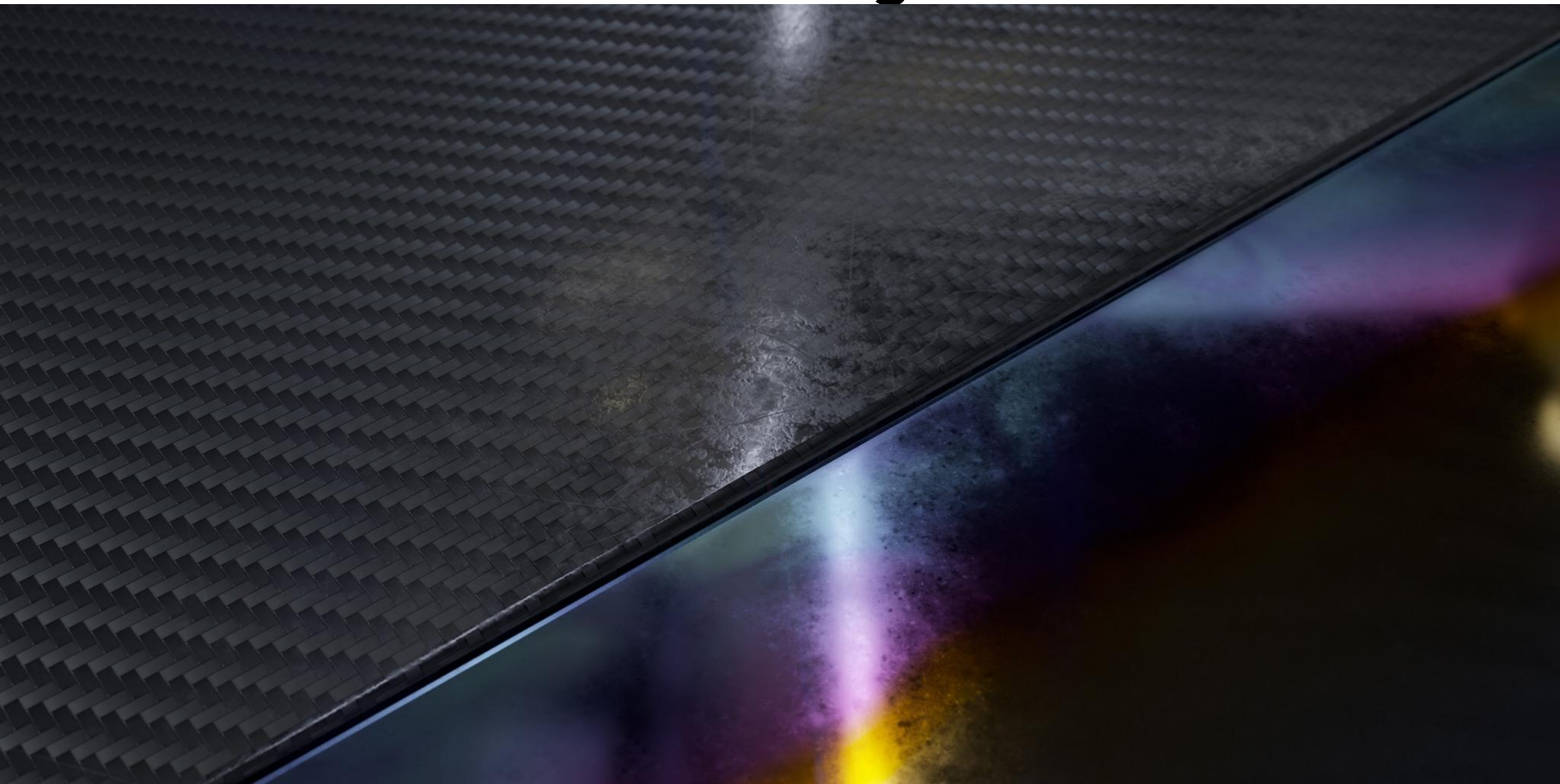
MDL in Substance Designer



MDL in Substance Designer



MDL in Substance Designer



Focus on Material Exchange

Freely choose where to author material content

create

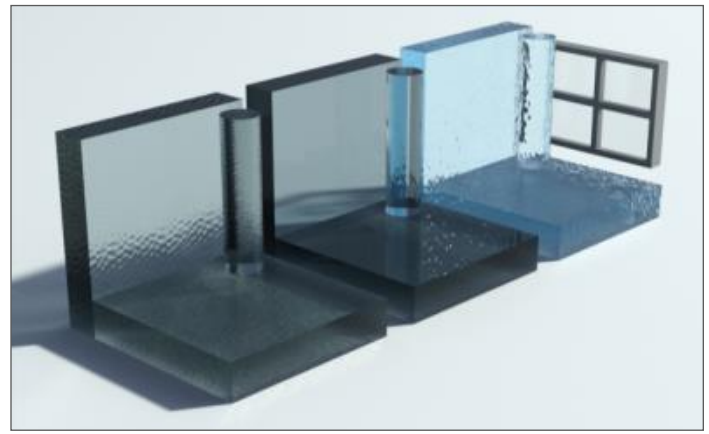
modify

consume

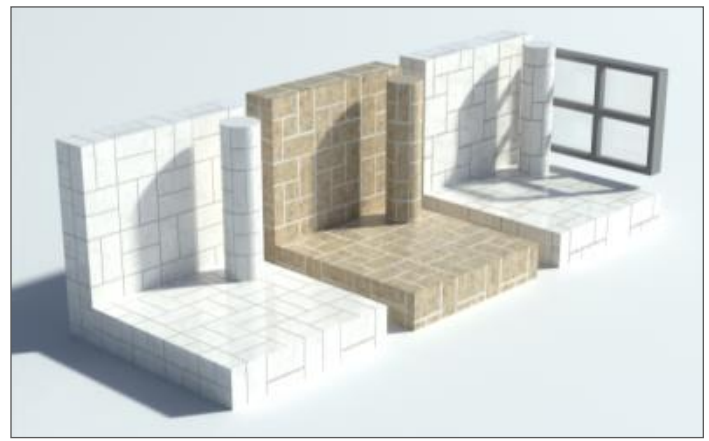
NVIDIA vMaterials 1.4

~1400 MDL materials verified for accuracy - FREE TO USE







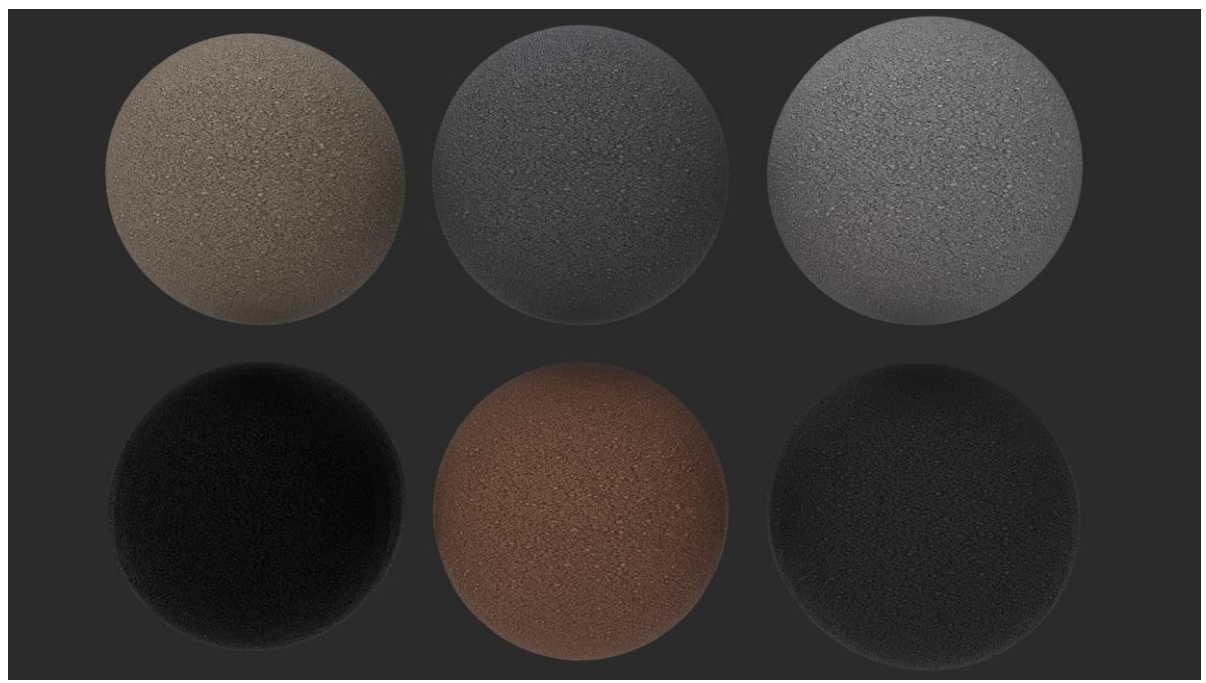
NVIDIA vMaterials 1.5 – Coming Q2 2018

More than 200 new material variants

vMaterials 1.4
ground asphalt

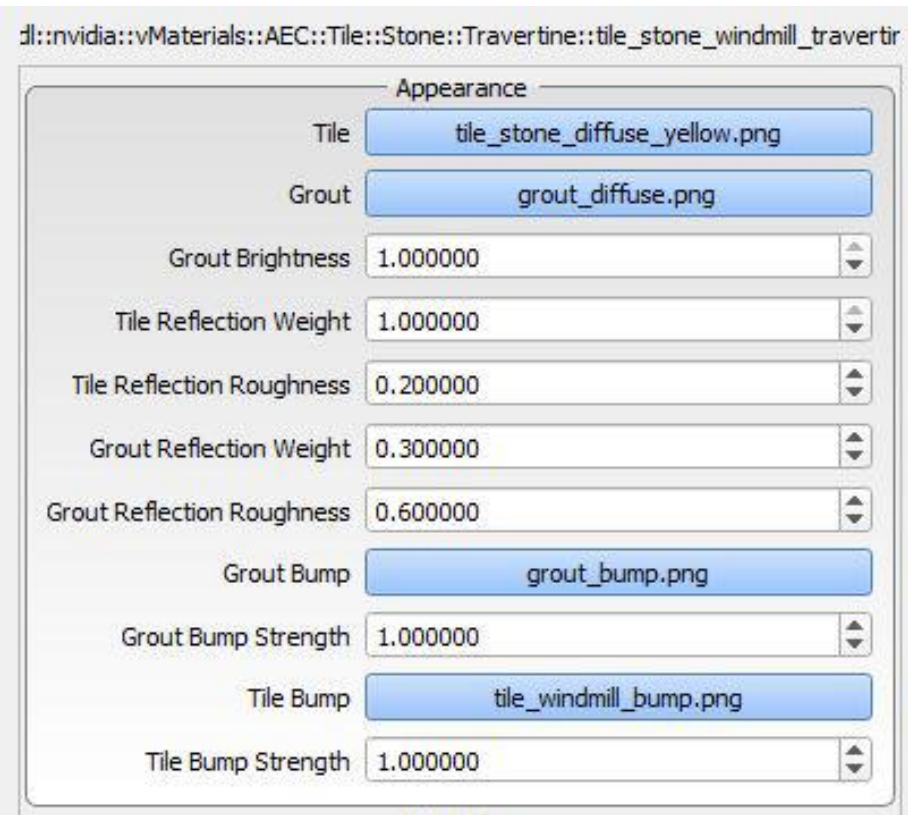
old variant is hidden

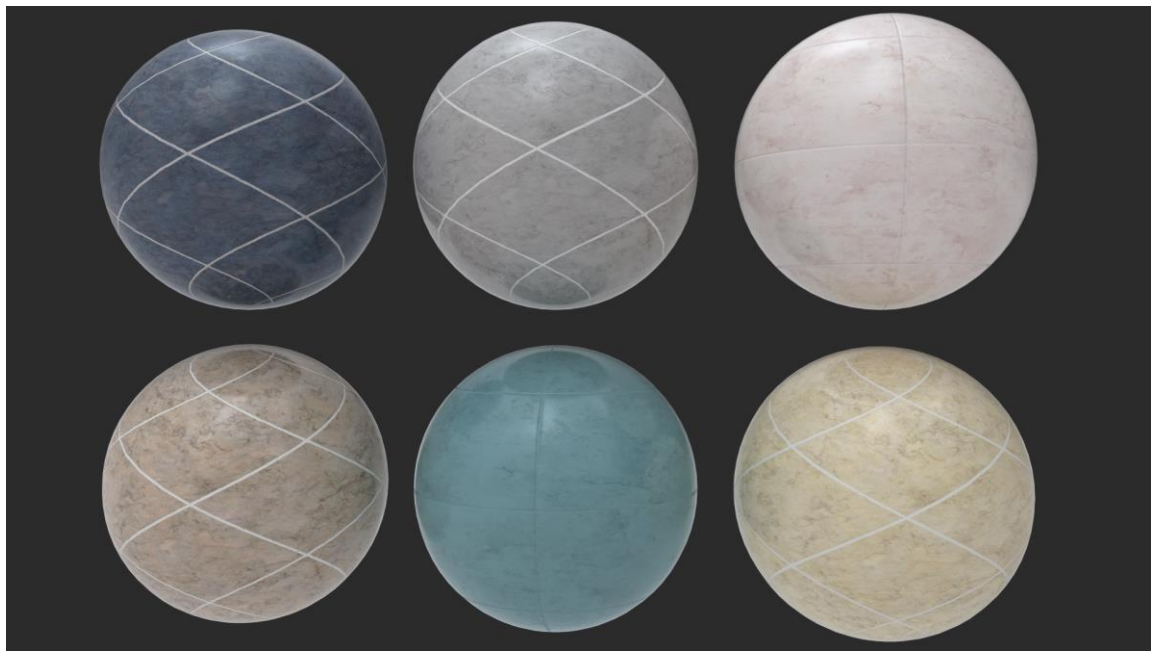
vMaterials 1.5: new presets



NVIDIA vMaterials 1.4

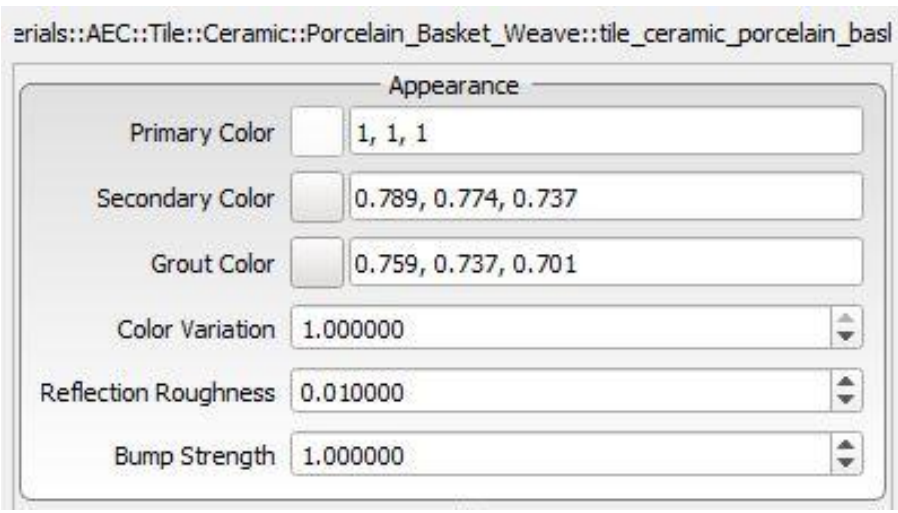
Harder to control parameters and texture parameters

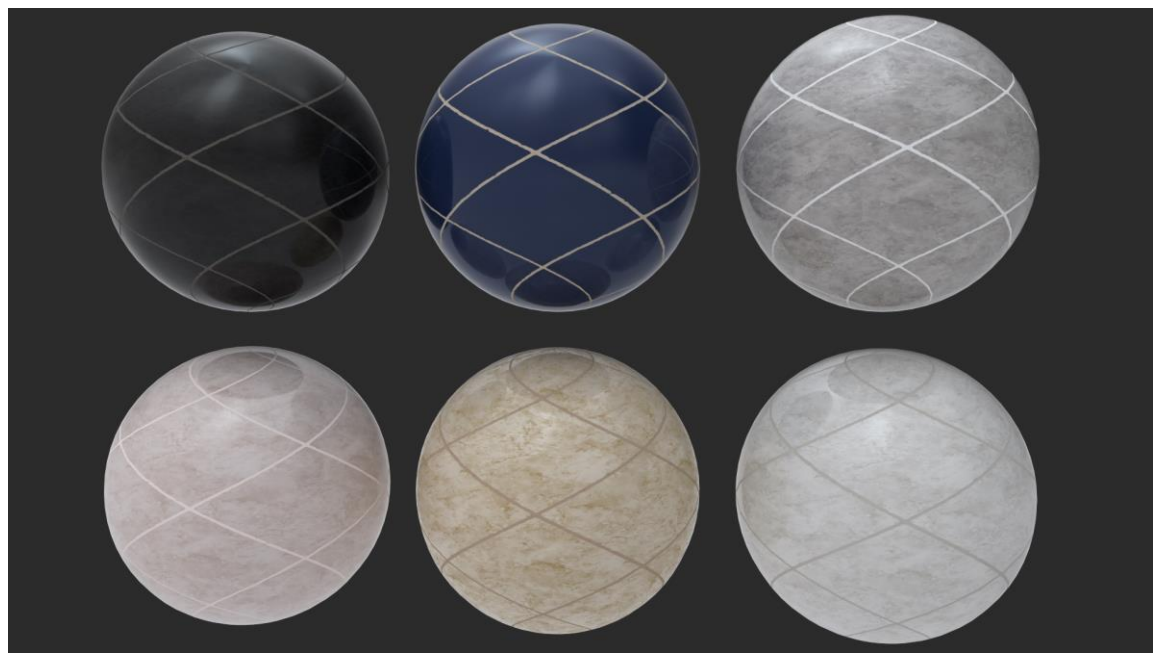




NVIDIA vMaterials 1.5 – Coming Q2 2018

More flexible and user-centric parameters





Become part of the ecosystem

Become Part of the Ecosystem

Integrate MDL enabled renderer

MDL is included

Write your own compiler

Based on the freely available MDL Specification

License the MDL SDK

Contact us for licensing information

Write Your Own Compiler

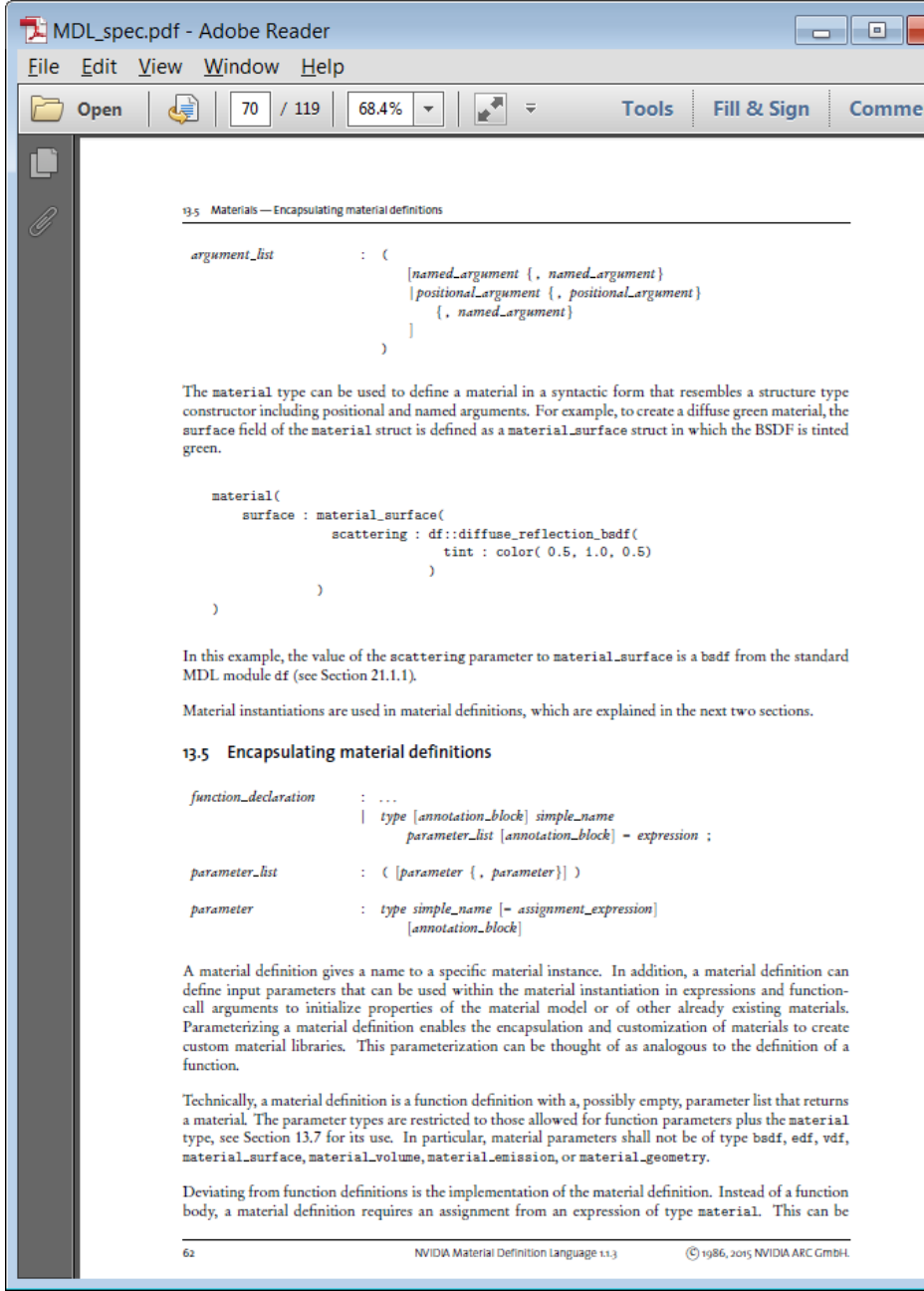
MDL Specification can be downloaded @

http://www.nvidia.com/mdl/

MDL conformance test suite

Syntactic conformance tests - available at request

Semantic conformance tests



MDL_spec.pdf - Adobe Reader

File Edit View Window Help

Open 70 / 119 68.4% Tools Fill & Sign Comme

13.5 Materials — Encapsulating material definitions

```
argument_list   :  (
                     [named_argument { , named_argument }
                     | positional_argument { , positional_argument }
                         { , named_argument }
                     ]
                   )
```

The `material` type can be used to define a material in a syntactic form that resembles a structure type constructor including positional and named arguments. For example, to create a diffuse green material, the `surface` field of the `material` struct is defined as a `material_surface` struct in which the BSDF is tinted green.

```
material(
    surface : material_surface(
                scattering : df::diffuse_reflection_bsdf(
                                tint : color( 0.5, 1.0, 0.5)
                             )
              )
)
```

In this example, the value of the `scattering` parameter to `material_surface` is a `bsdf` from the standard MDL module `df` (see Section 21.1.1).

Material instantiations are used in material definitions, which are explained in the next two sections.

13.5 Encapsulating material definitions

```
function_declaration   :  ...
                       |  type [annotation_block] simple_name
                              parameter_list [annotation_block] = expression ;

parameter_list         :  ( [parameter { , parameter }] )

parameter              :  type simple_name [= assignment_expression]
                              [annotation_block]
```

A material definition gives a name to a specific material instance. In addition, a material definition can define input parameters that can be used within the material instantiation in expressions and function-call arguments to initialize properties of the material model or of other already existing materials. Parameterizing a material definition enables the encapsulation and customization of materials to create custom material libraries. This parameterization can be thought of as analogous to the definition of a function.

Technically, a material definition is a function definition with a, possibly empty, parameter list that returns a material. The parameter types are restricted to those allowed for function parameters plus the `material` type, see Section 13.7 for its use. In particular, material parameters shall not be of type `bsdf`, `edf`, `vdf`, `material_surface`, `material_volume`, `material_emission`, or `material_geometry`.

Deviating from function definitions is the implementation of the material definition. Instead of a function body, a material definition requires an assignment from an expression of type `material`. This can be

62 NVIDIA Material Definition Language 1.1.3 © 1986, 2015 NVIDIA ARC GmbH.

MDL SDK 2018.0

Features

MDL 1.4

DB for MDL definitions

DAG view on materials
several compilation modes

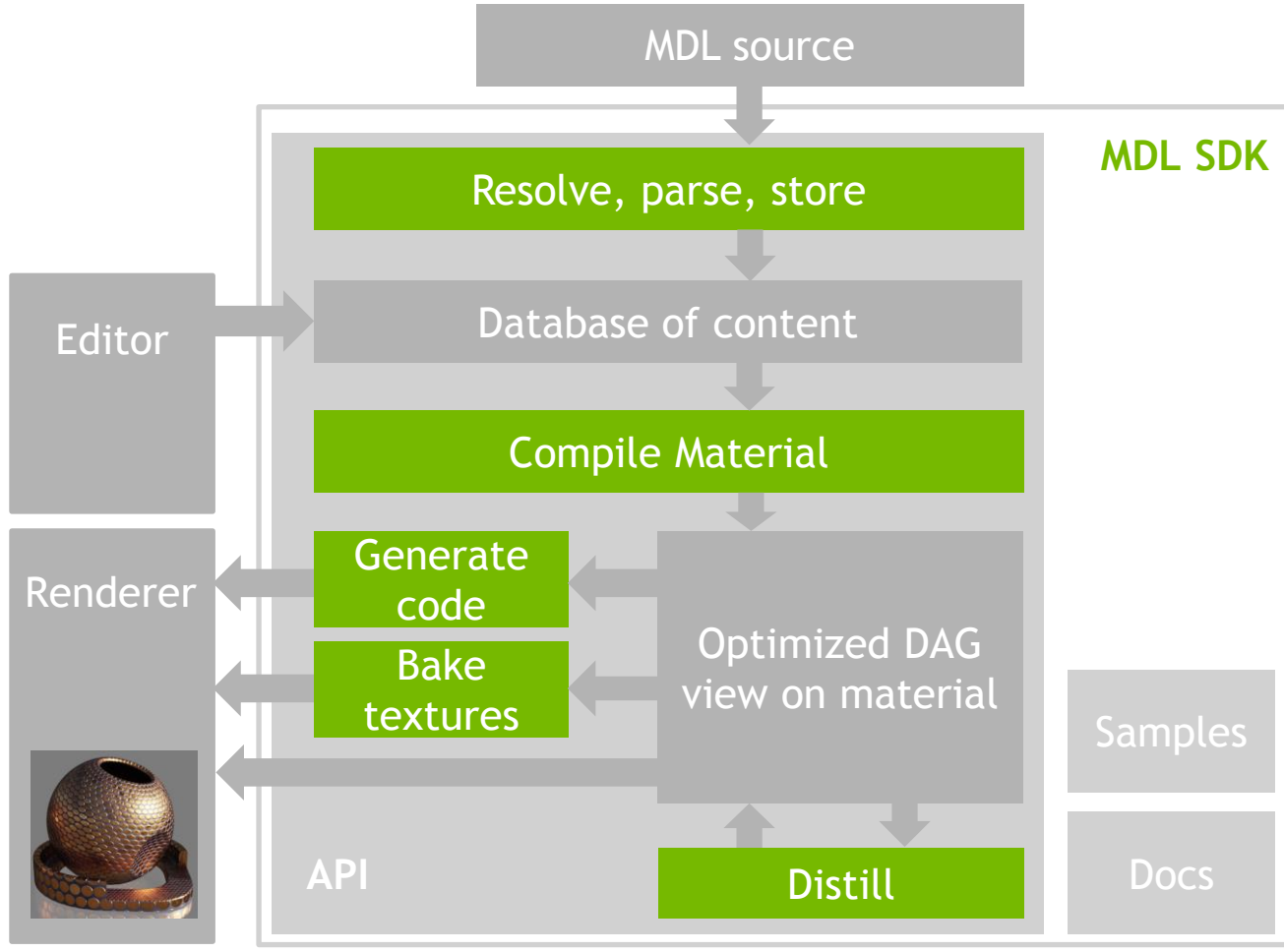
MDL editing

Code generators
PTX, LLVM IR, x86, GLSL (fcts. only)

Distiller and texture baker

Samples

Documentation and tutorials



MDL SDK 2018.0 - What is New

Features

MDL 1.4 support

Class compilation support in all modes

Link mode

Full material compilation with BSDF reference implementation

Improved distilling quality

Flexible render state binding in backends

API to enumerate all dependent resources

Access to SDK version at API entry point

Auto shutdown

SDK helper class for simplified access to annotations

New samples for all back-ends

Search in MDL Specification finds now names with '_'

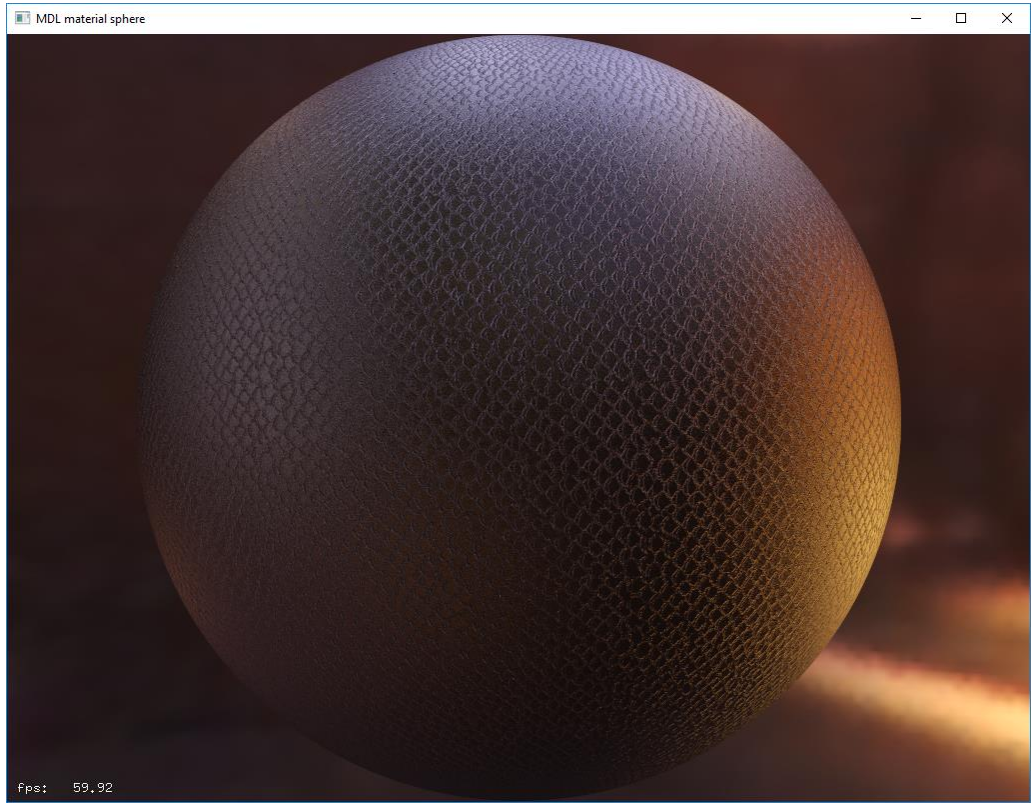
MDL SDK and OptiX

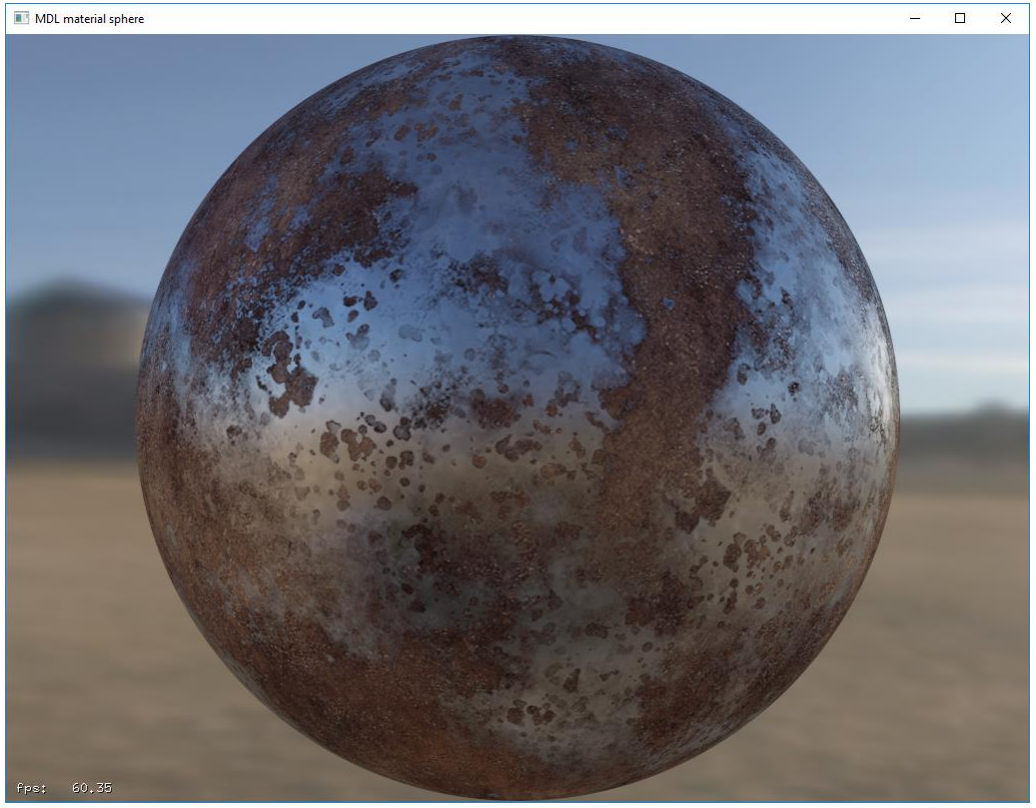
We will give you all you need…

- MDL SDK PTX backend produce PTX code suitable to be called by OptiX available since MDL SDK 2017.1

Full Material Compilation

OptiX and CUDA rendering samples with MDL SDK 2018.0 and OptiX 5.1





MDL in Realtime Rendering

Three approaches

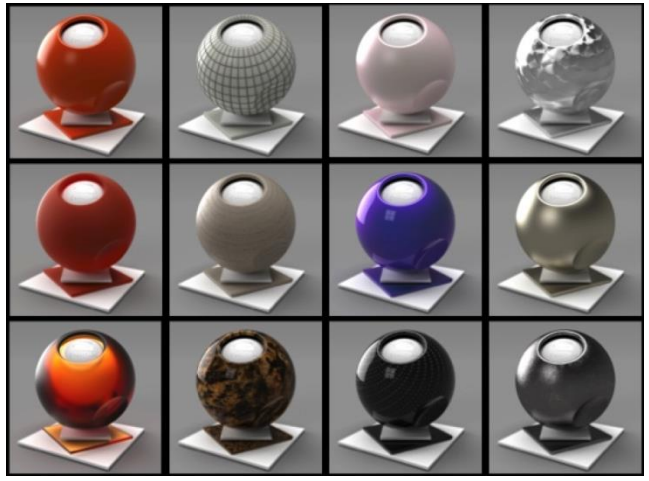
1. Ubershader
2. Compilation: on-demand shader generation
3. Distillation to fixed material model

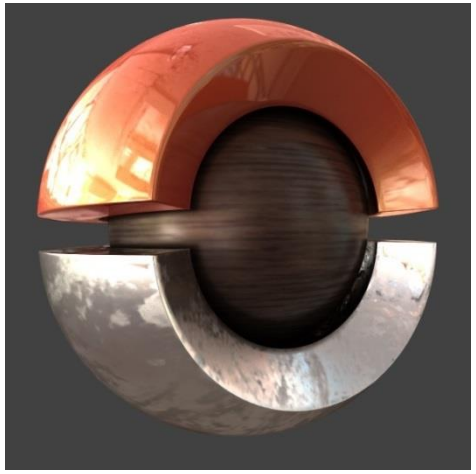
All based on MDL SDK

Compilation: On-demand Shader Generation

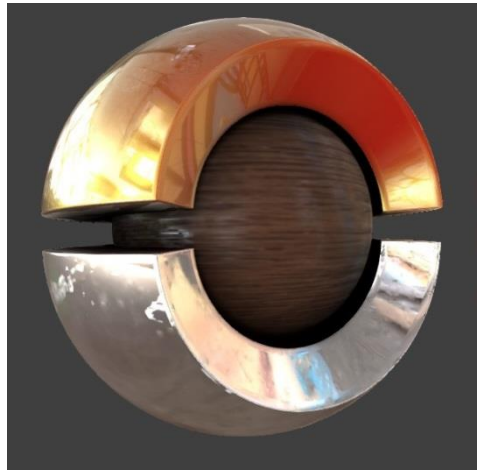
Example deployment

IC.IDO





Raytracer



GLSL Rasterizer

Distillation to Fixed Material Model

MDL Material

- Complex BSDF layering
- Complex procedurals

distill →

Fixed Material Model

- Simple BSDF structure
- One texture per parameter
- Examples
  - Disney-principled BRDF model
  - UE4 model (moving target)
  - normal map, cutout

Distillation to Fixed Material Model

MDL Material

- Complex BSDF layering
- Complex procedurals

distill →

Fixed Material Model

- Simple BSDF structure
- One texture per parameter
- Examples
  - Disney-principled BRDF model
  - UE4 model (moving target)
  - normal map, cutout

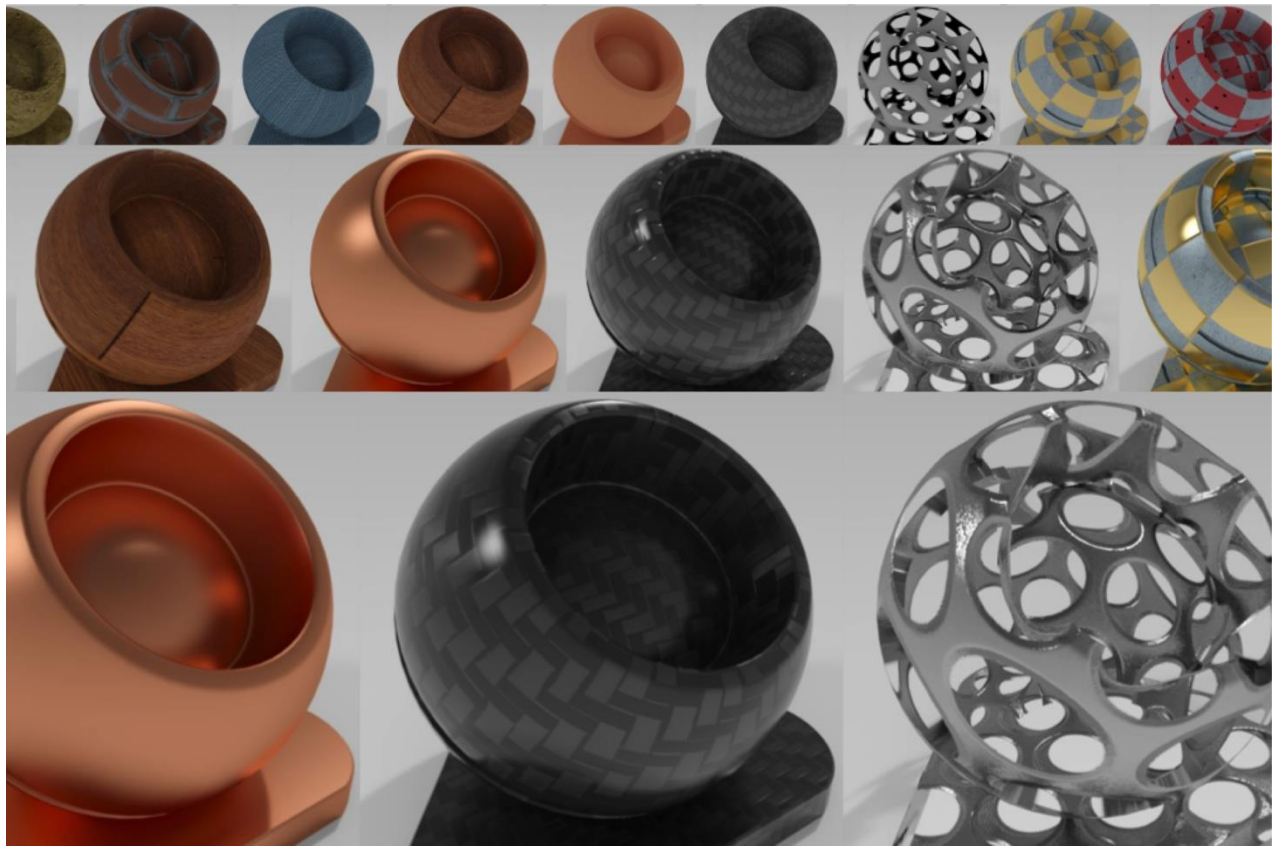
Approximate render result: Some materials will look quite different

Fast projection of material instances: Realtime editing

Flexible framework to target different fixed models (moving target)
not a fixed MDL subset (no “MDL lite”)

Distillation to Fixed Material Model

Results on vMaterials



diffuse-only

Fresnel(glossy, diffuse)

original

MDL Distilling

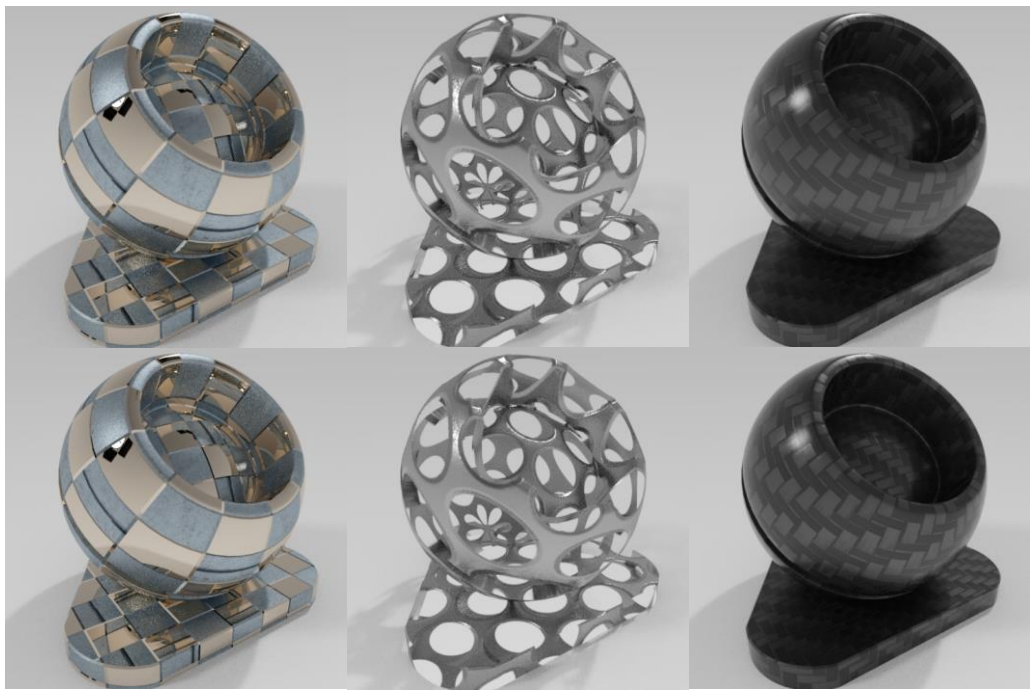
Released as part of Iray/MDL SDK

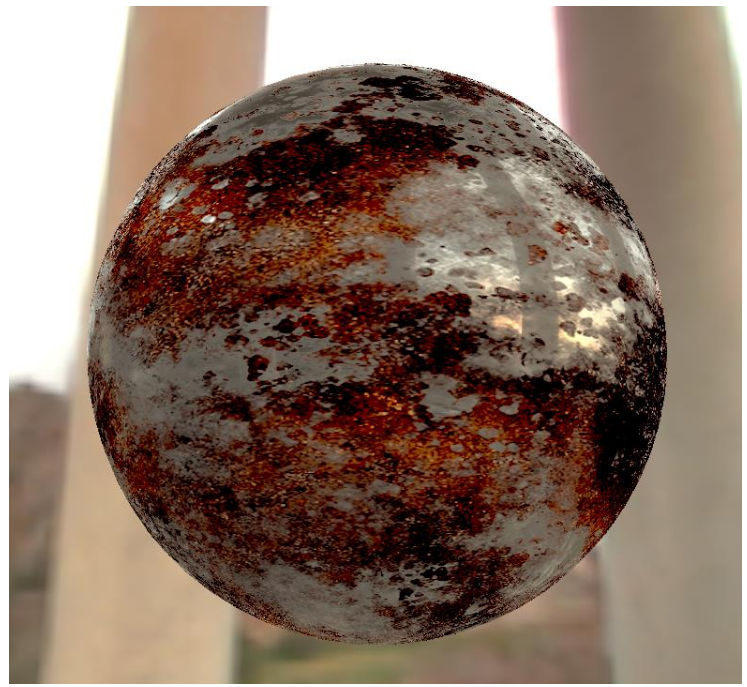
Example: UE4 target with clearcoat and transparency through alpha

GLSL rendering sample using Distilling and baking comes with MDL SDK 2018.1

MDL

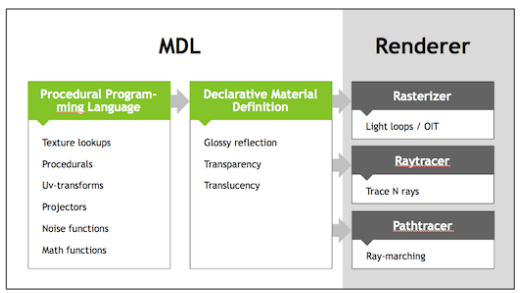
UE4





MDL Takeaways

What is MDL



Declarative Material Definition

Procedural Programming Language

MDL Ecosystem

NVIDIA vMaterials

MDL Advisory Council

Starting Material

MDL Specification

MDL Handbook

MDL SDK

MDL Backend Examples

MDL Conformance Test Suite

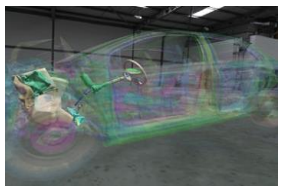
NVIDIA. DESIGNWORKS™

RENDERING


Iray SDK

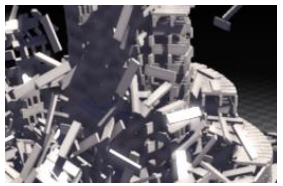

OptiX SDK


MDL SDK


NV Pro Pipeline

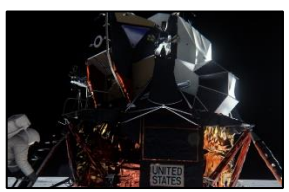

vMaterials

PHYSICS


PhysX

VOXELS


GVDB Voxels


VXGI

VIDEO


GPUDirect for Video

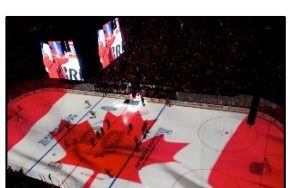

Video Codec SDK

MANAGEMENT


GRID SW MGMT SDK


NVAPI/NVWMI

DISPLAY


Multi-Display


Capture SDK


Warp and Blend

https://developer.nvidia.com/designworks

Further Information on MDL

www.nvidia.com/mdl
raytracing-docs.nvidia.com/mdl/index.html

Documents

NVIDIA Material Definition Language -- Technical Introduction

Material Definition Language -- Handbook

NVIDIA Material Definition Language -- Language Specification

MDL@GTC

Monday, March 26, 10:00 AM - 10:50 AM – Room 230C
Integrating the NVIDIA Material Definition Language MDL in Your Application

Monday, March 26, 10:30 AM – 10:55 AM – Hilton Santa Clara
MDL & Substance in Automotive

Wednesday, March 28, 2:00 PM – 5:00 PM – Westin Sainte Claire Ballroom
Iray Leaders