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Center for Nanotechnology

Image processing and Data Preparation for Structural Color Generation

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University of Pennsylvania

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www.nano.upenn.edu

Structural Coloration

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Pigmentary Coloration:

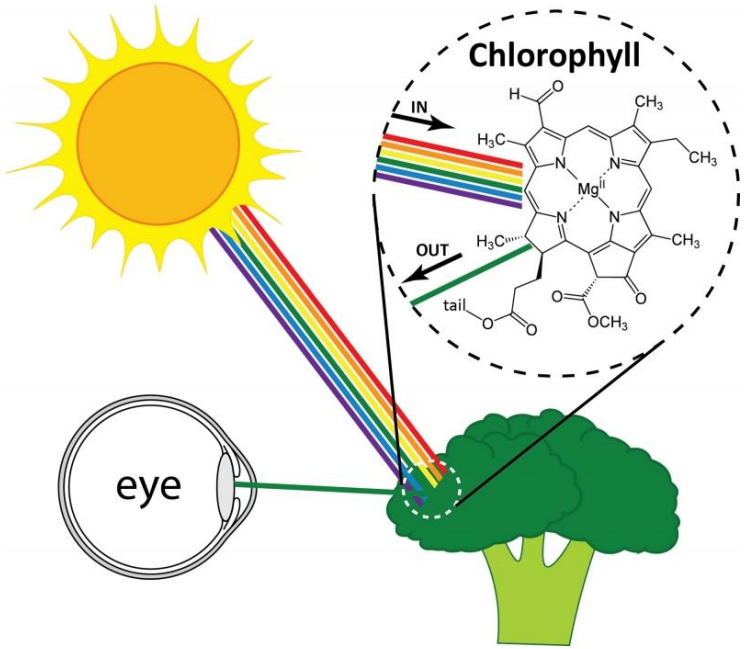

Figure 1. Pigment-based coloration in broccoli, illustrating the selective absorption of light by chlorophyll molecules which gives the perception of green light by the human eye. (Degen, 2020)

Structural Coloration:

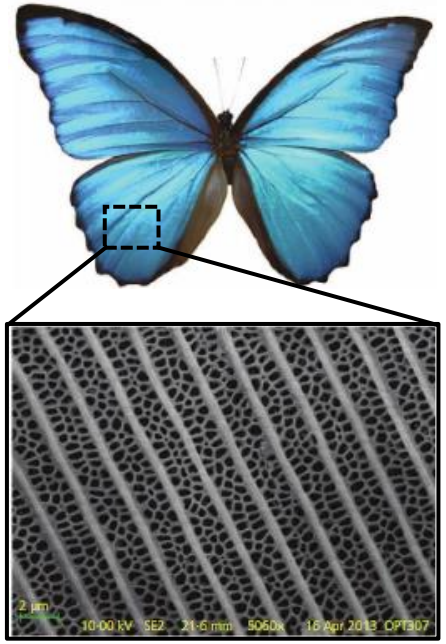

Figure 2. Close-up view of a Morpho butterfly's wings, showcasing the microscopic lattice structure responsible for its vivid blue hue, as revealed by SEM. (Das, Shanmugam, Kumar, & Jose, 2017)

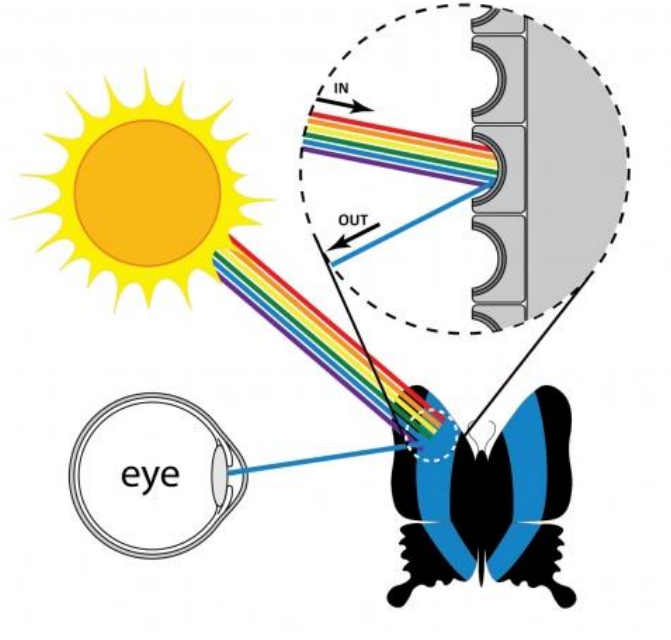

Figure 3. Structural coloration in butterfly wings, illustrating the manipulation of light using sub-wavelength nanostructures which results in the perception of blue light by the human eye. (Degen, 2020)

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Metasurface-based Artificial Structural Coloration

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Gratings:

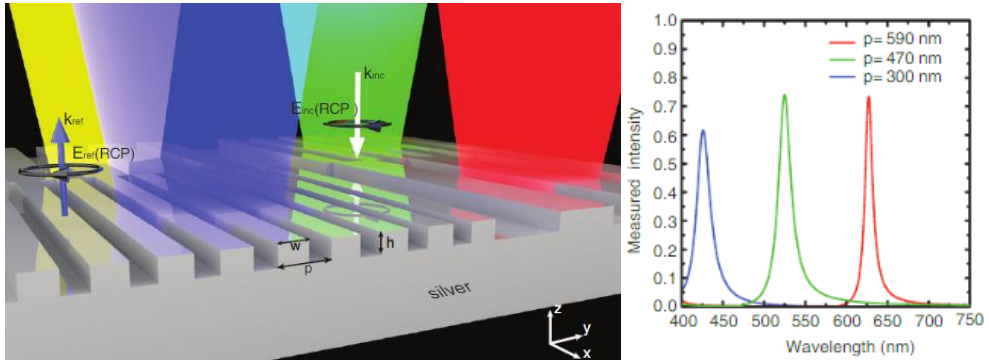


Figure 4. Reflective structural colors generated by a plasmonic metamirror with nano-grating structures (Song, et al., 2017)

Nanohole Arrays:

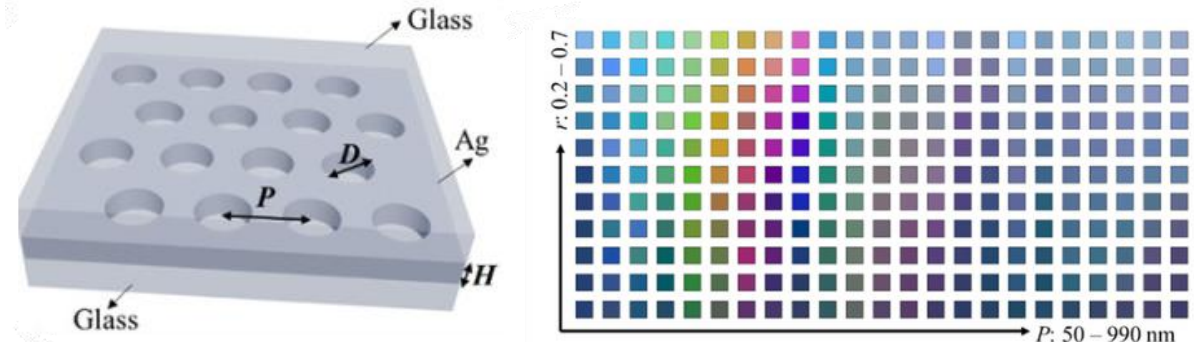
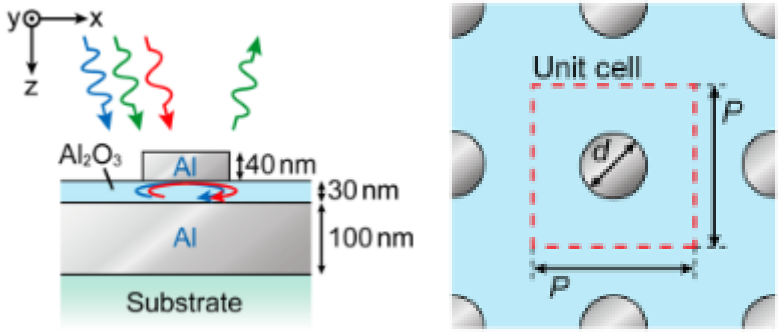


Figure 5. Various structural colors produced by a nanohole array structure by tuning its holes' radius and periodicity. (Liu, Zhang, Zhao, & Ai, 2023)

Nanodisk Arrays:



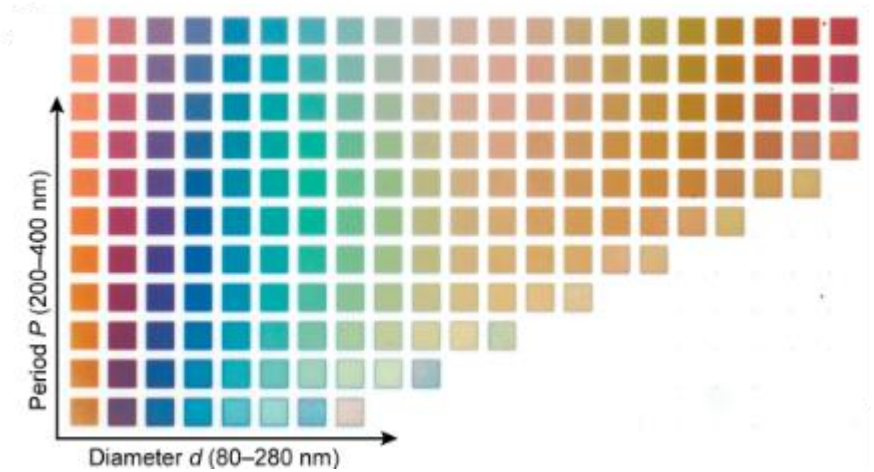


Figure 6. Color generation on resonant aluminum nanodisk arrays; Color tuning achieved by changing the periodicity and diameter of nanodisks. (Miyata, Hatada, & Takahara, 2016)

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Nanodisk Arrays:

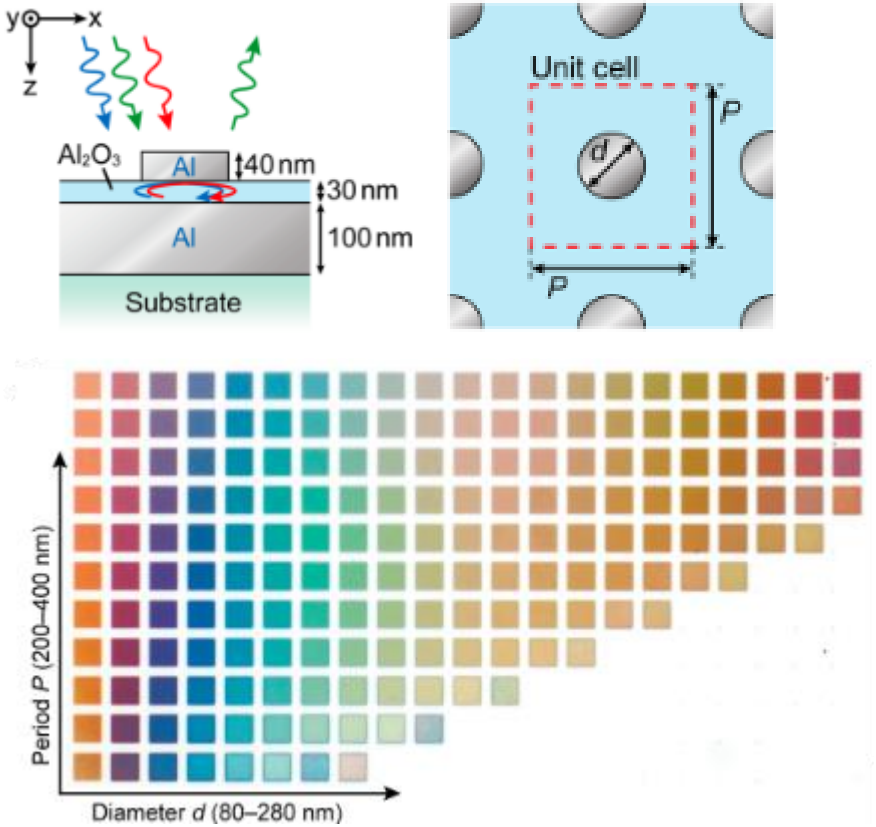

Figure 6. Color generation on resonant aluminum nanodisk arrays; Color tuning achieved by changing the periodicity and diameter of nanodisks. (Miyata, Hatada, & Takahara, 2016)

EBL & Nanofabrication:

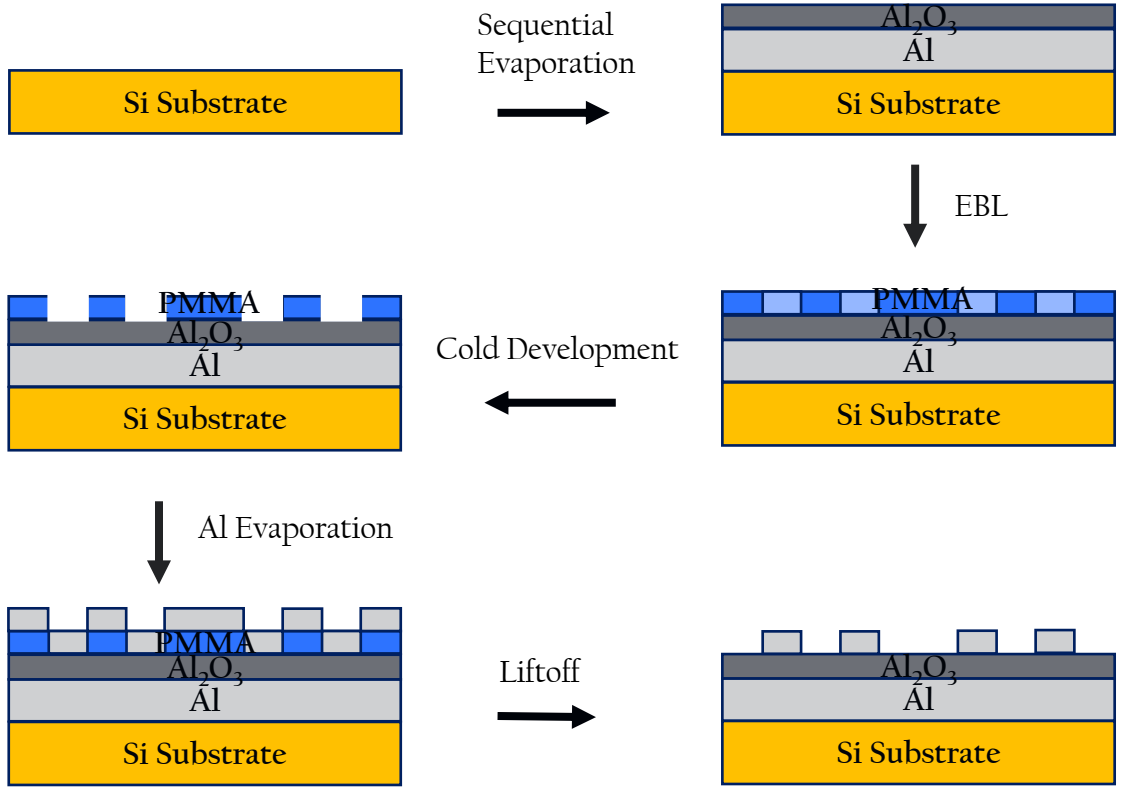

Figure 7. Nanofabrication steps for fabricating Al-Al_2O_3-Al metasurfaces for structural color generation

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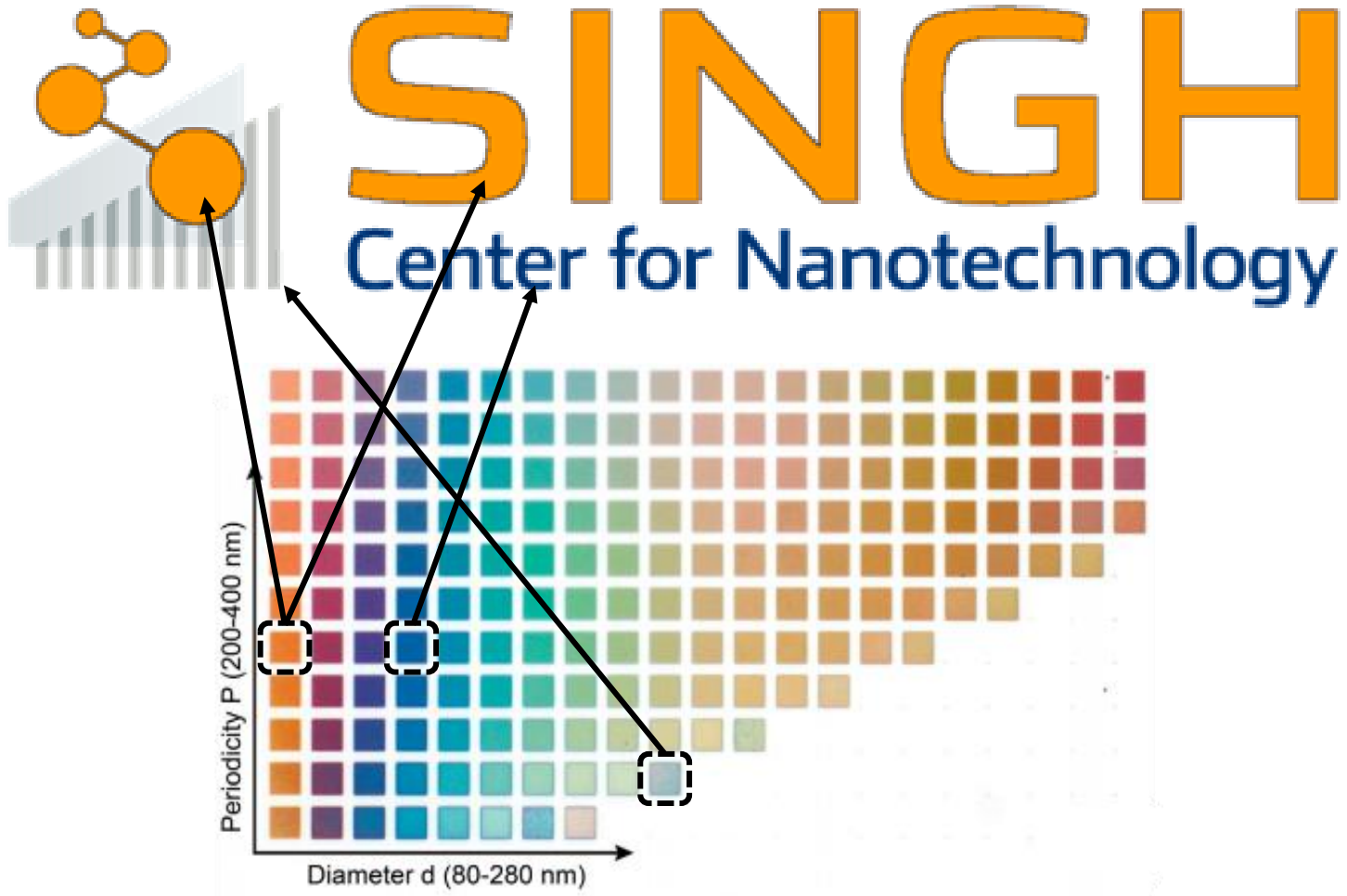
Structural Color Printing for Images



Preliminary Image Processing

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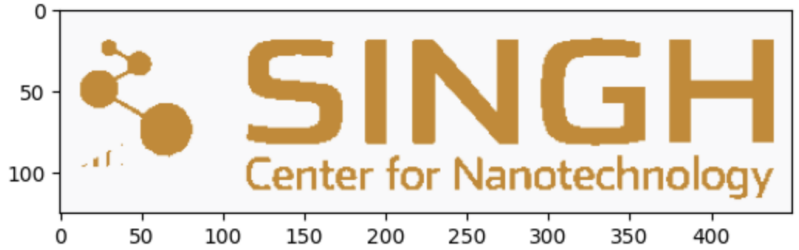
Image Segmentation:

K-means clustering algorithm

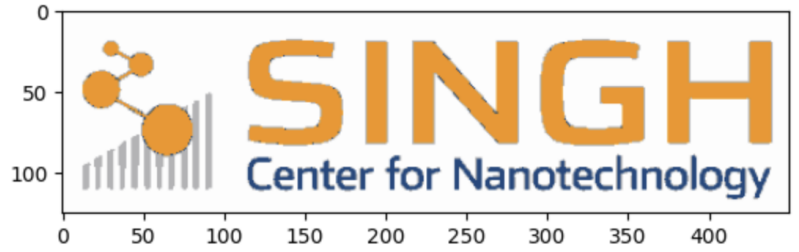
(k = 4)

(k = 2)



(k = 3)

(k = 4)



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Preliminary Image Processing

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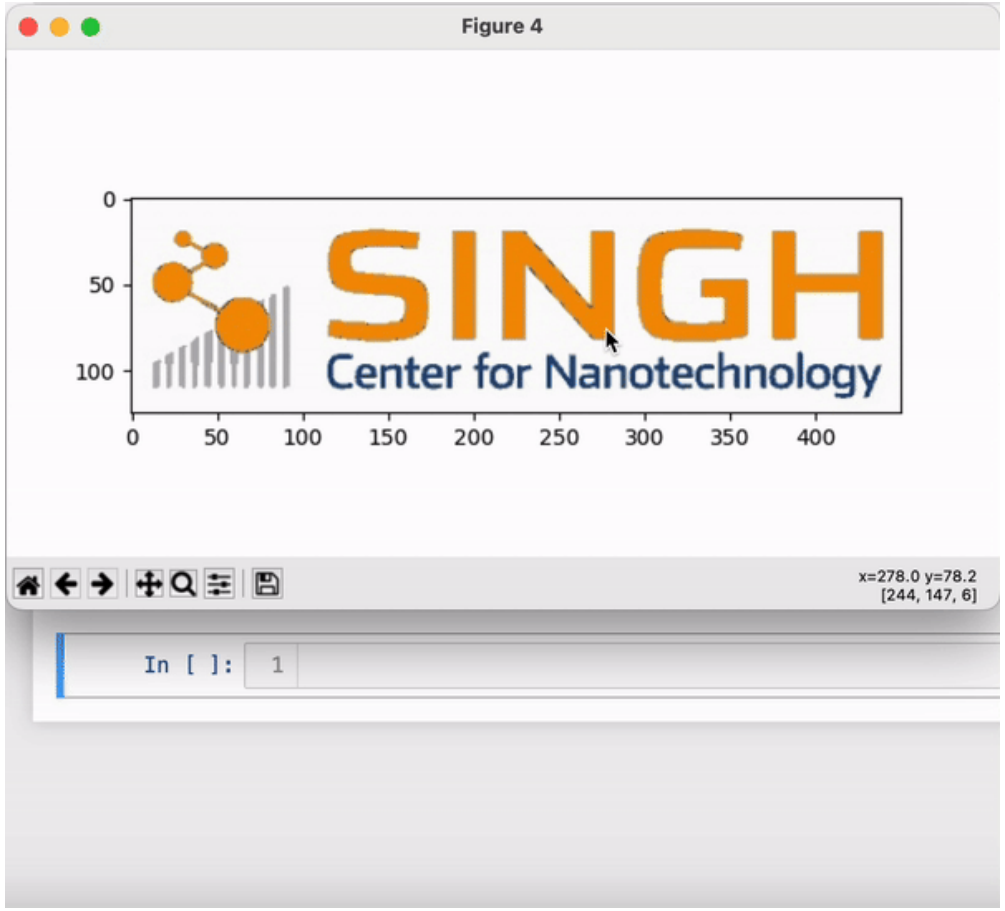
Color Picking and Nanostructure Matching:



Nanostructure Library:

Structure	(R,G,B)	Diameter (nm)	Periodicity (nm)	Color
Al (40 nm) – Al_2O_3 (30 nm) – Al (100 nm) – Nanodisk Arrays	(213, 139, 76)	80	200	
	(103, 80, 109)	90	200	
	(12, 117, 164)	100	200	
	(0, 160, 188)	110	200	
	⋮			
Ag (20 nm) – Glass – Nanohole Arrays (Sun, et al., 2014)	(239, 212, 95)	70	140	
	(248, 87, 124)	115	230	
	(116, 160, 162)	160	320	
	⋮			
. . . More Nanostructures and Colors				

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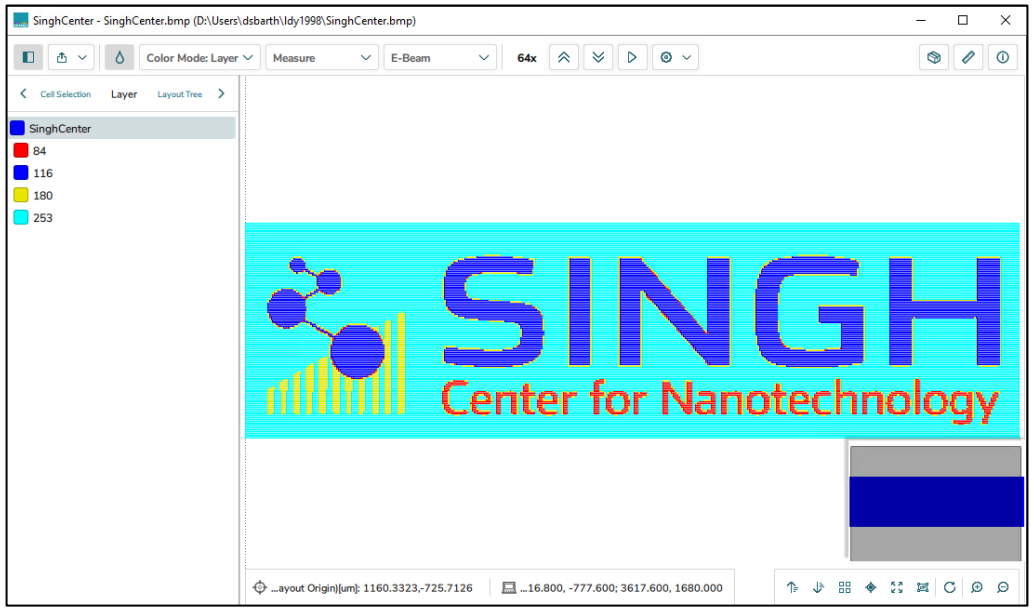
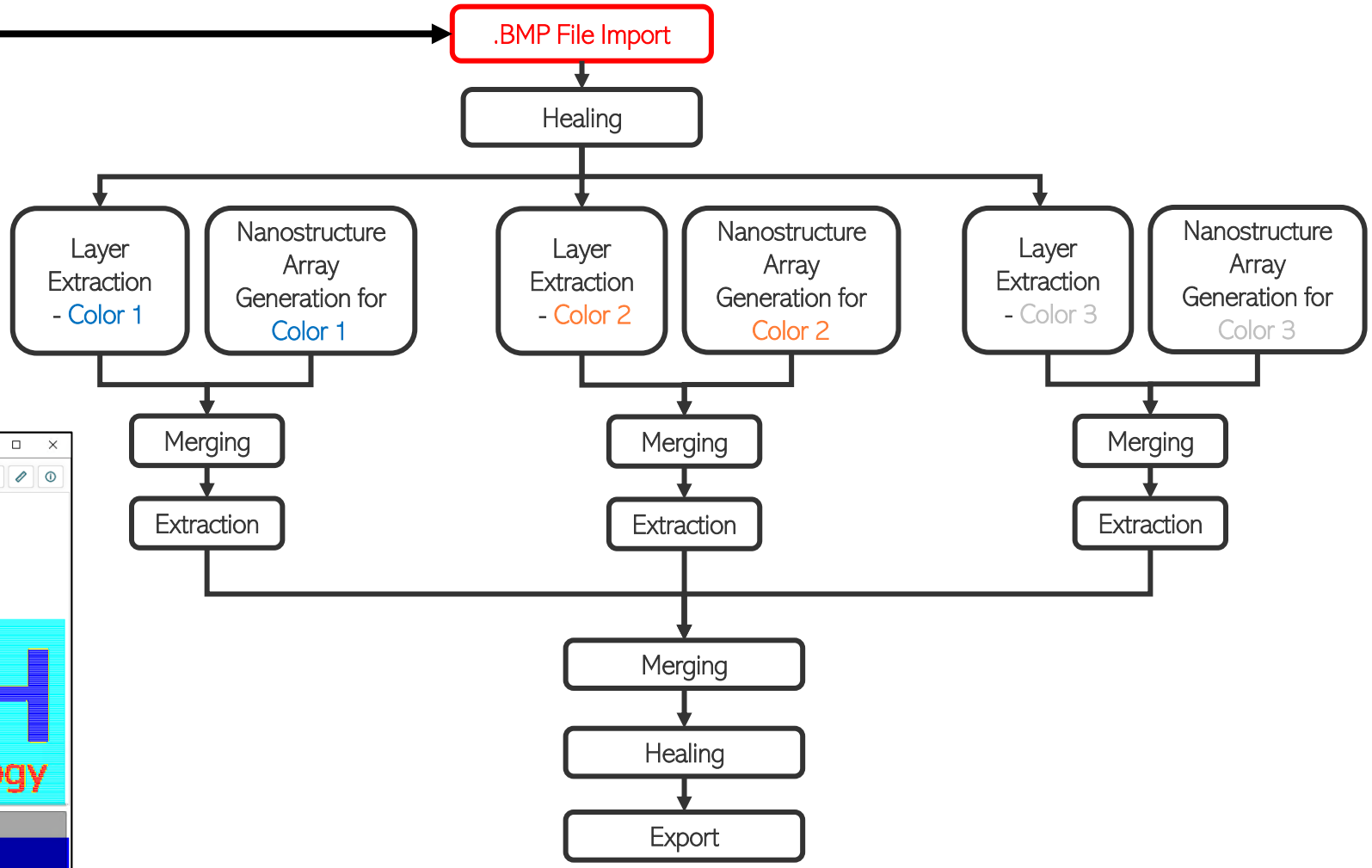
Preliminary Image Processing

.jpg to grayscale conversion

Export as .bmp



Beamer Flowchart:



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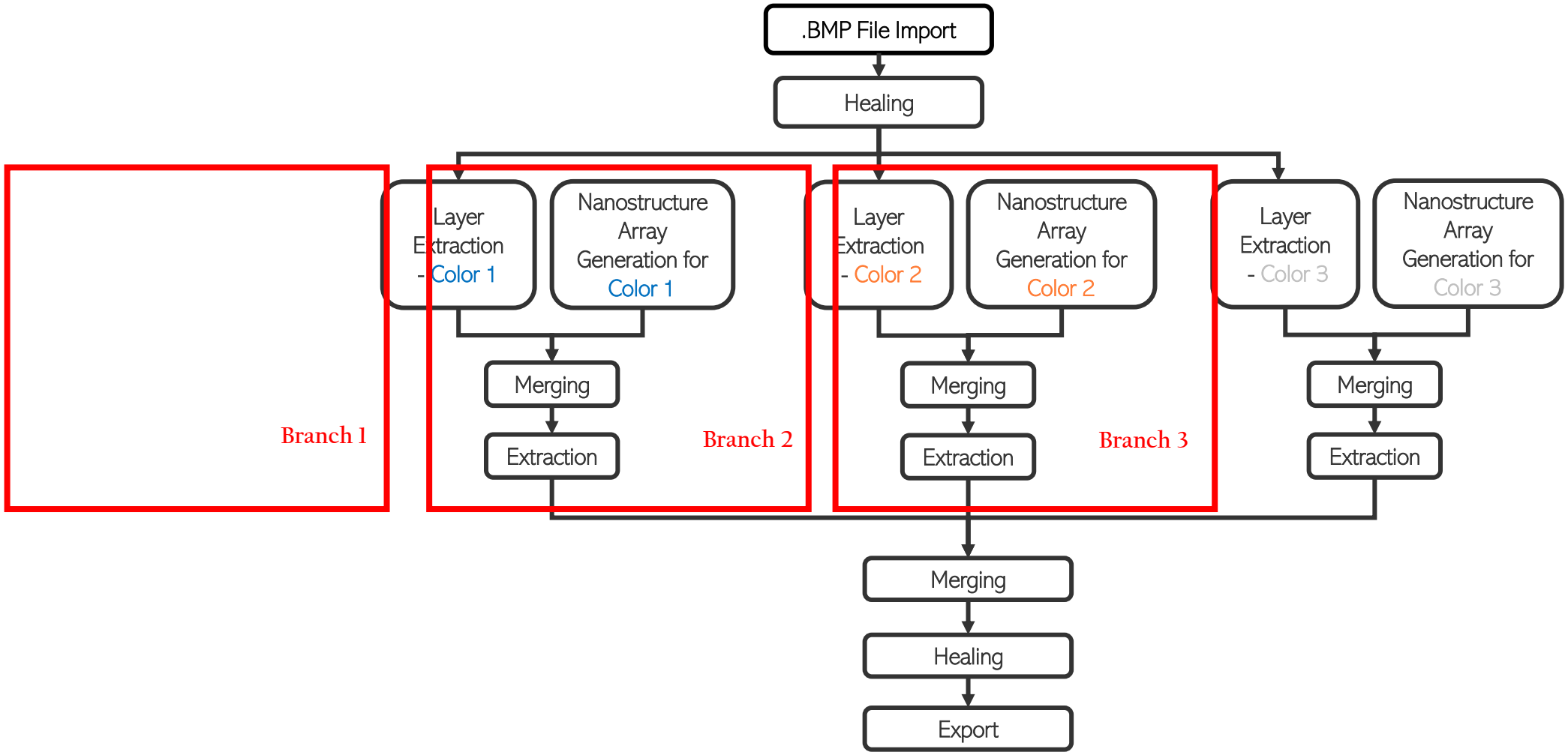
Data Preparation in Beamer



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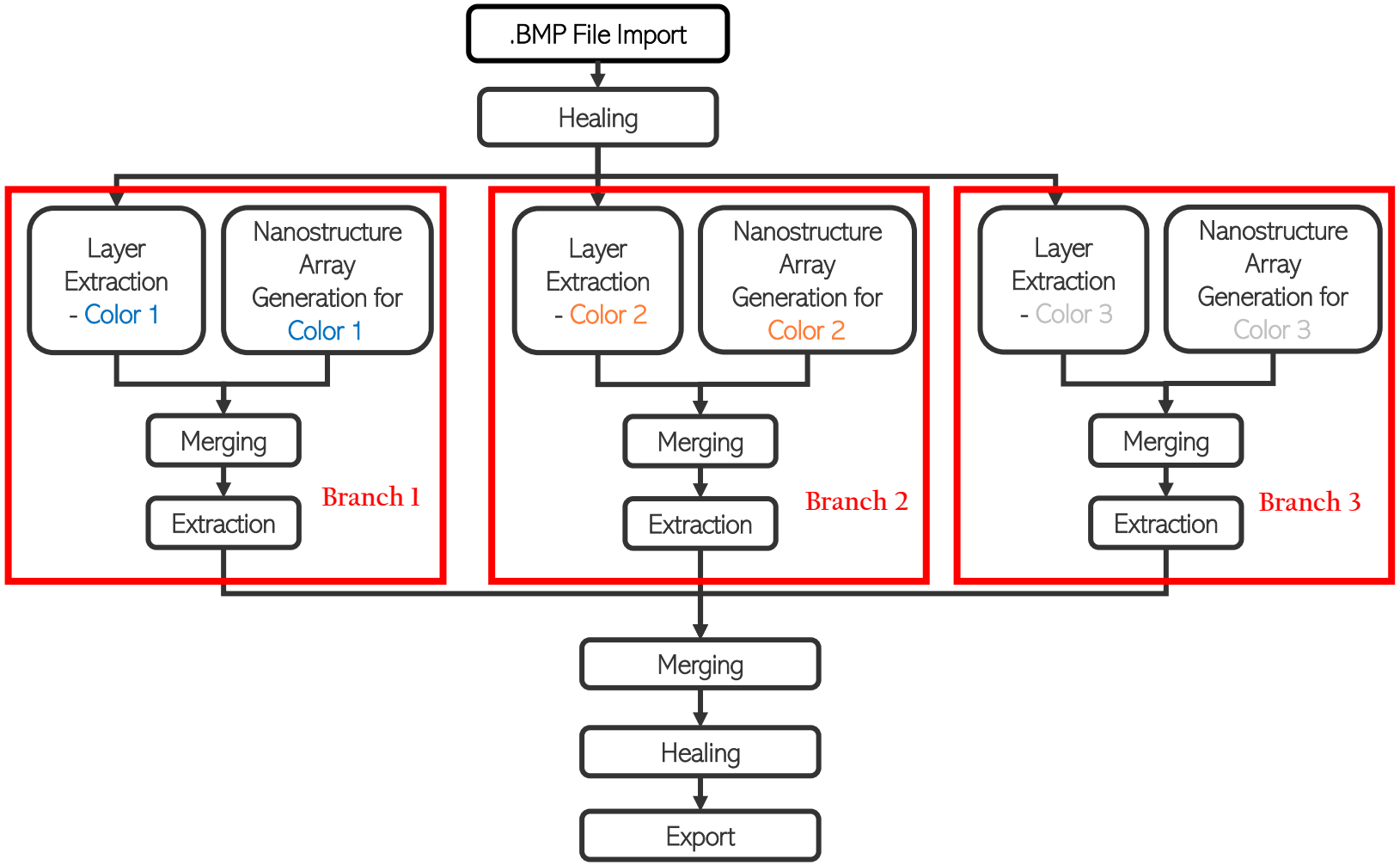

Data Preparation in Beamer

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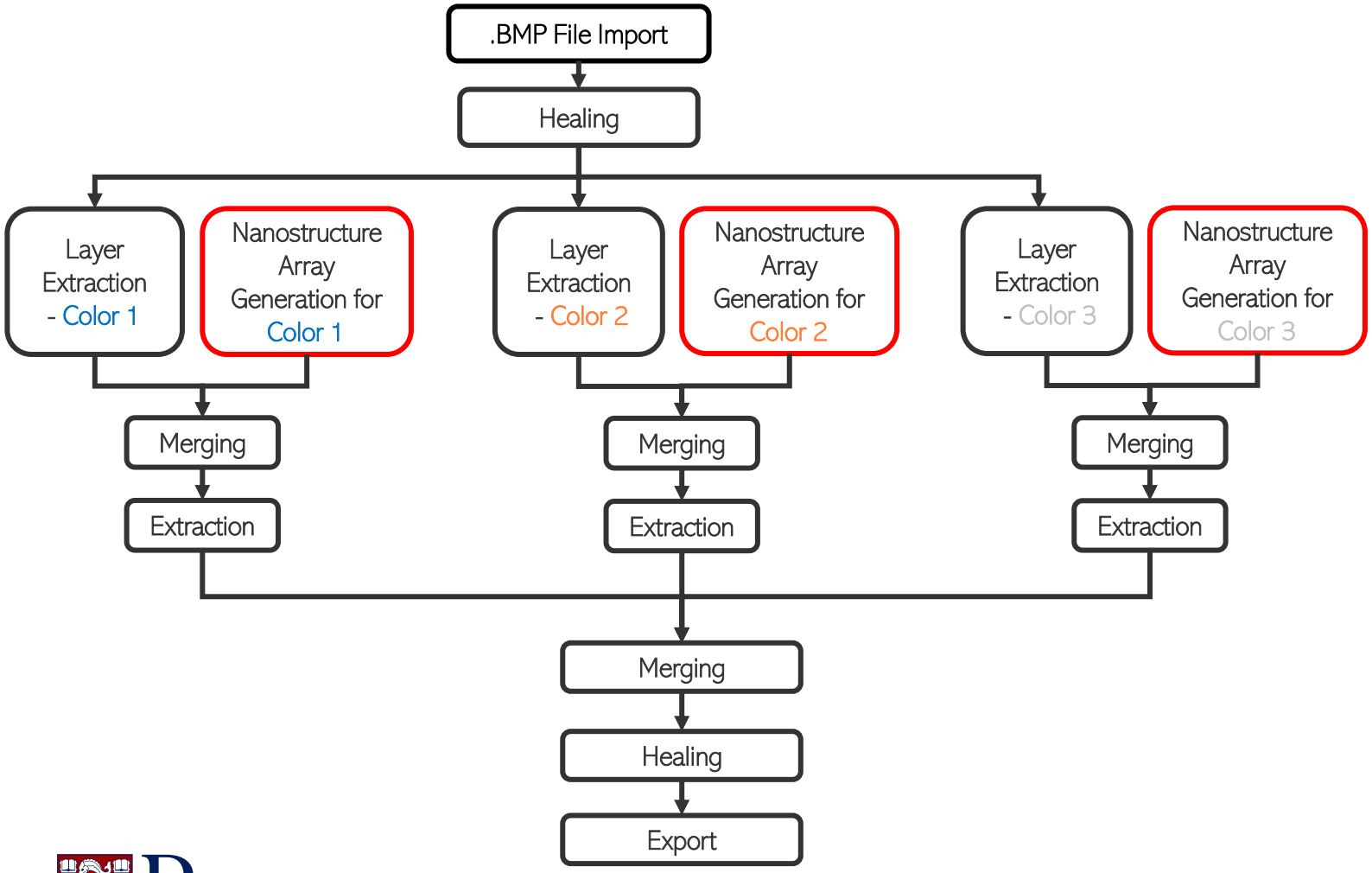

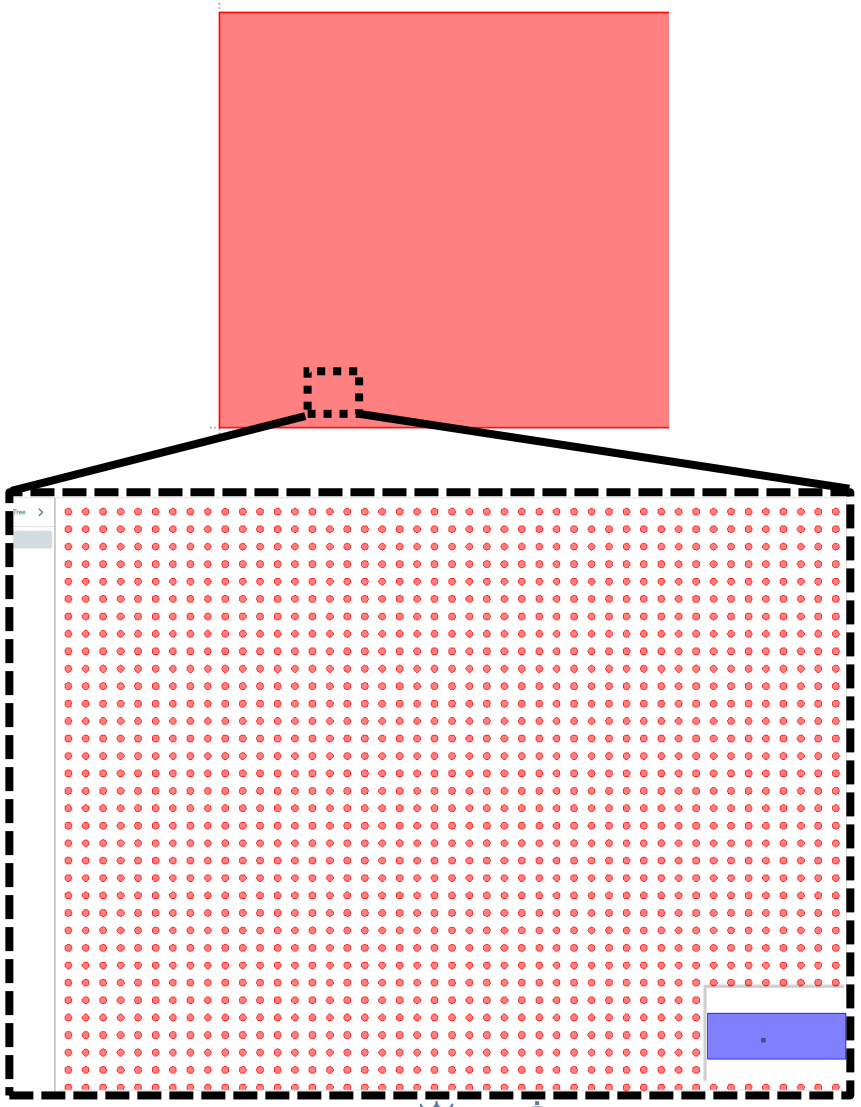

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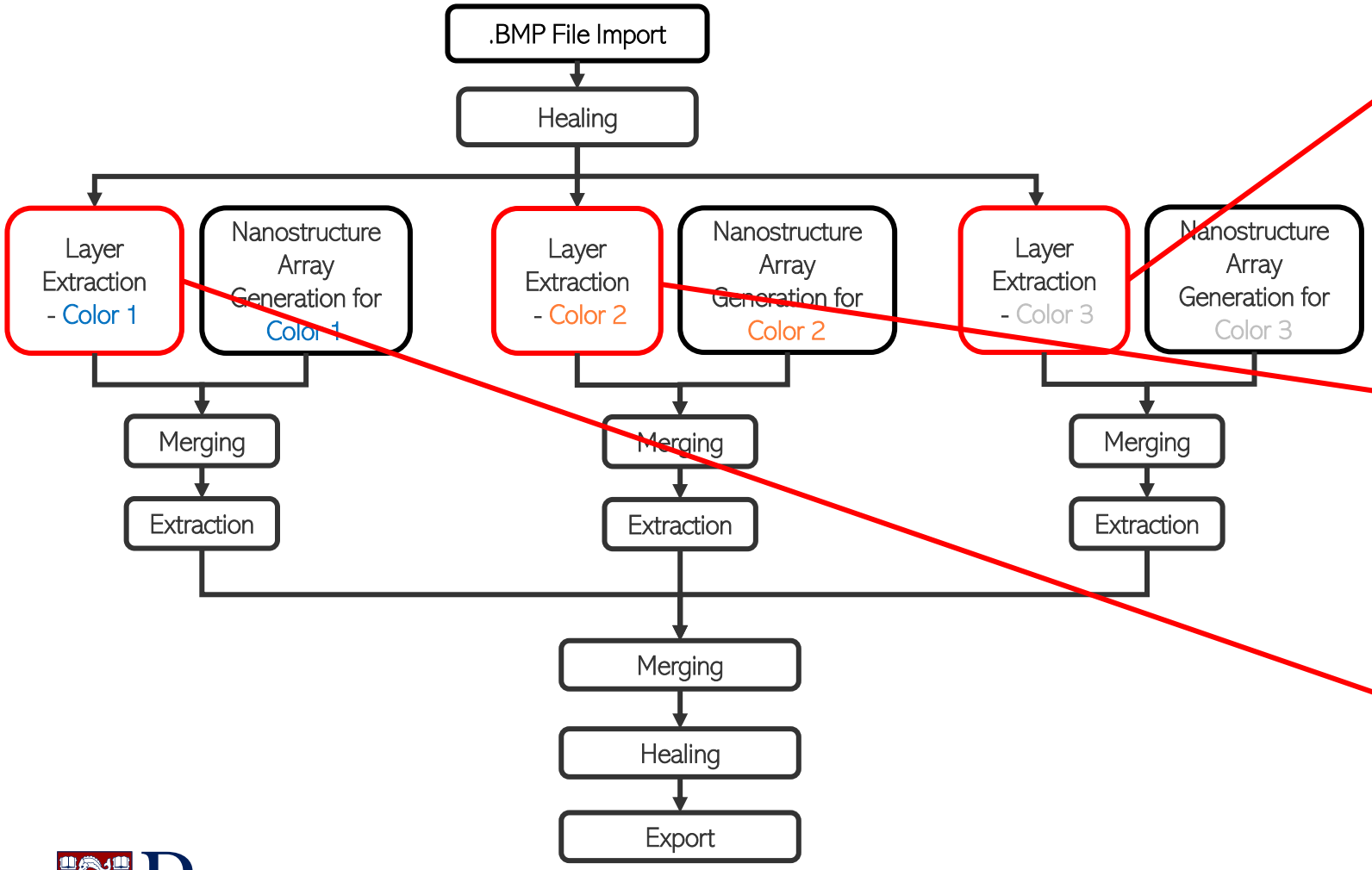

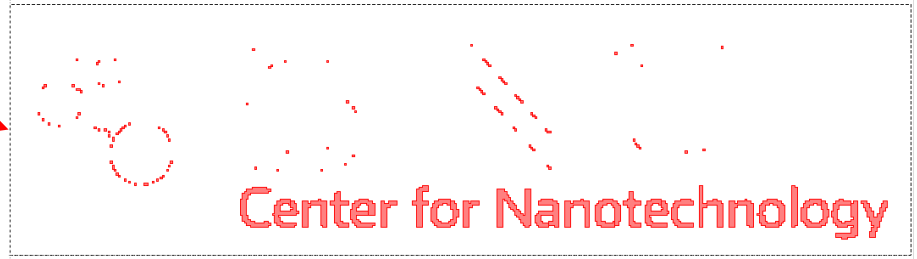

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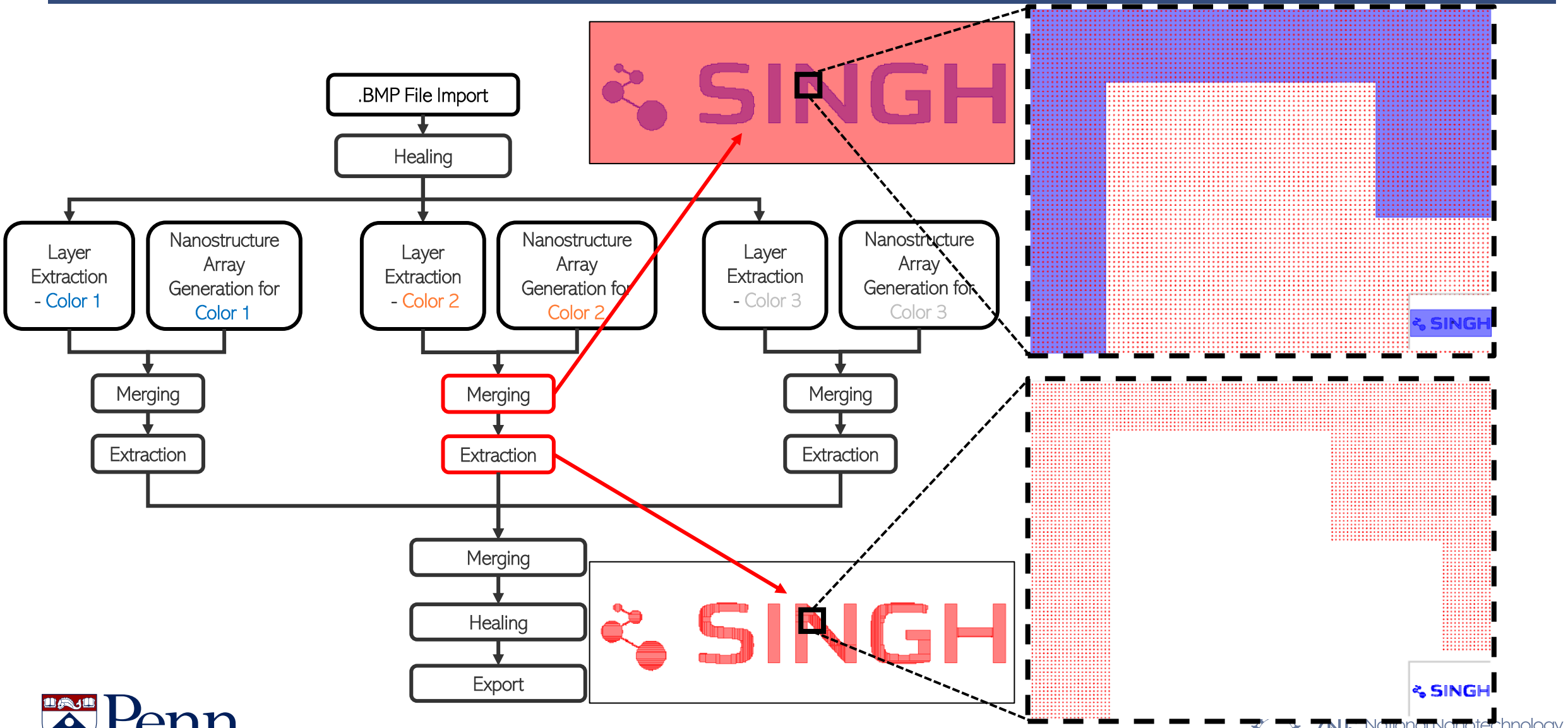

Region Extract

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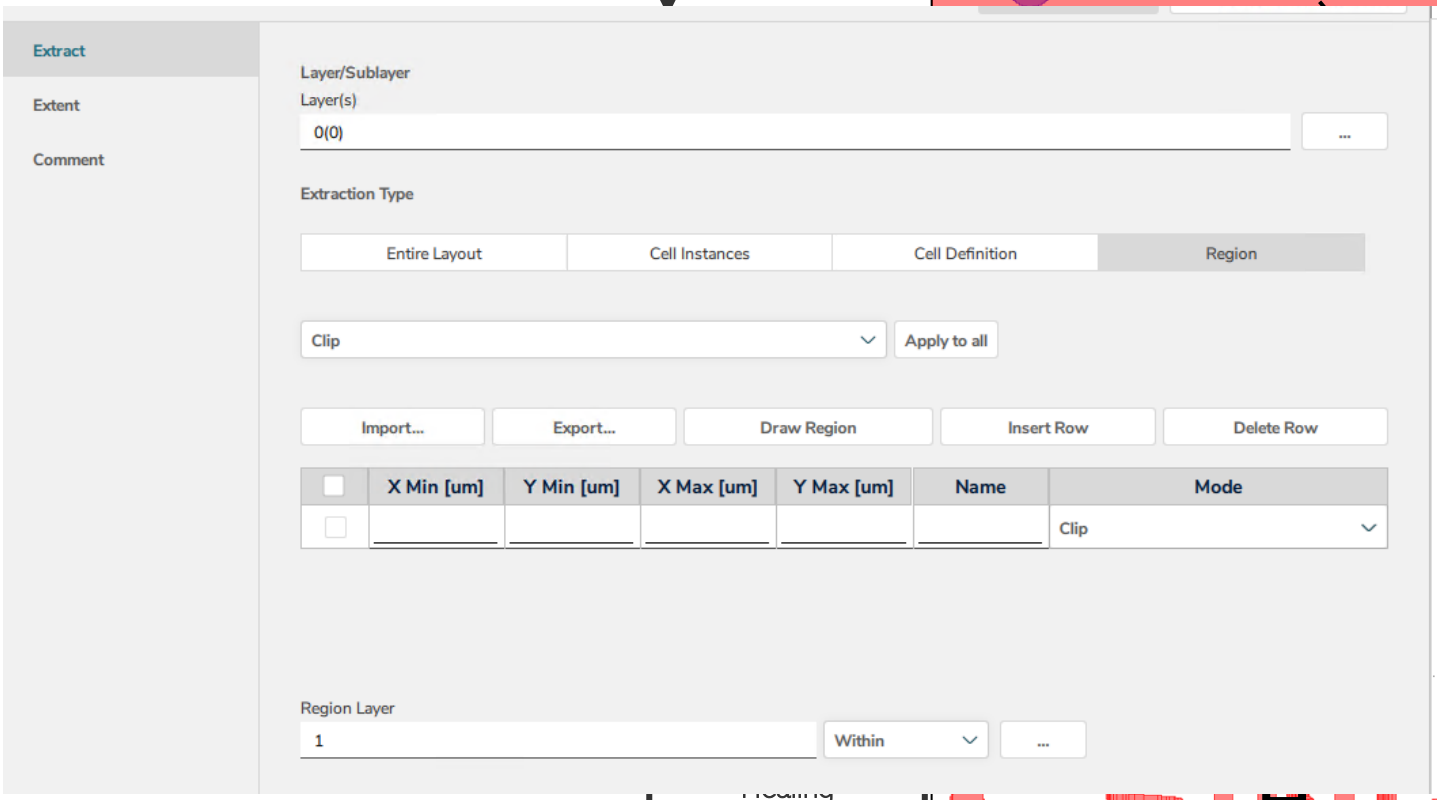
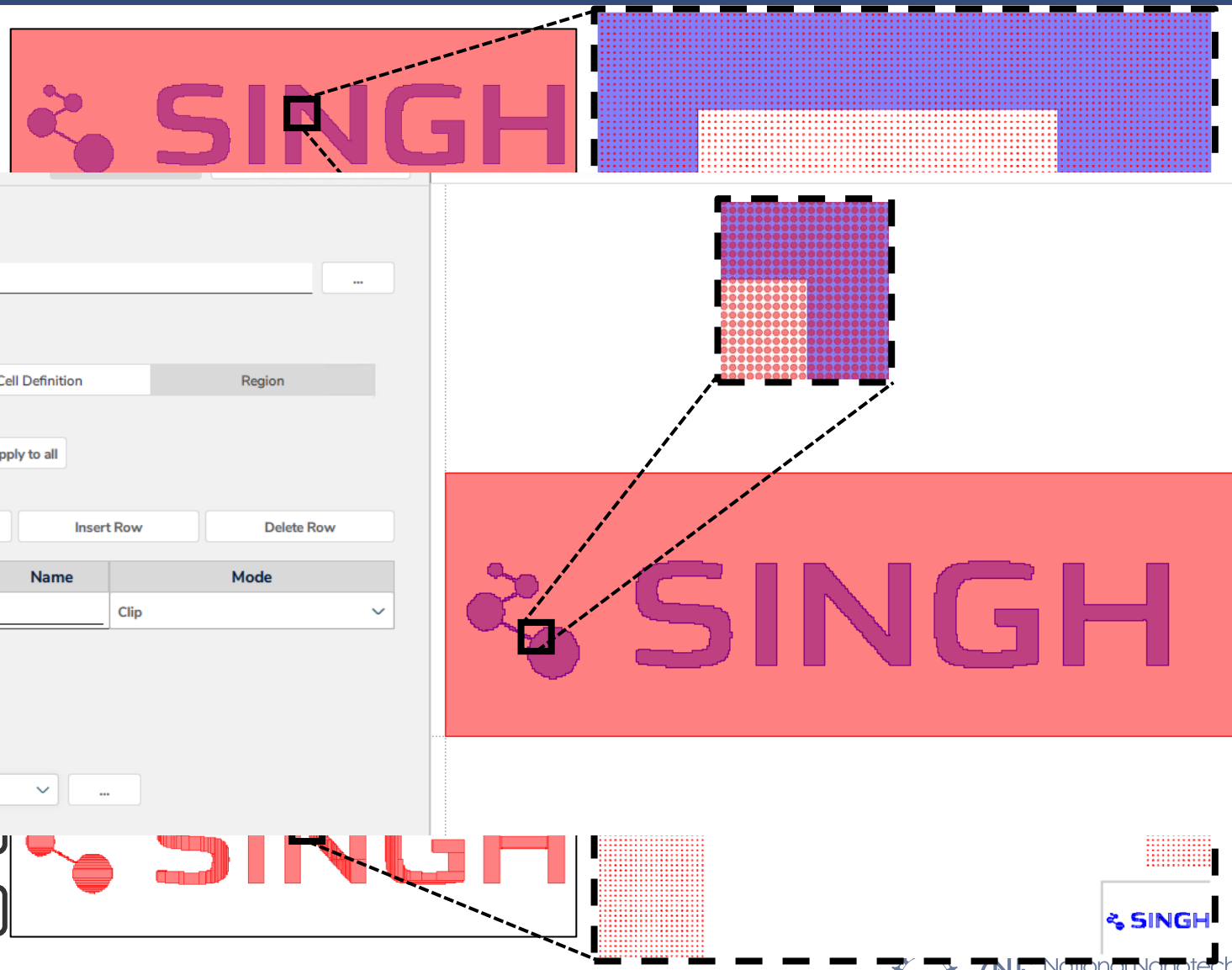
.BMP File Import





Export

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Fabricated Structural Color Images

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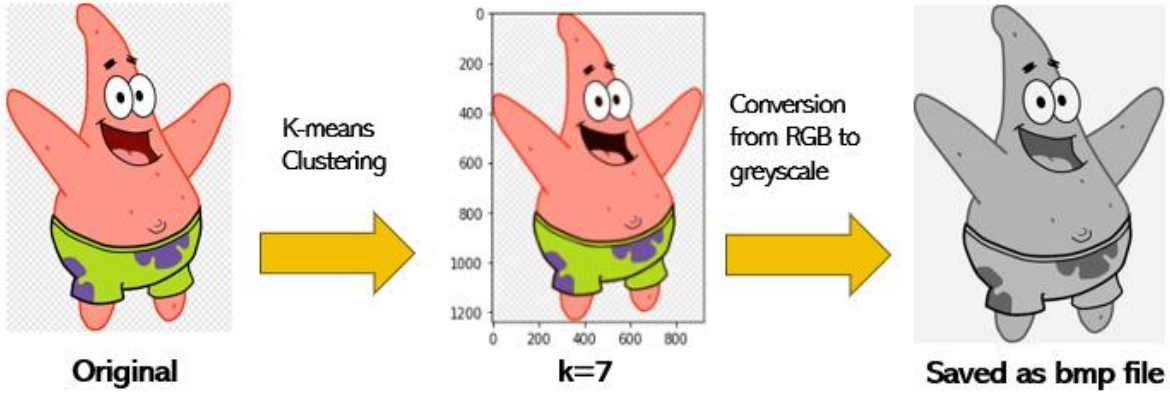
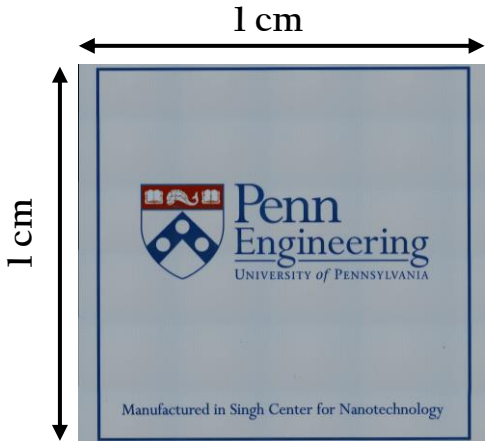
Patrick Star:



Squidward:

Penn Engineering Logo:



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Acknowledgement

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A special thanks to my project advisor, Dr. David Barth.

Reference

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