Poster Presentation : 재료

2021년도 한국현미경학회 춘계학술대회

Structural coloration in pheasant feather: investigation on the effects of thin cortex via focused ion beam sectioning

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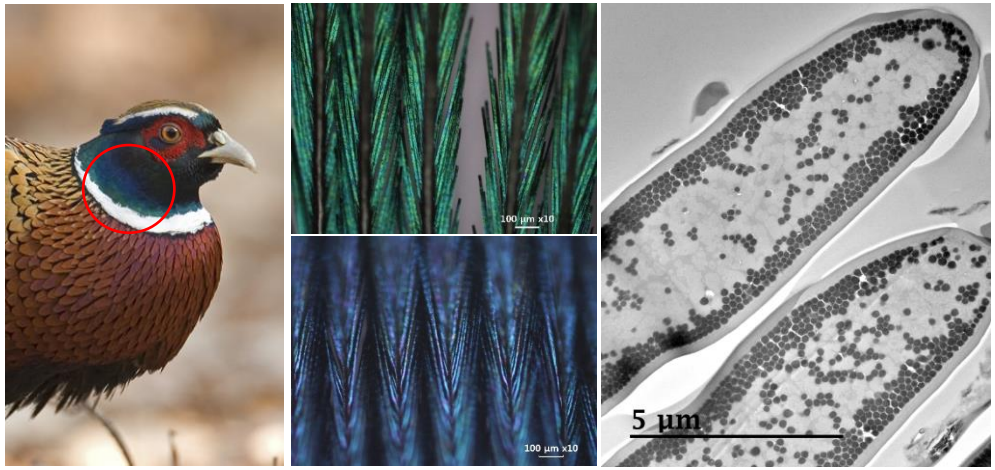
Korean Society of Microscopy

Structural coloration in avian feathers

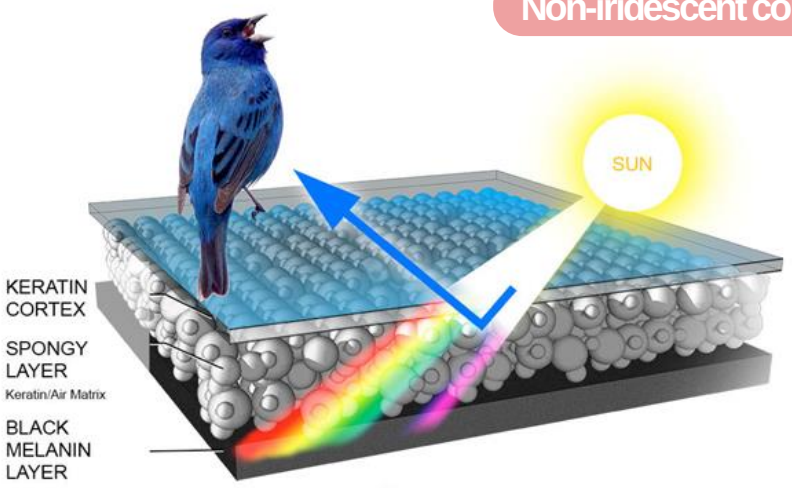
Characteristics of structural colors in nature

- Reflection based coloration using nano-photonic structures
- Brilliant colors under sun light exposure
- Eco-friend color generation
- Need to understand how nature embodies colors



Iridescent coloration

Non-iridescent coloration



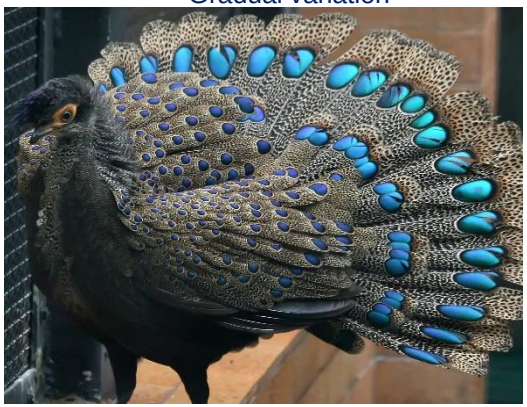
Source: Andrew Leach, How Birds Make Colorful Feathers, Bird Academy, Cornell Lab, Cornell University

Various models describing avian structural colors

Thin cortex

H. Yin et al.,
Phys. Rev. E. 74, 051916 (2006)

Thin cortex



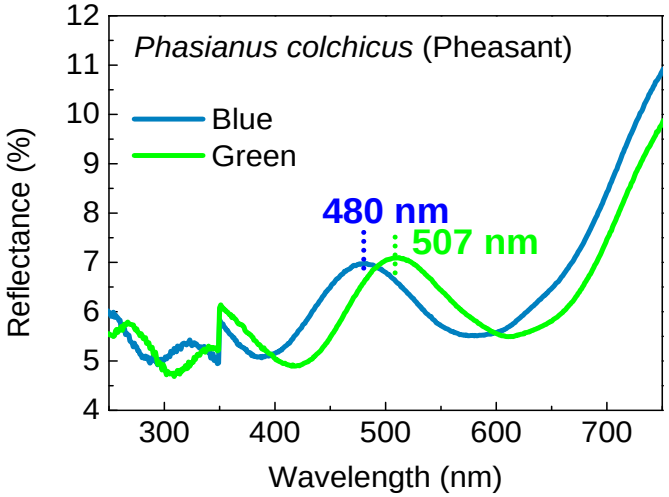
C. Eliason et al.,
Opt. Express, 22, A642 (2014)

Thin cortex

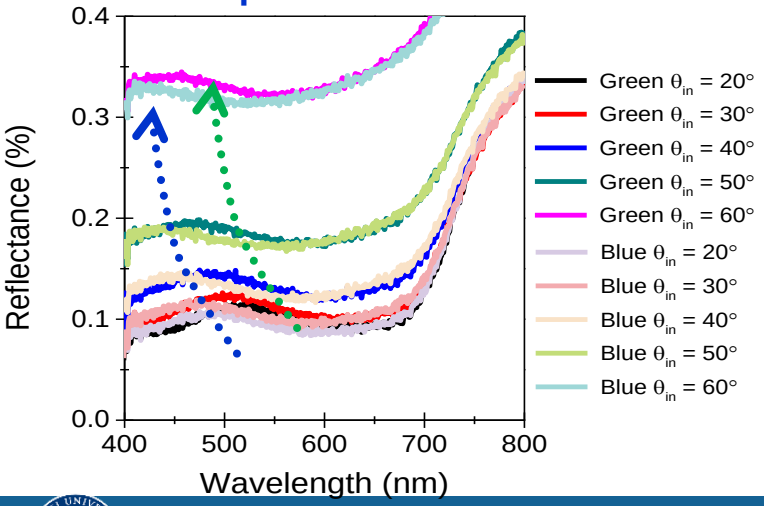
J. Zi et al., PNAS, 100, 12576 (2003),
J. Medina et al., Opt. Express, 23, 10198 (2015)

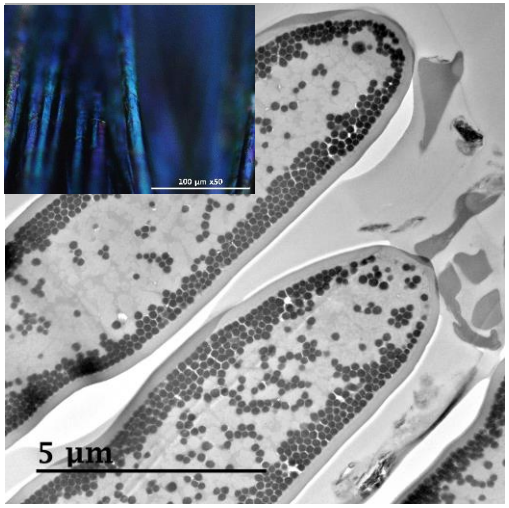
Optical and Structural properties of pheasant feathers

Measured reflectance via Cary 5000

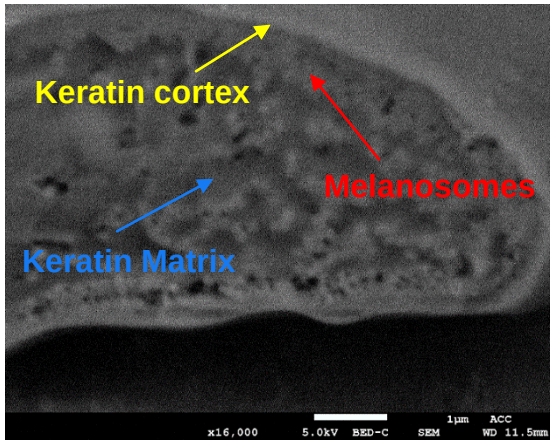


Specular reflectance





Backscattered Electron Imaging

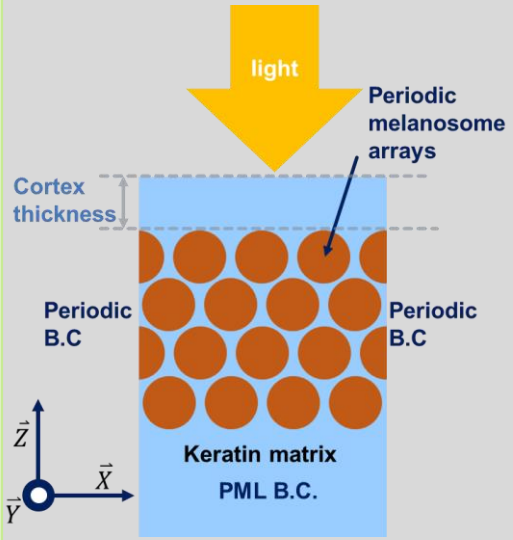


Dimensions

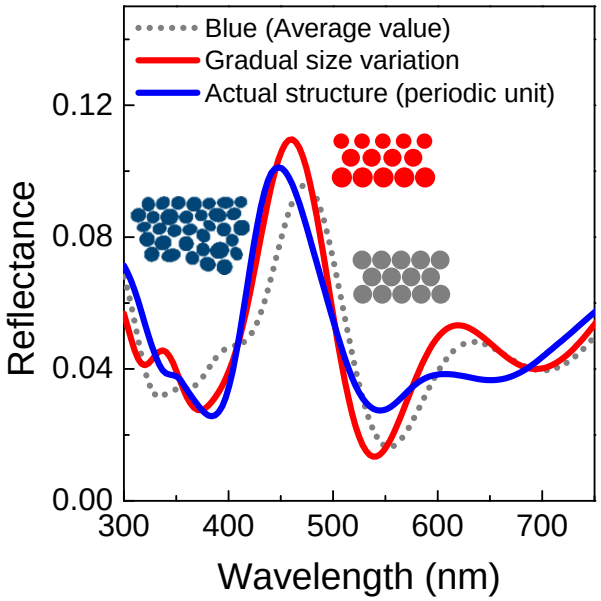
	Green	Blue
Diameter of melanosomes (nm)	125.04 ± 14.14	138.53 ± 16.55
cortex thickness (nm)	283.59 ± 30.24	259.53 ± 30.55
Interspacing (nm)	156.48 ± 15.54 (relatively loosely packed)	150.06 ± 13.66 (densely packed)
Layer numbers	2~4	3~4

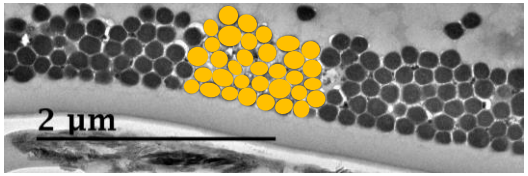
Simulation studies based on FDTD method

Calculated model

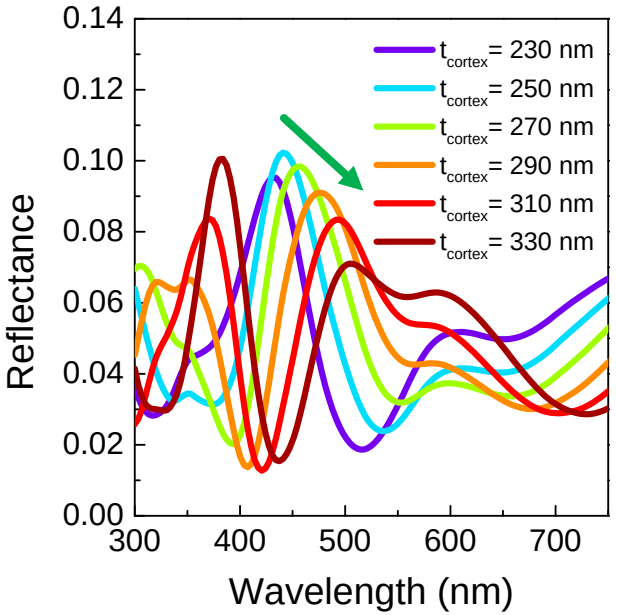


Calculated reflectance for the blue feather





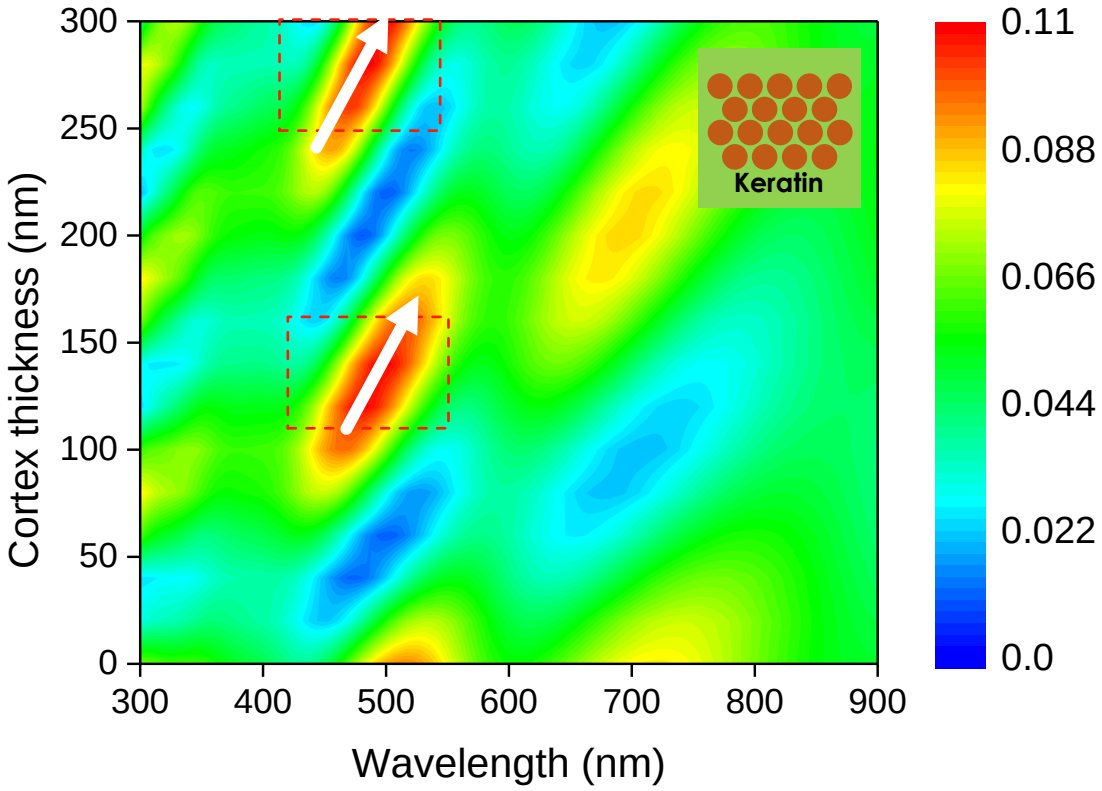
Calculated reflectance according to the cortex thickness variation



Perhaps, the cortex thickness is the most significant parameter to determine the color of the feather

Simulation studies based on FDTD method

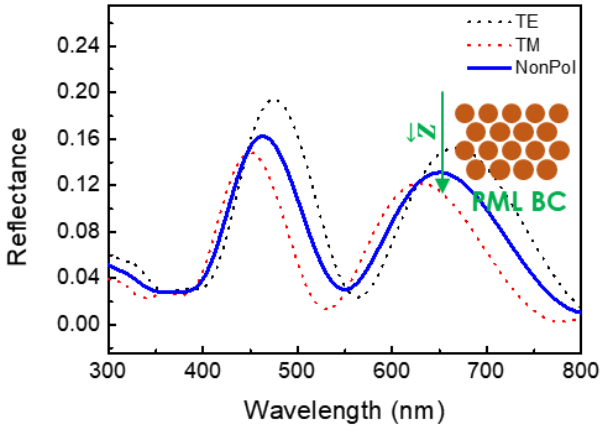
Melanosome arrays in the Keratin matrix



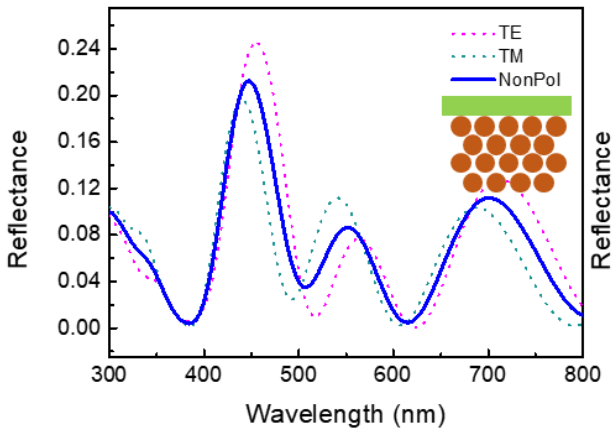
- There are regions (range of thickness) which exhibit strong reflection and red shift with the thickness increase (Red dotted box).
- As the cortex thickness increase, these regions will be seen repetitively.

Simulation studies based on FDTD method

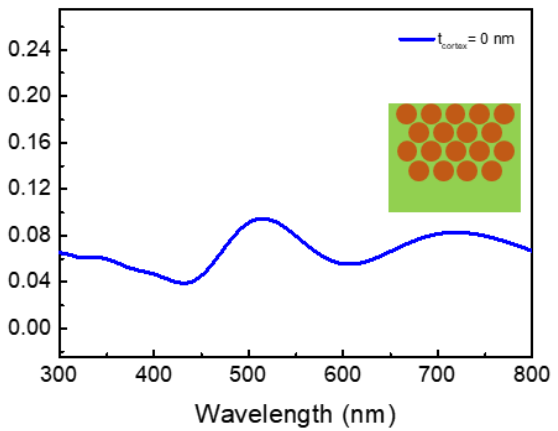
4 layer of melanosomes



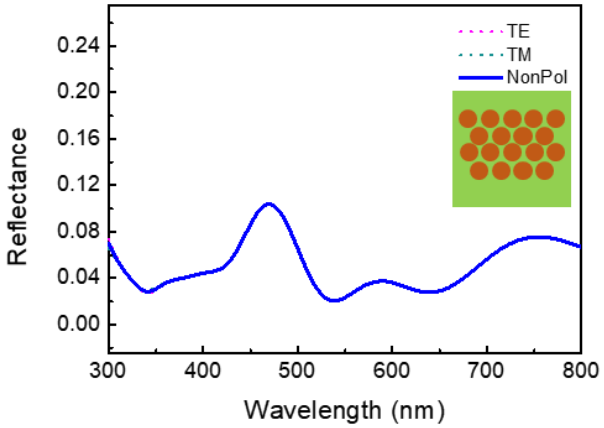
Thin Cortex on top of the melanosome layers



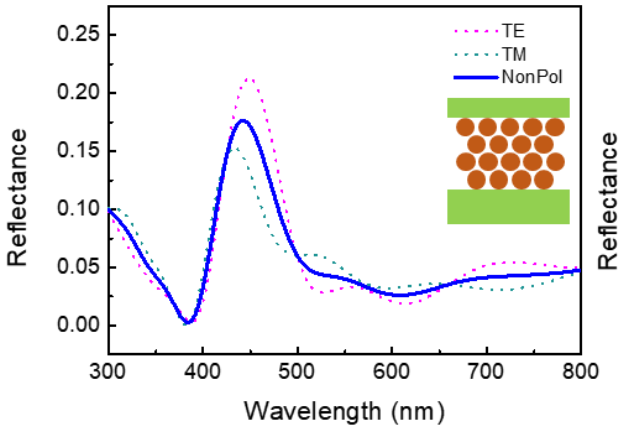
Melanosomes in the Keratin matrix without top cortex



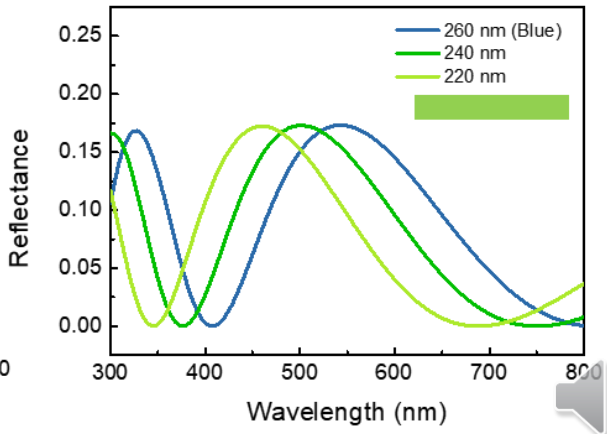
Melanosome in the Keratin matrix



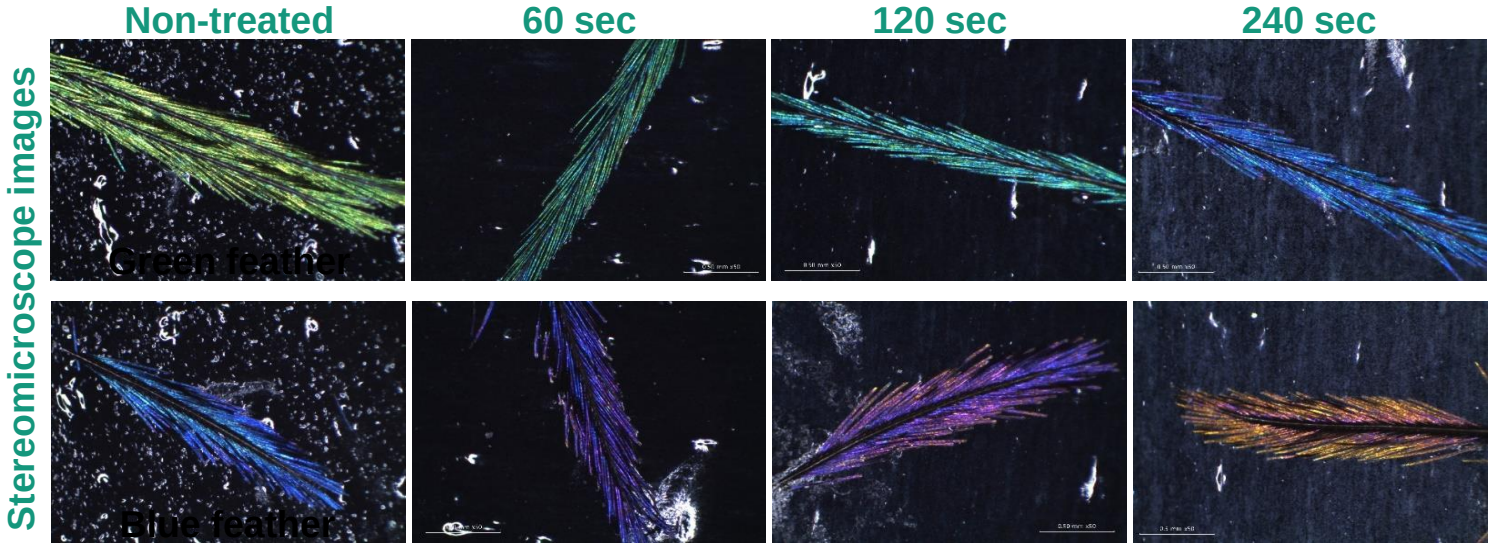
Melanosome layers between the keratins

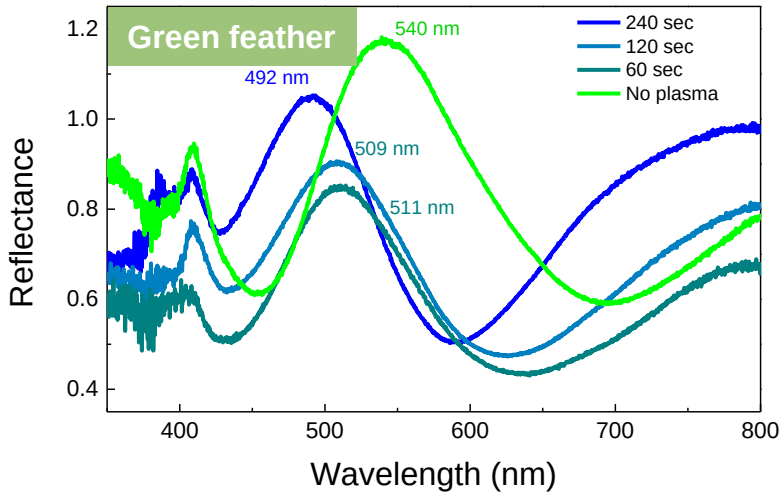


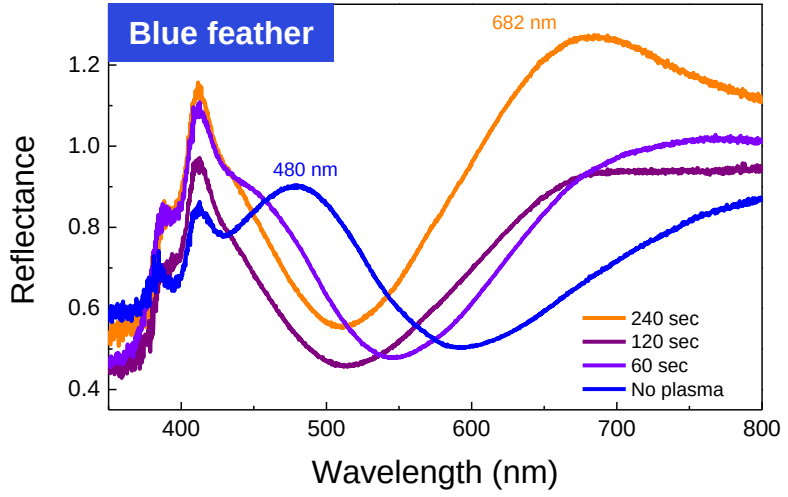
Thin Cortex only



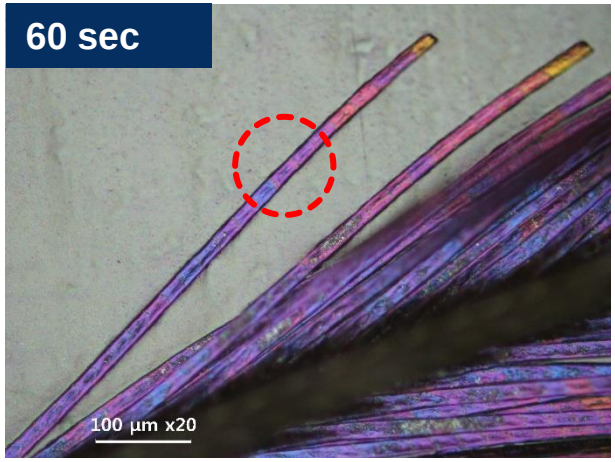
Effects of the plasma treatment

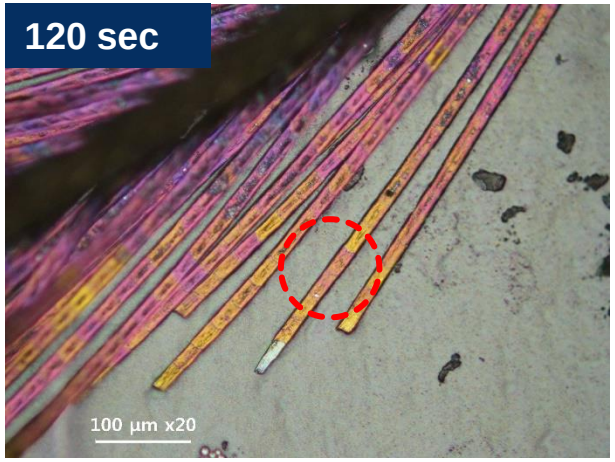


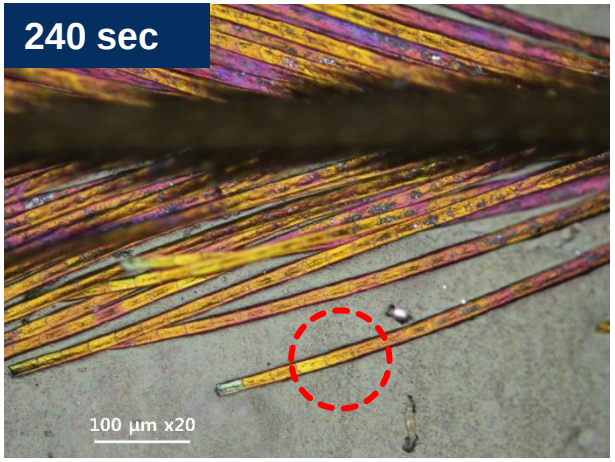


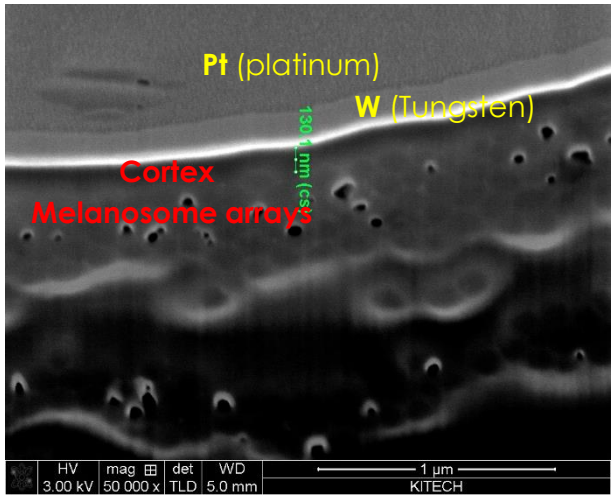


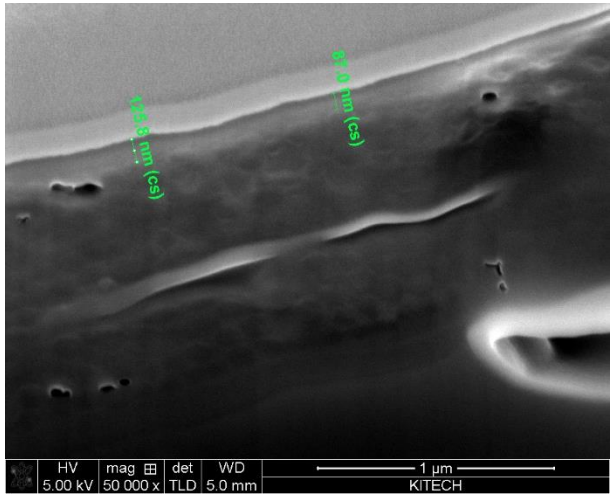
Point specific measurement using FIB

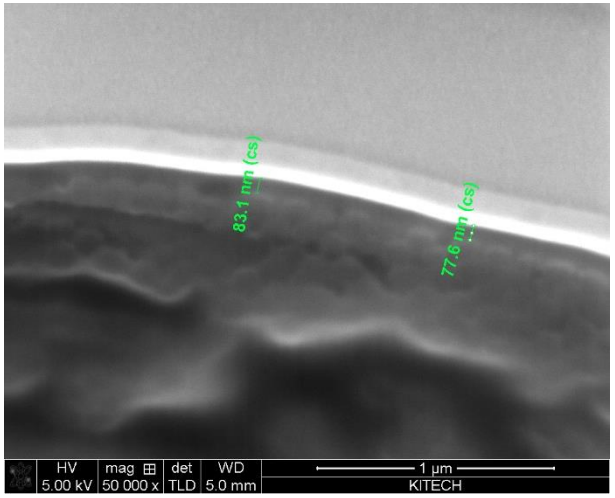












- The cortex thickness gradually decreases with the plasma treated time.
- To measure the thickness accurately using EM, the melanosome arrays need to be dyed.

Summary

- We analyze the nano-photonic structures of pheasant feathers to verify the mechanism of structural coloration using TEM and UV-Vis-spectrophotometer. There are significant differences in cortex thickness between the blue and green feathers.
- FDTD simulations for keratin filled melanosome arrays with thin cortex show the significant contribution of the cortex thickness on the color change. The thin cortex can act as a color filter that passes light with blue-green wavelengths.
- We demonstrate the color changes of pheasant feathers according to the cortex thickness using a plasma treatment and confirm the thickness variations by FIB sectioning technique.

Acknowledgements

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