

Color enhancement in yellow sapphire

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Natural yellow sapphire is colored by one or the combination of two different chromophores, Fe^{3+} and the trapped hole- Fe^{3+} ($\text{h}\cdot\text{Fe}^{3+}$) colour center. Fe^{3+} chromophore is typically found in basalt hosted related while the $\text{h}\cdot\text{Fe}^{3+}$ chromophore occurs in yellow sapphire that contains low iron metamorphic sapphire (1).

In this presentation, our aims are 1) to study the effect of annealing on natural yellow sapphires with different chromophores and 2) to study the cause of color enhancement in yellow sapphire that was created by irradiation. All studied samples were fabricated to be optical wafer with a

polished window perpendicular to the crystal's c-axis. For annealing experiments, we studied 15 samples from Sri Lanka, Madagascar and Australia. The samples were heated at varied temperatures from 500°C to 1550°C for fixed durations of 6 hours in air. The color appearance and spectroscopic data were examined before and after each step of heat treatment. FTIR, UV-Vis-NIR spectra and chemical analysis using LA-ICP-MS were collected at the same area. Effect of annealing results showed in table 1.

| Chromophores | Before heat | After heat |
|--|---|---|
| Only $\text{h}\cdot\text{Fe}^{3+}$ | <ul style="list-style-type: none"> • (very) light yellow • medium to strong 3161 cm^{-1} • $\text{h}\cdot\text{Fe}^{3+}$ absorption | <ul style="list-style-type: none"> • stronger yellow at 900°C and above • 3161 cm^{-1} reduced and may transform to 3000 cm^{-1} series • increase $\text{h}\cdot\text{Fe}^{3+}$ absorption |
| Only Fe^{3+} | <ul style="list-style-type: none"> • yellow • may show 3000 cm^{-1} series • only Fe^{3+} absorption | <ul style="list-style-type: none"> • no changed in appearance • 3000 cm^{-1} series disappeared • no changed in UV spectra |
| $\text{Fe}^{3+} + \text{h}\cdot\text{Fe}^{3+}$ | <ul style="list-style-type: none"> • light to medium yellow • weak to medium 3161 cm^{-1} • $\text{Fe}^{3+} + \text{h}\cdot\text{Fe}^{3+}$ absorption | <ul style="list-style-type: none"> • stronger yellow, may be in unexpected zones • 3161 cm^{-1} reduced • increasing of $\text{h}\cdot\text{Fe}^{3+}$ absorption |

Table 1: Effect of annealing on yellow sapphire with different chromophores.

Irradiation is another treatment to create a yellow coloration in corundum. In our preliminary study, we selected 3 samples from Sri Lanka, Burma and Australia. Samples were irradiated using gamma rays (Co-60) at 50 and 500 kGy. The color appearance and spectroscopic data were examined before and after each step of irradiation. Results showed that strong yellow color is induced after irradiation

(figure 1). FTIR spectra displayed no creation nor destruction of FTIR features typically observed in corundum with irradiation, whereas UV-Vis-NIR spectra revealed strong trapped hole feature after irradiation (figure 2).

In our study, sapphire that colored by $\text{h}\cdot\text{Fe}^{3+}$ can create yellow coloration in corundum by either annealing in air or irradiation. In contrast, sapphire that colored by only Fe^{3+} will not affect to color at experimental conditions.



Figure 1: Color-calibrated photo of sapphire from Sri Lanka before and after gamma irradiation. Path length/thickness: 1.404 mm

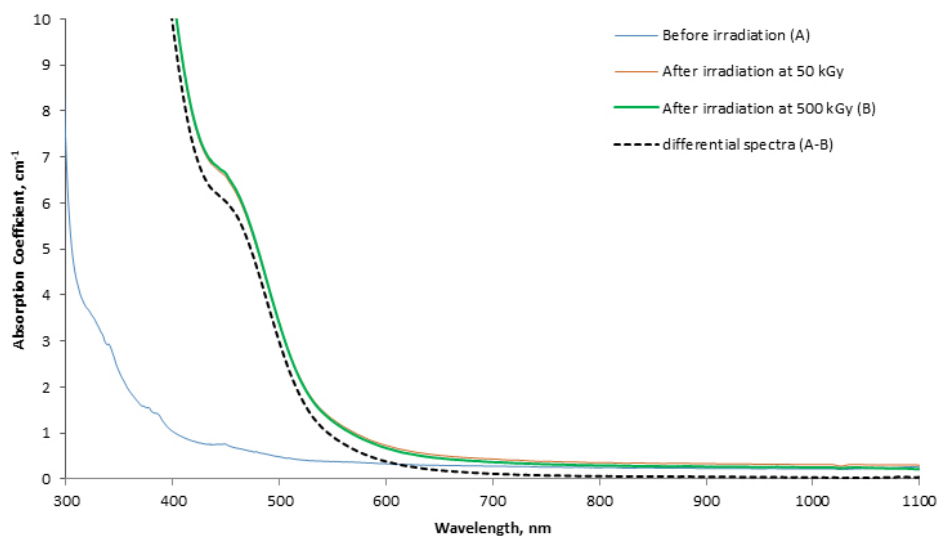


Figure 2. Polarized UV-Vis-NIR spectra comparisons between before and after irradiation with a gamma irradiation dose of 50 and 500 kGy. The difference spectrum revealed a significant increase in trapped hole.

References

Atikarnsakul U., Emmett J. L. 2021. Heat treatment effects on the behavior of the 3161 cm^{-1} feature in low-iron metamorphic yellow sapphire. *Gems & Gemology*, 57(3), 283-288.

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