Gemological Characteristics and Chemical Composition of Color-Change Garnet claimed to be from Tanzania

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Introduction

Color-change garnet is a silicate mineral with a chemical composition intermediate between the pyrope and spessartine end members. Its chemical formula is $(Mg,Mn)_3Al_2(SiO_4)_3$. The color-change effect is caused by trace amounts of transition elements, mainly chromium (Cr^{3+}) and vanadium (V^{3+}), within the crystal structure. As a result, the gemstone displays different colors under different light sources, typically appearing green to bluish green in daylight and changing to red or purplish red under incandescent light, closely resembling alexandrite.

Materials and Methodology

Twenty transparent color-change garnet samples (Figure 1), fashioned in a round brilliant cut and reportedly from Tanzania, were examined (Figure X). The samples were classified into four color groups: two green (CG_11-12), six light blue (CG_21-26), six yellowish green (CG_31-36), and six bluish green stones (CG_41-46). Their weights ranged from 0.037 to 0.072 ct. The gemological properties of the samples were investigated using standard gemological instruments, including measurements of specific gravity, refractive index, fluorescence, and internal inclusions. The chemical compositions were analyzed using an Energy-Dispersive X-ray Fluorescence spectrometer (EDXRF), and the causes of color were investigated using an Ultraviolet–Visible–Near Infrared spectrophotometer (UV-Vis-NIR). All experiments and analyses were conducted at the Department of Mineral Resources and the Faculty of Science, Chiang Mai University, Chiang Mai, Thailand.

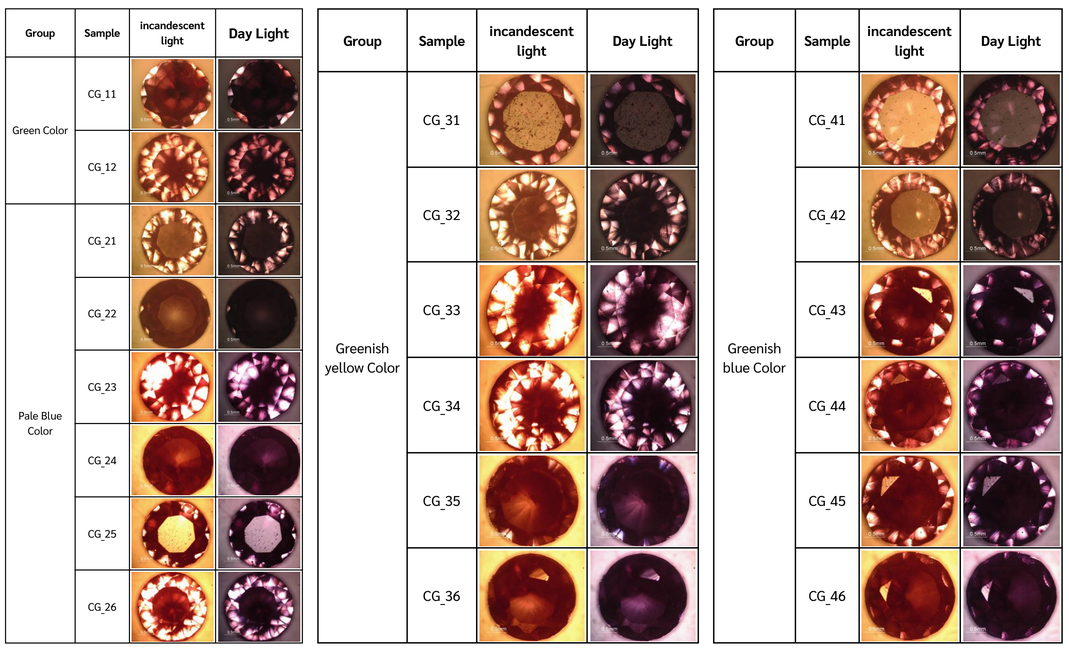


Figure 1. Twenty color-change garnet samples showing color changes under daylight and incandescent light.

Results

Gemological Properties

Twenty color-change garnet samples studied were transparent. The specific gravity of all samples ranged from 3.65 to 4.15. The refractive index could not be determined because it was beyond the upper limit of the tools. No fluorescence was observed under ultraviolet light. Internal inclusions observed in the color-change garnets included healed fractures and needles (Figure 2).

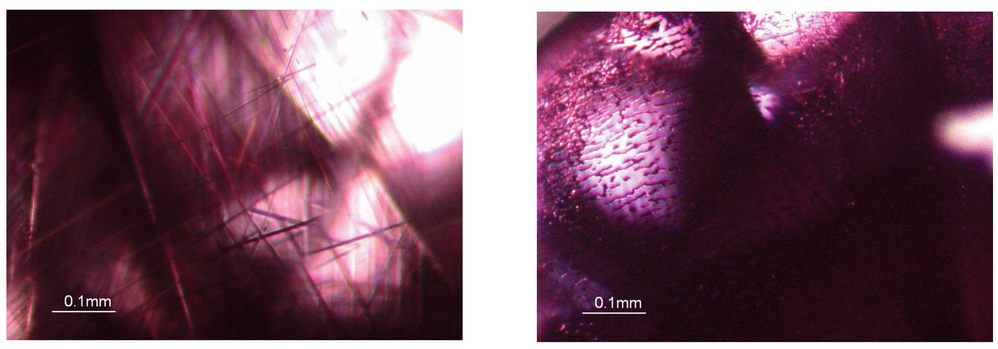


Figure 2. Needle and heal fracture inclusion in garnet from Tanzania.

Chemical Analysis

The elemental composition was analyzed using Energy-Dispersive X-Ray Fluorescence (EDXRF). Most samples showed magnesium contents ranging from 8.05-12.03 wt%, calcium 2.22-4.68 wt%, aluminum 17.53-18.61 wt%, silicon 34.2-35.58 wt%, titanium 0.02-0.35 wt%, manganese 26.54-31.71 wt%, iron 3.05-3.66 wt%, chromium 0.14-0.29 wt%, and vanadium 0.29-0.81 wt%.

Absorption spectra

The analysis using UV–Vis–NIR spectroscopy showed that the color-change garnet samples exhibited absorption bands in the range of 380–800 nm. (Figure 3). The obtained spectra showed an absorption band at approximately 410 nm, which was associated with Mn^{2+}, V^{3+}, and Cr^{3+}. Absorption bands at 424 nm were attributed to the electronic transition of Mn^{2+} and Fe^{3+} in the garnet structure. Absorption bands at 460, 484, and 506 nm were related to Fe^{2+} and Mn^{2+}. Absorption bands at 574 nm corresponded to electronic transitions of V^{3+} and Cr^{3+}.

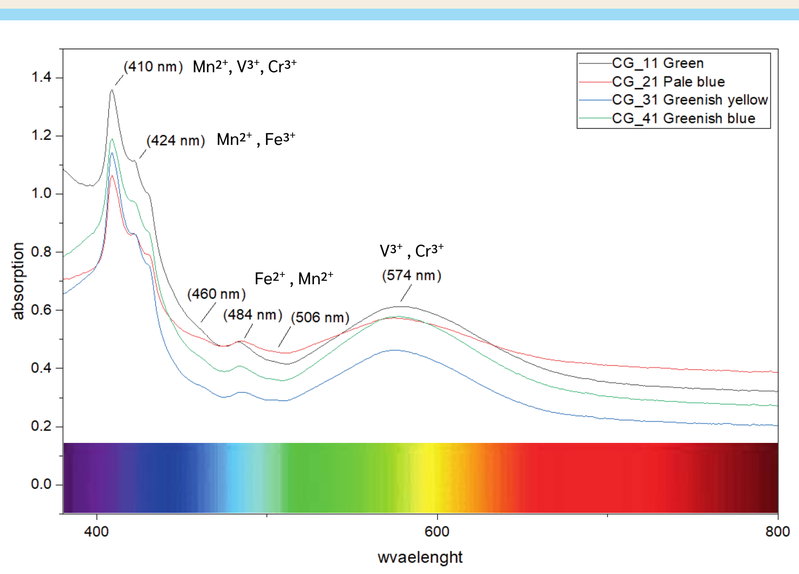


Figure 3. Absorption bands of the samples in each color group: CG_11, CG_21, CG_31, and CG_41.

Conclusion

The results of this study indicated that the color-change garnets from Tanzania contained small amounts of transition elements that play an important role in the optical properties of the gemstone. Chemical analysis revealed the presence of chromium (Cr^{3+}) and vanadium (V^{3+}), which were considered the main chromophores responsible for the color-change phenomenon. UV–Vis–NIR spectroscopic analysis showed several absorption bands associated with electronic transitions of Mn, Fe, Cr, and V. In particular, Cr^{3+} and V^{3+} significantly influence light absorption in the visible region, resulting in the transmission of different wavelengths under different light sources. Therefore, the color-change phenomenon observed in the studied garnets was related to the presence and interaction of transition elements, especially chromium and vanadium, within the crystal structure. These elements affected light absorption in different spectral regions and produced the characteristic color-change effect observed in color-change garnets from Tanzania.

References

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