

Spectroscopy of transition metal ions in glasses: from color to history

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Color is one of the most striking properties of transition metal (TM) elements in glasses. This is illustrated by the richness of the color palette of medieval stained glass windows: a relevant testimony of the high mastery of ancient glassmakers. Because the obtained color depends on the elaboration conditions, glass composition (raw materials and coloring agents) and melting conditions, the determination of the subtle relations between chemistry, structure and optical properties of the glasses helps understanding the history of art and techniques.

Combining optical and x-ray spectroscopies offers a unique tool to determine the speciation of TM and its subtle changes in glasses. Here, minerals provide key references to understand the relation between spectral signatures. Complementary data obtained on model glasses allow determining the influence of glass chemistry and melting conditions. [1,2]



Figure: Stained glass window panel D4 (detail) from the Sainte-Chapelle of Paris, France (15th c.), showing typical colours: all contains copper, but in various oxidation states.

With the development of a specific portable UV-vis-NIR optical spectrometer [3] this approach could be extended in its non-destructive application to real early and late medieval stained glass windows of the Sainte-Chapelle of Paris, one of the most famous French gothic buildings. From the determination of the speciation of the main TM: Fe, Mn, Cu and Co, in ancient glasses, I will present the inference of peculiar information about medieval glassmaking technologies [2,4].

[1] M. Hunault, *et al.*, (2014) *J. Am. Ceram. Soc.*, **97** 60–62.

[2] M. Hunault, *et al.* (2016) *J. Am. Ceram. Soc.*, **99** 89–97.

[3] M. Hunault, *et al.*, (2016) *Appl. Spectrosc.*, **70**. [4]

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