Observations of Wavelength Shifts in Europium Doped Calcium Fluoride Under Shock Compression by Time-resolved Luminescence Spectroscopy

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Introduction

Time-resolved luminescence spectroscopy is an important characterization method which allows us to study, among other things, excited states in matter and the response of materials at the molecular level when subjected to a dynamic stress. If a stress, such as a shock wave, is applied to a material that fluoresces, its fluorescence spectrum shifts by a measurable wavelength.[1] We can study the effects of shock and release waves analyzing the shift in wavelength.

Procedure

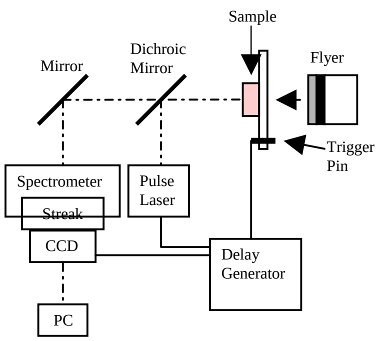

Figure 1: The Experimental Setup

Figure 1 shows the experimental set up. The sample, a transparent CaF_2 crystal doped with Eu, is mounted on a base plate that also has a trigger pin attached. The flyer which impacts the sample is made from either aluminum or stainless steel, depending on the speed at which it is fired from a propellant gun. The trigger pin is used to obtain an electric trigger pulse for the Nd:YAG pulse laser. The mirrors are used to aim the laser normal to the sample surface pre-impact and then to collect the luminescence during and after the impact. The luminescence was transmitted to a spectrometer and then the streak camera. A Charged Coupled Device (CCD) camera then creates a time-varying luminescence image which is displayed on the PC.

Results & Discussion

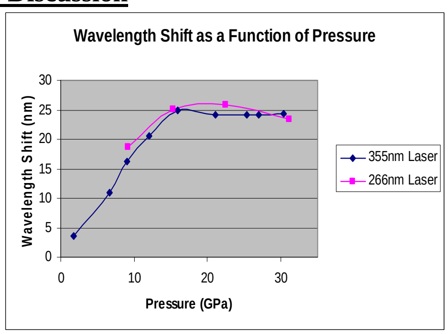

Figure 2: Experimental Data

Fig. 2 shows the relationship between the shift in wavelength and the applied pressure. From the figure we can see that up to a pressure of around 15GPa, the wavelength shift tends to rise linearly with increased pressure. This is in agreement with the typical activity of other crystalline materials that fluoresce.[2] A possible explanation for this is that the speed of the shock and release waves that travel through the sample when it is shocked increase as the applied pressure increases. However, we also see that at a pressure around 15GPa, the wavelength shift stops increasing at about 15GPa. From that point on, any increase in pressure no longer results in an increased wavelength shift. This result is so far unexplained and remains the topic for further study. Finally, the third thing that we can see from Fig. 2 is that the wavelength shift is independent of the wavelength used by the YAG laser. In this example we used a wavelength on the edge of the visible spectrum, 355nm, and an ultraviolet wavelength, 266nm. This is an important result because it means that the wavelength shift is directly a result of the applied pressure and independent of the intensity of the pulse laser.

Conclusion

The three main conclusions are: (1) At pressures below about 15GPa, the wavelength shift increases with increased pressure, (2) from around 15GPa and onward, an increase in pressure does not result in an increased wavelength shift, and (3) the YAG laser set to different wavelengths does not have an effect on the shift. A topic for further study is to determine why the wavelength shift does not continue to increase with pressure beyond about 15GPa.

References

1. T. Kobayashi, T. Sekine, et al. Physical Review B 69 (5): Feb 2004
2. T. Sekine, T. Kobayashi, et al. Am Mineral 91 (2-3): 463-466 Feb-Mar 2006

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