Abstract. New emission spectra for MgO and CaMgSi2O6 glass are observed from 430 to 920 nm. Taken with previous data, we suggest that transparent solids display three regions of light emission upon shock compression: (1) characteristic radiation such as observed in MgO and previously in other minerals, (2) heterogeneous hot spot (grayish-yellow) radiation observed in CaMgSi2O6 and presumably in all transparent solids undergoing shock-induced phase transformations, and (3) blackbody radiation observed in the high pressure phase regions in NeAl2O4, MgO, Ca2MgSi2O6, CaAl2Si2O8, and Mg2Si2O5. The onset of region (1) was defined as the onset of shock-induced breakdown whereas the onset of region (2) delineates the isostatic pressure required to achieve local thermal equilibrium in the shocked solid. We also propose that the hot spot temperature and corresponding shock pressure determined in region (2) delineate points on the fusion curves of the high pressure phase.

Introduction

Although shock were techniques have been used to study the pressure-density relation of important minerals, shock temperatures have, to date, largely been calculated. Recently, methods for temperature measurement were developed by Lyzenga and Atkeson (1975) who used a single channel optical pyrometer system, and Sugiura et al. (1982) who used 300 channel spectrometers in order to measure radiation over the optical range. Kondo and Atkeson (1983) and Kondo et al. (in press) constructed a similar system for radiative temperature calibration (Fig. 1) to measure the shock temperatures of various materials. This method determines the temperature and the emissivity of the shock-heated sample at the isostatic pressure of 3.0 GPa. Figure 2 compares the results obtained at 3 GPa with those obtained at 1.0 GPa and 2.0 GPa. The data presented in this paper were obtained at 1.0 GPa and 2.0 GPa. In these experiments the importance of the pressure-temperature of the shock was demonstrated by Atkeson et al. (1983) and the pressure-temperature of the shock was used in these experiments. The shock-temperature of the shock was determined by the technique of Atkeson et al. (1983).

Experimental

Our experiments were conducted using a 40 MeV gas-filled tandem accelerator which is capable of delivering the desired neutron velocities. The neutron beams were determined by direct beam interception and flash X-ray photography (Fig. 1).

Can the shock travel through the sample?

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Fig. 1. Diagram for observing shock-induced emission of transparent materials. The light travels along the paths indicated. Sample mass estimates the surface effects. Date and time are recorded by oscilloscope (after Kondo and Atkeson, 1983). 

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### Table 1: Radiative Characteristics of Shocked CaO, ZrO, and MgO

<table>
<thead>
<tr>
<th>Shot Sample</th>
<th>Projectile Vel. (km/s)</th>
<th>Shock Pressure (GPa)</th>
<th>Theoretical Color Continuum Temp., °K</th>
<th>Radiant Emissivity, ε</th>
<th>Maximum Radiance, ( \frac{W}{m^2 \cdot ster \cdot \mu m} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Anf1</td>
<td>2.38</td>
<td>37.5</td>
<td>1576</td>
<td>3300</td>
</tr>
<tr>
<td>36</td>
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<td>39.7</td>
<td>1686</td>
<td>3135</td>
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<tr>
<td>36</td>
<td>Anf3</td>
<td>2.44</td>
<td>38.6</td>
<td>1600</td>
<td>2845</td>
</tr>
<tr>
<td>36</td>
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<td>85</td>
<td>490</td>
<td>519</td>
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<tr>
<td>36</td>
<td>MgO</td>
<td>2.20</td>
<td>35.1</td>
<td>147</td>
<td>121.4</td>
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<tr>
<td>36</td>
<td>MgO</td>
<td>2.43</td>
<td>62.3</td>
<td>514</td>
<td></td>
</tr>
</tbody>
</table>

(Jones and Abrams, 1980), and MgO (Vaselines and Abrams, 1981).

### Results and Discussion

A steel control shot (Fig. 1a) was performed to determine if significant light could be generated by the shock produced in the 80 μm air environment of the impact chamber (Fig. 1a). The smooth curve passing through the absorptive data (Fig. 1a) represents the best fit greybody curves. The greybody fit to Anf1 (not shown) was dubious due to the high noise to signal ratio. The data for Anf3 and Anf4 fit the greybody formula well and it can be confidently stated that they are thermal spectra. These color temperatures are twice as high as those predicted as described above. The emissivities are much lower than if the material radiated as a blackbody (Table 1). These results are similar to those found in shocked NaCl, CaO, CaCl₂·2H₂O, and MgO (Kondo and Abrams, 1983; Kondo et al., in press). The spectra from the three MgO shots (Fig. 2b) were surprising as a lower temperature greybody spectrum was expected. Instead, a band emission

![Spectral Radiance vs Wavelength](image1.png)

**Fig. 2 a)** Observed spectra for CaO, ZrO, and control (steel). **b)** Observed spectra for MgO.

![Proposed Phase Diagram](image2.png)

**Fig. 3** Proposed phase diagram of NaCl based on temperature of Kondo and Abrams (1983), MgO neutron transmissivity of Buffington et al. (1963), Abrams et al. (1983), and also Lysenga (1969). MgO melting point determination (Fritts et al., 1971) and high pressure X-ray diffraction (Bassett et al., 1968).
spectra centered at 700 m was observed. MgO does not undergo a phase change to pressures of 210 GPa (Vasiliou and Ahrens, 1981).

Although temperature and low density of anorthite is interpreted as resulting from low-melting temperatures produced by nonmetallic deposition of energy due to shear instabilities, we believe these results due to phase transformation as suggested by Gagy et al. (1979, 1980). This phenomenon is also found by Baillou and Ahrens (1983) who photographed light emitted by crystallographically controlled shear bands in (w-x)-crystal quartz. In (w-x) quartz the onset of room temperature and density of anorthite was observed by Baillou et al. (1983) to correlate with phase transition to high silica.

We suggest, therefore, that there are three regimes of light emission from minerals: (1) the characteristic radiation regime, (2) the heterogeneous hot spot radiation (graybody) regime, and (3) the blackbody equilibrium shock temperature regime.

For minerals such as MgO (i.e., pressures below a phase transition) only characteristic radiation is excited. In regime (1) the emission is unique for each mineral, even when superposed on light emitted by radiation from regime (2) as in Kondo and Ahrens (1985; Komdo et al., in press).

The heterogeneous hot spot regime, as small regions of the solid collapse inward, nucleate the growth of denser high pressure phase, phase instabilities are produced from stored strain energy. This occurs until a thin layer of melt coats the high pressure phase with the result that the shear band temperature is constrained to the existence of high pressure phase. Phase instabilities are related to the small fraction of melt in the aggregates (i.e., at successively higher pressures in a mixed phase regime, the amount of melt remains small, resulting in low instabilities). In regime (3) for which data for minerals have been reported above 2000 K, by Koyama et al. (1985, Lyzenga and Ahrens 1980, Lyzenga 1982, 1983, Ahrens et al. 1982, Lyzenga et al. 1983, Ahrens 1985), the material becomes sufficiently heated to a continuous temperature by the shock, such that thermal instabilities are rapidly equilibrated. The observed instabilities are close to unity.

The best example of radiation in the heterogeneous regime yielding data pertinent to establishing the fusion curve is for the B3 phase of NaCl (Kondo and Ahrens 1982, Figure 3). Here, and also for SiO2 (Figure 4, the graybody spectra of Kondo and Ahrens (1983) are contoured by characteristic radiation. For NaCl the B3-liquid phase boundary is close to that suggested by Bundy (1971) and consistent with the B3 liquid phase boundary inferred from the shock temperature measurements of Koyama et al. (1985). The Pu-322 trajectories of the NaCl in Figure 3 for B3 and liquid phase are that of Ahrens et al. (1982). The two least characteristic radiation contoured fusion quartz shots (Kondo et al. 1983) represent the melting point of anorthite at 23 and 30 GPa (Fig. 4). The inferred B3 anorthite solidus in Pu-space (Fig. 5), based on charactertic raiation, demonstrates that these high temperature-high pressure observations are consistent with the hypothesis of constraint of shear band temperature to the solidus.


References

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