An Interpretation of the MBSL Temperatures Deduced from Metal Atom Emission

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Abstract: Recent MBSL observations of metal atom line emissions from a variety of metal carbonyls seeded into Ar display similar effective emission temperatures in the range of 5,000-6,000K. The interpretation explored here is that the metal emission occurs within a narrow time window during bubble collapse corresponding to the observed temperatures, and that the peak collapse temperature can be much higher. Coupled chemical-hydrodynamic bubble collapse calculations are presented which demonstrate that for the very small metal atom mole fractions expected in these experiments the onset of metal atom ionization occurs around 6,000K, thus precluding the observation of the non-ionized atomic lines at much higher temperatures.

INTRODUCTION

Recent MBSL experiments on a variety of metal carbonyls seeded into Ar bubbles display metal atom emission spectra which have been fit to effective emission temperatures in the 5,000-6,000K range (1). This same temperature range has been previously observed for C2 emission from MBSL of Ar in silicone oil (2). The issue arises as to whether or not this is the peak bubble collapse temperature regime for MBSL. The viewpoint adopted here is that the molecular and atomic emissions observed in MBSL occur within well defined time windows during the collapse and re-expansion processes which are substantially separated from the moment of peak collapse. It was previously demonstrated through the use of a coupled chemical kinetic-hydrodynamic model that the chemistry giving rise to C2 MBSL only occurs around 5,000K even for bubbles with much higher peak collapse temperatures (3). Similar calculations are presented here, based on the chemical properties of metal atoms, which demonstrate that metal atom emission also occurs in the vicinity of 5,000K.

MODEL CALCULATIONS AND DISCUSSION

The bubble dynamics were simulated with the Keller-Miksis model using the Carnahan-Starling equation of state and electronic heat capacity for Ar (4). The fractional ionization of the seed metal atoms was calculated using the Saha formula with an ionization energy of \(E_{\text{ion}} = 7eV\) (this is representative of the transition metals used in the experiments). The computed bubble properties are shown in Figure 1 for an Ar bubble in H2O. While the experimental conditions for MBSL can vary widely, this choice is sufficient to illustrate that the metal atom emission time windows are well separated from the region of peak collapse. Figure 1 illustrates several interesting points. First, the bubble spends much more time in the vicinity of 5,000K than at the much higher temperatures. Second, the pressure broadened line widths above about 10,000K are enormous and thus tend to obscure the spectral line structure. Both of these effects mitigate the contribution of the higher temperatures to the metal atom spectra; however, the most significant factor is displayed in Figure 2. The actual metal atom mole fraction in the emitting bubbles is not known. Simple estimates, based on ideal solutions, suggest \(\chi_M = 10^{-4}\). This is likely a gross upper limit due to the expected rapid diffusive depletion of metal atoms from the bubble into the liquid; this is analogous to Ar rectification of air bubbles (5). For \(\chi=10^{-6}\) and \(T=7,000K\) it is seen from Figure 2 that approximately 90% of the metal atoms are ionized. The ion emission lines which are expected to be present fall at much shorter wavelengths than the neutral atom lines and are not experimentally accessible. Synthetic spectral calculations of the metal atom emissions are underway and will be presented at the meeting.
FIGURE 1. Calculated pressures, temperatures, and pressure broadened emission line widths during bubble collapse.

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REFERENCES