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Laser enhanced the formation of LiH particles inside crossed arms heat pipe oven

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ABSTRACT

We are reporting laser enhanced chemical reaction for the formation of LiH inside crossed arms heat pipe oven that may be aimed towards the laser enrichment of the isotope of interest. In addition, an interesting feature of particle formation in the crossed arms region of the heat pipe oven (HPO) is presented. The temperature gradient between the cold and hot parts across the crossed arms region causes the convection currents to develop, that results in the formation of fog due to the lithium clusters in the presence of helium as buffer gas. When helium gas is replaced by hydrogen, large size particles were observed through naked eye from the scattering of laser light passing through the HPO. At the interface between the localized cold and hot regions of the convection currents, the density of LiH molecules increases up to certain limit where they condense into bigger particles. Gravity forces the particles to fall down and they are forced to follow the convection current flow path.

1. Introduction

Heat pipe oven [1] offers well defined homogenous metal vapors of alkali metals and crossed arms heat pipe oven offered additional opportunity to investigate the fluorescence produced by light-vapor interaction. The generation of metallic alkali micro-particles inside the heat oven (HPO) at vapor to gas phase interface is relatively a complex process and has been studied extensively [2–4]. Granquvist and Buhrman [2] produced ultrafine metallic particles in a heated oven in the presence of an inert gas. Allegrini et al. [3] reported large production of potassium microparticles upon resonant laser excitation in the presence of noble gas. They argued that disequilibrium is caused at the gas/vapor boundary due to the strong local heating of metallic vapor caused by high absorption rate of the laser; a supersaturated region is created where the metallic vapor condenses and produces ultrafine particles. Atutov et al. [4] reported the formation of sodium microparticles on the border between the cold and hot zones and described an explosive vaporization of sodium microparticles when sodium vapor is excited with resonant cw laser radiation. Pichler et al. [5] reported the alkali fog formation at the border where hot alkali vapor meets colder noble gas. Similarly, Kolwas et al. [6], Jakubczyk et al. [7] and Demianiuk and Kolwas [8] reported the studies about the laser initiated cluster formation of sodium vapor.

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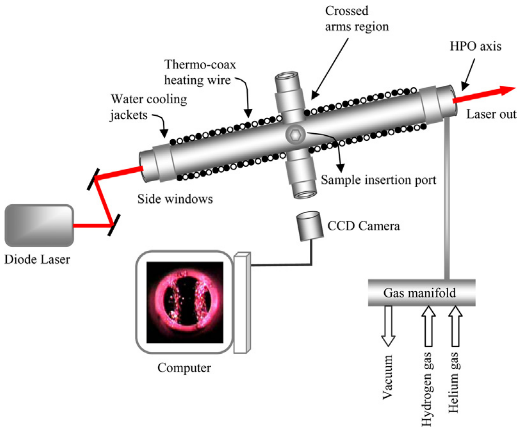

Fig 1. Experimental set up for studying the laser enhanced chemical reactions for the formation of LiH and the development of convection currents in the crossed arms region of the HPO.

In addition, a number of authors [9–14] have reported the micron size particles from the condensation of alkali hydride when these hydrides are formed through resonant excitation of alkali vapor. Tam et al. [9] reported for the first time the formation of micron size cesium hydrides particles in the presence of hydrogen gas when Cs vapor was excited with resonant laser light. Later on, Happer [10] described the particle formation from the alkali hydrides when alkali vapor is excited using resonant laser in the presence of hydrogen gas and named the phenomena as "laser snow". He elucidated that these particles are highly charged and can be swept in any direction with small electric field and this phenomena may lead separation of alkali isotopes. Tanaka et al. [11] described the shapes of laser produced CsH crystalline particles, suspended them by an electric field to allow growing large enough to observe by an optical microscope. Omnès [12] and Picquè et al. [13] further studied the "laser snow" mechanism in the cesium hydrogen system. Similarly, Yabuzaki et al. [14] reported the formation of NaH crystalline particles of when sodium vapor is excited by a cw laser in the presence of hydrogen gas.

In this article, we present an interesting phenomenon for the development of lithium fog structure in the vicinity of the crossed arms region with helium as buffer gas. In addition, when helium is replaced by hydrogen, very interesting phenomena regarding the formation and flow of LiH particle (snow balls) in the crossed arms region is observed by naked eye. The formation of LiH particles in our case is due to high temperature gradients in the vicinity of the convection currents and this finding is different from the reported earlier [9–14] for other alkali hydrides that were initiated by laser enhanced chemical reactions.

2. Experimental setup

Fig. 1 illustrates the experimental setup used in these studies. It consists of a crossed arms heat pipe oven (HPO), gas manifold system containing helium and hydrogen gases, diode laser module FLMM-0670-812-2W (HTOE, China), CCD camera (GP-KR222 Panasonic) coupled with computer. The heat pipe oven (HPO) is designed and constructed locally using stainless steel SS 304, that is considered good for vacuum systems. The HPO is a stainless steel tube of length 30 cm, inner diameter 40 mm and wall thickness of 5 mm. A thermo-coax heating wire is wrapped around the heat pipe tube to produce the required temperature for appropriate vapor pressure of alkali metals. Thermo-coax heating wire is wrapped in such a way that the magnetic field produced due to flow of dc current in one direction is cancelled with adjacent wire. Thermocoax heating wire can increase the temperature of HPO up to 1000 °C. At the ends of the HPO, two cooling jackets through which chilled water was flowing are used to separate the quartz windows from the heating zone. Viton O rings are used for sealing the quartz windows. The cooling jackets serve two purposes, first it saved viton O-rings from damaging and second it produces an interface barrier between hot and cold region and therefore avoids the coating of metal vapor on quartz windows. The central portion of the HPO consists of two crossed arms with cooling jackets having chilled water flowing through them, a sample insertion port of diameter of 25 mm and beneath it a sample container of inner diameter of 25 mm and depth of 50 mm. A piece of pure naturally occurring lithium metal (∼99.99%) is loaded in the sample holder through the sample insertion port where the thermo-coax heating wire allows the temperature of the sample container to reach anywhere up to 1000 °C. The winding of the thermo-coax wire around the sample container was adjusted in such a way that the temperature of the sample container is somewhat kept lower than the HPO, this may help to drain down the molten lithium in the HPO tube. The windows at both ends of the heat pipe are used for the laser to pass through the lithium vapor inside the cell and the other two at the centre are used for viewing the laser vapor interactions being carried out inside the heat cell. Diode laser module used in these studies emits a spectral bandwidth of ∼3 nm centered at 671 nm at 25 °C and coupled to a fiber optic delivering 2 W output power. The laser diode module can be temperature tuned to get maximum lasing at the wavelength of interest. A high resolution CCD camera is interfaced with computer to capture each and every event happening inside the crossed arms of heat pipe.