Light-Induced Atomic Desorption from siloxane film loaded with Rb and Cs

C Marinelli, A Bogi, F Della Valle, A Burchianti, E Mariotti, S Veronesi, L Moi
Dipartimento di Fisica, Università di Siena, via Roma 56, I-53100 Siena, Italy
marinelli@unisi.it

Abstract. We observe Light-Induced Atomic Desorption of Rb and Cs atoms from PDMS coated cell containing both atoms at the same time. The desorption rate and the relative vapor density variation have been simultaneously measured for both alkali atoms as a function of the desorbing light intensity and frequency. They show the same behaviour upon the different illumination conditions. This work demonstrates the possibility to provide light controlled atomic dispenser delivering different atomic species using LIAD effect.

1. Introduction
Light-Induced Atomic Desorption (LIAD) is a complex effect involving atoms, dielectric films and light and consists of a huge emission of alkali atoms from siloxane films when they are illuminated by light [1]. The effect has been observed for Na, K, Rb and Cs atoms desorbed by weak illumination of cells coated with polydimethylsiloxane (PDMS) [2-6], octamethylcyclotetrasiloxane OCT [5] and paraffin [7]. The LIAD efficiency is enough to produce a Rb atomic source at room temperature controlled by light [8] or to load a magneto-optic trap (MOT) [9,10]. Very recently LIAD directly from a pyrex surface has been used to load a Bose-Einstein Condensate (BEC) in a microelectronic chip [11]. Detailed experimental analysis of LIAD effect has been made in the last few years both measuring the vapor density changes in sealed cells and the atomic velocity distribution in special vacuum chambers with the Time of Flight (TOF) technique [12]. Measurements have been done as a function of the film temperature, the desorbing light intensity and frequency, the illumination time [4,5]. These works clearly show that the atomic bulk diffusion, both with and without cell illumination, plays a major role in the effect that is no more a simple surface effect.

In order to explore the possibility to set up light controlled atomic dispensers delivering one or more atomic species and to well understand the effect, we have prepared PDMS coated and sealed cells where both rubidium and cesium have been distilled. This approach allows one to compare the behavior of the two alkali atoms without taking care of the possible differences existing between two cells in which the coating may have different thickness, purity, homogeneity, defects etc. Moreover it should put in evidence the differences coming from different atoms adsorbed in the same film. Preliminary results have been reported in reference [13]. A similar approach has been adopted by Alexandrov et al. [7] with paraffin-coated cells.

2. Experimental apparatus
The experimental apparatus is shown in figure 1. A cylindrical Pyrex glass cell (total length 62 mm; external diameter 20 mm) that is coated with a PDMS film is connected, through a short capillary, with a reservoir containing an amalgam of Cs and Rb and sealed with a good vacuum inside. The
coated cell preparation has followed a standard procedure described elsewhere [4]. Two diode lasers tuned to the Rb D line and to the Cs D line respectively, have been used as probe beams.

The intensities have been reduced by means of neutral filters, in order to make negligible hyperfine pumping and saturation effects. The transmission signals are detected by two photodiodes and sent to the data acquisition system. The desorption-adsorption processes are detected by simultaneously monitoring of the vapor density changes of the two alkali atoms when desorbing light is on or off. The diode lasers are frequency modulated, the absorption spectra are continuously acquired and the absorption changes are obtained by fitting the atomic line profiles. This acquisition system allows us to collect data with the same accuracy for both alkali atoms during several hours. In order to make a precise and reproducible analysis as a function of the desorbing light frequency, different desorbing light sources have been used, like for example an Ar$^+$ laser, various diode lasers, a dye laser, a high pressure Hg lamp. In all measurements the cell has been illuminated in the same geometrical conditions independently of the light source using an electronically driven shutter and proper optics.

3. Experimental results

After few days from the cell preparation the coating start to desorb Rb and Cs atoms in a stable manner when light sources shine the walls of the cell. Typical desorption signals for Rb and Cs atoms are shown in figure 2. When the cell is illuminated, the vapor density $n$ increases, reaches its maximum $n_{max}$, and then slowly decreases back to the equilibrium value. If the desorbing light is switched off a faster decay of the signal is observed. The relative vapor density variation as a function of the time, induced by the desorbing light, is

$$\delta_{LAD}(t) = \frac{n(t) - n_0}{n_0}$$

where $n_0$ is the vapor density at thermal equilibrium when the cell is not illuminated.

In figure 2 $\delta_{LAD}(t)$ as a function of time is shown for both atoms, the desorbing light is provided in a) by an Ar$^+$ laser tuned on 488nm and in b) by a diode laser at 685nm. The relative vapor density changes are the same for both alkalis even when they are as large as one order of magnitude. The measurements has been performed using many different desorbing light wavelength and intensity and the obtained signals are completely overlapped, moreover they show the same dynamical behavior. The fact that $\delta_{Rb}(t)$ and $\delta_{Cs}(t)$ are so well coupled supports the following hypothesis: no competition between the two alkali atoms takes place, they don’t saturate the coating; the atomic diffusion is the same for both alkalis both in the dark and in presence of light; the effect does not depend on specific properties (for example polarizability and level structure) of the two atoms.
Following the same approach developed in previous works [4,5], we study the behavior of the parameters

\[ \delta_{Rb, Cs}^{max} = \frac{n_{Rb, Cs}^{max} - n_{Rb, Cs}(0)}{n_{Rb, Cs}(0)} \]  

and

\[ R_{Rb, Cs} = \frac{1}{n_{Rb, Cs}(0)} \left( \frac{dn_{Rb, Cs}}{dt} \right)_{t=t_0} \]  

\[ \delta_{Rb}^{max} \text{ and } \delta_{Cs}^{max} \text{ give the maximum relative increases of the vapor densities, } R_{Rb} \text{ and } R_{Cs} \text{ is the relative increasing rate of the vapor density immediately after the light switching on at } t=t_0 \text{ for rubidium and caesium respectively. In agreement with our model and with previous experimental results obtained on Rb and Cs cells, } \delta_{\text{max}} \text{ should show square root dependence with the desorbing light intensity while } R \text{ a linear dependence with the desorbing light intensity.} \]

\[ \delta_{Rb}^{max} \text{ and } \delta_{Cs}^{max} \text{ as a function of desorbing light intensity; b) } R_{Rb} \text{ and } R_{Cs} \text{ as a function of desorbing light intensity. The desorbing light is provided in by an Ar+ laser tuned on 488nm.} \]
In figure 3a) \((\delta_{Rb}^{\text{max}})^2\) and \((\delta_{Cs}^{\text{max}})^2\) and figure 3b) \(R_{Rb}\) and \(R_{Cs}\) as a function of the desorbing light intensity, from an Ar\(^+\) laser tuned on 488nm, are shown. The two species show the same dependence, within the error bars, upon all the experimental conditions, and the dependence on the desorbing light intensity for the two atoms is in agreement with our model prediction.

The dependence of the maximum relative increases of the vapor densities \(\delta^{\text{max}}\) as a function of the desorbing light intensity has been measured using different light sources. The measurements have been done by keeping constant the desorbing light intensity and the illuminated area. It is known from previous measurements, that LIAD effect from siloxane coatings decreases by increasing the desorbing light wavelength \([1,6,14]\) and seems to show a threshold at long wavelength \([6,14]\). The result of our measurements shows that the maximum relative increases of the vapor densities is the same for Rubidium and Cesium for any fixed desorbing light wavelength we used, in the range 457-810nm. From our measurements \(\delta^{\text{max}}\) increases according to a very fast dependence on the desorption photon energy for both atoms; moreover no resonances are observed.

4. Conclusion

We have demonstrated the possibility to realize atomic dispensers controlled by light delivering two atomic species at the same time. In our experiment we show that is possible to store Rb and Cs atoms inside organic films, like PDMS, without they saturate the coating. No competition between the two atoms, no difference in the dynamics and frequency dependence of LIAD effect for the two species has been observed. The effect does not seem to depend on specific properties of the two atoms but it is due to non resonant processes involving the polymer and the particle weakly bounded with it.

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