Investigation of the mechanism of low channel damage in AC-LEP by gas introduction

Prasongporn Ruengpirasiri[1], Phan Trong Tue[1], Hidekazu Miyahara[2], Akitoshi Okino[3], Yuzuru Takamura[1]
[1] School of Materials Science, Japan Advanced Institute of Science and Technology (JAIST)
[2] School of Science, University of Tokyo
[3] FIRST, Institute of Innovative Research, Tokyo Institute of Technology
E-mail: s1620442@jaist.ac.jp

Liquid electrode plasma (LEP) is an alternative excitation source for elemental analysis. LEP forms in a vapor bubble generated inside a narrow-center microchannel by using high-voltage power. Preliminary experiment results revealed that less channel damage was observed when using AC-LEP compared to DC-LEP[1]. However, the mechanism is still unclear. In this study, we will study the mechanism by introduction of bubble and detailed comparison with DC-LEP.

The channel was prior carved on the PDMS sheet by photolithographic technique, consisted of two liquid inlets, one gas inlet, and one outlet with two 2-mm diameter holes. The experimental setup is shown in figure 1. AC-LEP was generated with specially power-controlled AC-power source (Plasma Concept Tokyo, Japan). DC-voltage supply (Nissei-Giken, Japan) was used as power supply for DC-LEP. The plasma was observed with a microscope and a UV-VIS Spectrometer. For measurement of channel width, the chip dimension was observed by optical microscope. To compare channel damage, both AC-LEP and DC-LEP conditions were optimized to obtain same signal intensity of lead (Pb) in 0.1 M HNO_3. In AC-LEP, liquid flow rate of 30 μL min^{-1} and Ar gas flow rate of 0.03 μL min^{-1} (in case of gas introduction) was used with 30 cycles of 1-second integration time. Meanwhile, in DC-LEP, liquid flow rate of 100 μL min^{-1} was introduced and 1400 V of applied voltage with 3 msec on-time and 2 msec off-time was applied for 100 cycles of 20 times repetition.

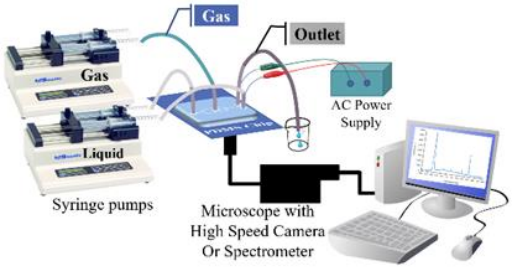

Figure 1 Experimental Setup

We confirmed that same signal intensity level (same LOD) is obtained in all cases. From Figure 2, AC-LEP showed lower channel damage compared to DC-LEP, especially in the case with argon gas introduction. One of the reasons of the lower damage is considered as follows. DC power source provides higher power to generate bubble directly in narrow channel. However, when introduce gas in DC-LEP, they also shown lower channel expansion because of the introduced bubbles, which can assure our assumption. In AC-LEP case, plasma can be generated with lower power by support of seeds of bubbles came from outside of narrow channel generated at electrodes by electrolysis of water. By argon gas introduction, plasma almost immediately and regularly generated just after applied the voltage, which contributes better results. These results indicate further potential of plasma in micro channel. In practical viewpoints, AC-LEP can be used as excitation source for on-site, portable and continuous elemental analyzer in environmental monitoring, industry, agricultural and food products security in future.

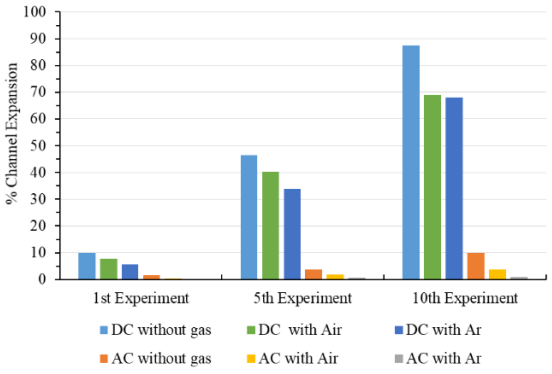

Figure 2 The graph showed the comparison of % channel expansion in DC-LEP and AC-LEP at different experimental time.

Reference: [1] D. V. Khoai, H. Miyahara, T. Yamamoto, P. T. Tue, A. Okino, and Y. Takamura. Jpn. J. Appl. Phys. **55**, 02BC23 (2016)