STUDIES ON SUITABLE MATERIALS FOR A LASER-HEATED ELECTRON-EMISSIVE PLASMA PROBE★

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Received September 26, 2006

Experimental investigations on the electron emission properties of various materials with different absorption coefficients, reflections coefficients and work functions, heated by an infrared diode laser with a maximum power of 50 W, were performed in a test chamber to check whether they are suitable for a laser heated emissive probe.

Key words: emissive probe, laser, graphite, lanthanum hexaboride, plasma diagnosis.

INTRODUCTION

The direct measurement of the plasma potential poses a major challenge to plasma diagnostic, and the sole tools for localized measurement of this parameter are certain forms of electric probes. For many decades emissive probes have been used in laboratory plasmas for a direct determination of the plasma potential Φ_{pl}. Only during the last years emissive probes have been applied for the first time also in the edge plasma region of fusion experiments for measuring Φ_{pl} and related parameters such as the electric field and fluctuations of the potential and electric field [1, 2]. Usually the probes are made of tungsten and/or tantalum wire heated to emission. Unfortunately, this type of probes has some disadvantage. For example, if a wire probe is not heated very cautiously, it often melts and needs replacement, in particular when high emission currents are needed. On the other hand, when an emissive wire probe is used, the entire battery or power supply has to float electrically with the probe. Due to the inevitably large capacity of such instruments, together with the also inevitable cable capacities, the upper cut-off frequency is reduced. In order to overcome all

★ Paper presented at the National Conference on Applied Physics, June 9–10, 2006, Galați, Romania

these drawbacks, a laser-heated emissive probe can be used. This will allow a better detection of high frequency plasma potential fluctuations and its lifetime is higher. The concept of a laser heated emissive probe was introduced a few years ago [3, 4]. Different materials have been tested in order to check which one is more suitable for such a probe. In this paper the results of two materials, LaB_6 and graphite, are presented, but measurements for other materials were also performed. The results obtained with these materials as tips for probes have been presented elsewhere [5].

EXPERIMENTAL SET-UP

The experiments were performed first in a test device at the Max-Planck-Institute for Plasma Physics in Greifswald, Germany of 20 cm length and 14 cm diameter (Fig. 1). Small cylindrical pieces of 2 mm diameter and heights of about 4 mm were used as probe tips. These were fixed on a Mo-wire of 0.2 mm diameter which was inserted into a fitting ceramic tube. The probe tips were heated from the front side through a quartz-glass window by an infrared high-power diode laser JenLas HDL50F from JenOptik, Jena, Germany, with a maximum laser power of 50 W at a wavelength of 808 nm.

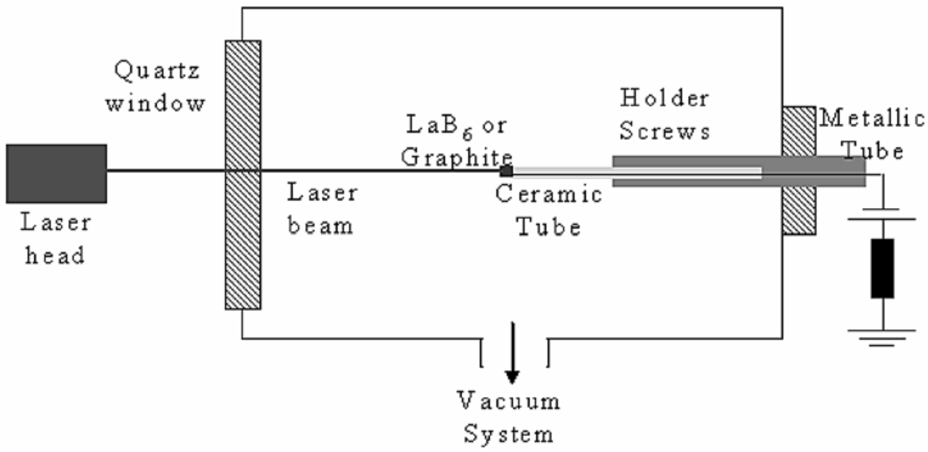
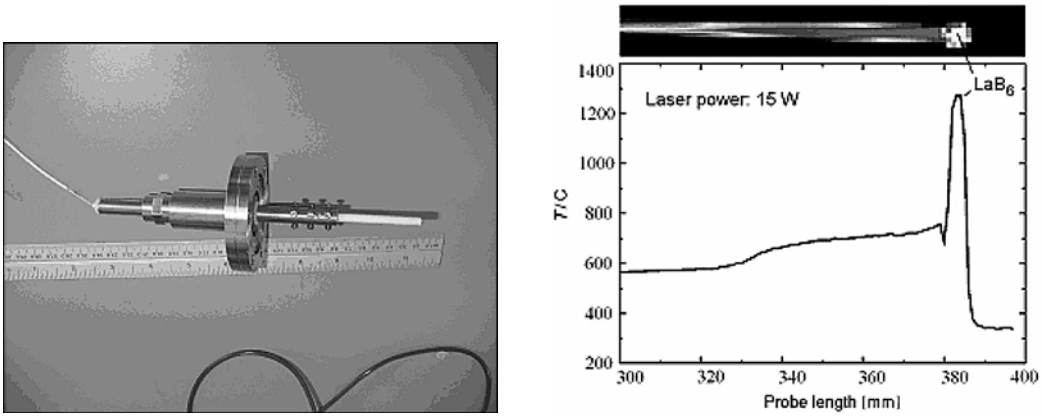


Fig. 1 – Schematic representation of the experimental set-up.

The laser beam is coupled into a fibre cable of 3 m length terminated by an output head, with which a focal spot of 0.6 mm diameter is produced in a distance of 20 cm. Temperature measurements of the probe tip and of the current to the wall for different background pressures and heating times were carried out. The temperature of the probe tips was measured by means of a PV11 Mycro-Pyrometer and a thermo graphic camera.

EXPERIMENTAL RESULTS

Two types of experiments were carried out: "short time heating" experiments in which the probe tip was heated from 20 to 90 seconds using different laser powers, and "long time heating" ones. In both experiments the tip temperature and emission current collected at the wall were measured. Modifying the applied potential on the probe, the current to the wall was measured and current-voltage characteristics for each material were made. In this paper the graphite and LaB_6 results are presented.



a) b)

Fig. 2 – (a) Probe design; (b) Temperature distribution in along probe ceramic shaft obtained with an infrared camera.

The temperature distribution along the probe shaft for 15 W laser heating power, measured by a thermo graphic camera, is shown in Fig. 2(b) The temperature is highest on the tip of the probe, where it reaches almost 1300°C. Along the tube it decreases.

The temporal evolution of the emission current has been measured for different laser heating powers in the test chamber. In all cases, the emission current increases rapidly and reaches saturation after about 20 s, but we have come to the conclusion that a real thermal equilibrium does not establish until about five minutes heating time or even more. For short heating times the emission current was usually not so stable, but after some minutes of heating a good stability was obtained. For each heating power the temperature was measured using a PV11 Mycro-Pyrometer and the temperature and a graph of temperature versus heating power was made.

We observe that the graphite emission current is more stable than the LaB_6 one, but the tip of LaB_6 has a bigger emission current at the same heating power.

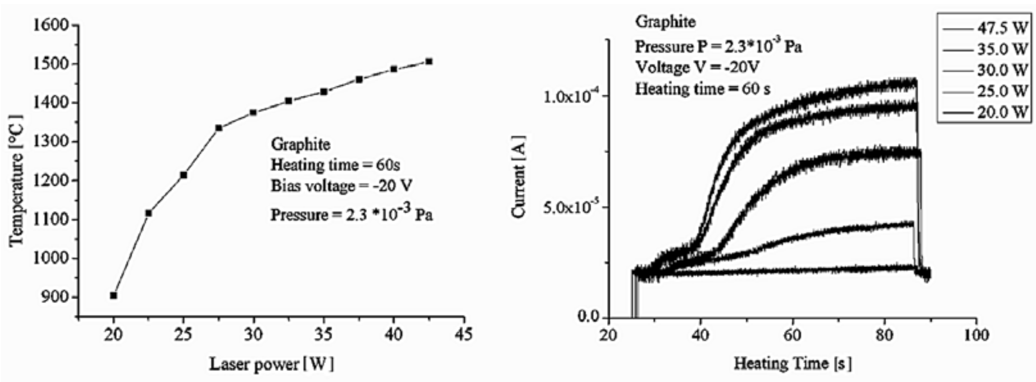


Fig. 3 – Temperature *vs*. laser power and current to test chamber wall *vs*. time for graphite laser heated emissive probe. The exposure time (heating time) was 60 seconds and the applied potential on the probe was $V = -20$ V.

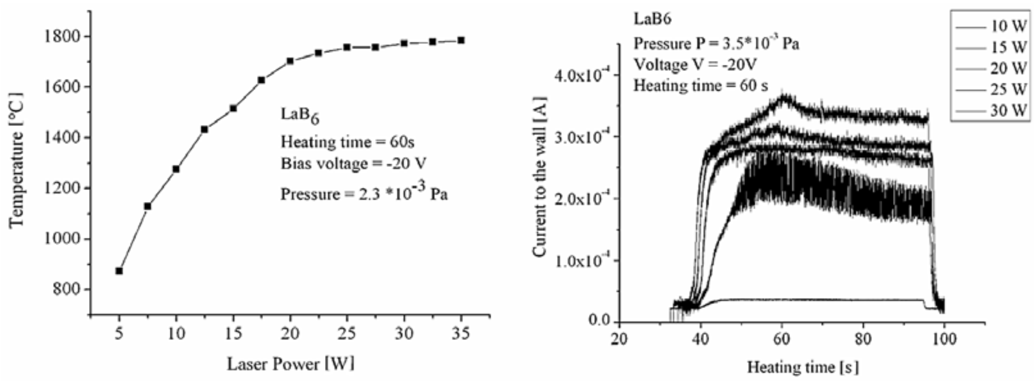


Fig. 4 – Temperature *vs*. laser power and current to test chamber wall *vs*. time for LaB_6 laser heated emissive probe. The exposure time (heating time) was 60 seconds and the applied potential on the probe was $V = -20$ V.

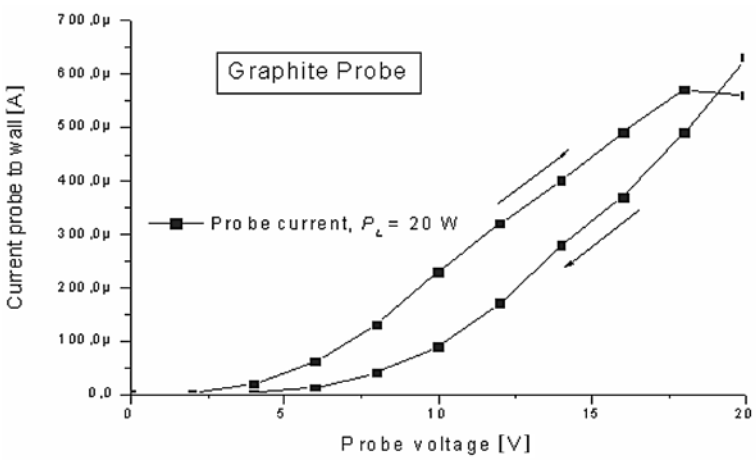


Fig. 5 – Current-voltage characteristic $I_p(V_p)$ of the graphite probe for constant laser heating power.

For the second experiment the heating power was kept constant whereas the applied potential on the probe was modified. The resulting *I–V* characteristics are presented in the next figures.

A hysteresis loop appears for LaB_6. This is due to the fact that for this heating power the emission was high enough and a discharge was formed between the probe tip and the test chamber walls.

CONCLUSION

More stable currents are observed in case of graphite than with LaB_6 (with a probe head of the same diameter) at the same biasing voltage. Graphite is more stable even for higher bias voltages applied to the probe and for different pressures.

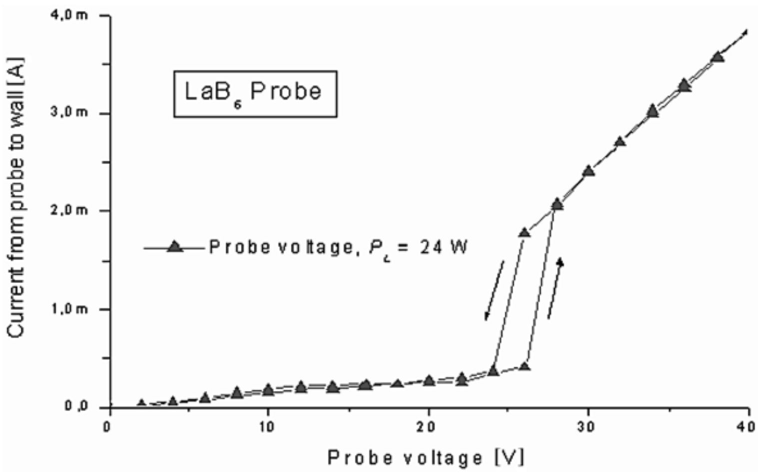


Fig. 6 – Current-voltage characteristic $I_p(V_p)$ of the LaB_6 probe for constant laser heating power.

We have proved that these materials can be used to construct a laser-heated electron emissive probe which can produce a much higher emission current than a conventional emissive wire probe. It has also a much longer life time since we have observed no evaporation or sputtering of the LaB_6 piece even after many hours of constant strong irradiation with the infrared laser. A laser-heated probe would have an incomparably longer lifetime and thus higher reliability than a wire probe. Due to these facts a laser heated emissive probe can be used in denser and hotter plasmas and it would be especially well suited for detecting high frequency plasma potential fluctuations.

REFERENCES

1. R. Schrittwieser, C. Ionita, P. C. Balan, J. A. Cabral, J. H. Figueiredo, V. Pohoata, C. Varandas, Application of emissive probes for plasma potential measurements in fusion devices, Contrib. Plasma Phys., 41, 494–503, 2001.
2. J. Adámek, I. Ďuran, M. Hron, J. Stöckel, P. Balan, R. Schrittwieser, C. Ionita, E. Martines, M. Tichý, G. Van Oost, Fluctuation measurements with emissive probes in tokamaks, Czech. J. Phys., 52, 1115–1120, 2002.
3. S. Ono, S. Teii, Laser heated emission of electrons from a carbon coated metal surface and its application to the emissive probes measurements, Rev. Sci. Instrum., 50, 1264–1267, 1979.
4. M. Mizumura, S. Uotsu, S. Matsumura, S. Teii, Probe system with bias compensation using a laser heated emissive probe for RF discharge plasma diagnostic, J. Phys. D: Appl. Phys. 25, 1744–1748, 1992.
5. R. Schrittwieser, A. Sarma, G. Amarandei, C. Ionita, T. Klinger, O. Grulke, A. Vogelsang, T. Windisch, Results of direct measurements of the plasma potential using a laser-heated emissive probe, Physica Scripta, T123, 94–98, 2006.