29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. **26B**, P-1.017 (2002)

SHOCK WAVE PROPAGATION IN GASES AND LOW TEMPERATURE PLASMA UNDER SUBATMOSPHERIC PRESSURE

S. Nanobashvili, G. Gelashvili, M. Mdivnishvili, I. Nanobashvili, G. Rostomashvili

Institute of Physics, Georgian Academy of Sciences,
Tamarashvili St. 6, GE-380077 Tbilisi, Georgia

Abstract
Results of investigation of the shock wave dynamics under subatmospheric pressure in neutral gases and weakly ionized low temperature plasma are presented. The characteristics of spherical and plane configuration shock wave excitation and propagation in gases in the pressure region $1\ Torr < p < 100\ Torr$ are studied. The same is done for the plane configuration shock wave in weakly ionized plasma in the pressure region $1\ Torr < p < 10\ Torr$. It is shown that when $p = 3\ Torr$ it is still possible to fix successfully the shock wave appearance and propagation in various neutral gases. The pressure dependence of the shock wave propagation velocity and amplitude is determined experimentally. It is shown that when the pressure decreases the shock wave amplitude decrease and the increase of the Much number take place. In the case of plane shock wave Much number reaches the value $M = 5.2$ under the pressure $p = 3\ Torr$. As for shock wave propagation in low temperature plasma our experiments showed a significant decrease of wave amplitude and simultaneous increase of its velocities up to 35%. The increase of the shock wave velocity is related to the heating of neutral gases in plasma.

Introduction

The study of the shock wave propagation in gases in the wide range of pressure is one of the interesting problems of nonlinear gasodynamics. Shock wave dynamics in the case of atmospheric pressure of the medium is studied quite well. There exists also a number of investigations which deal with the study of gas flows when the pressure of the medium is low ($p < 1\ Torr$). The study of the nonlinear gasodynamocal events in ionised gas and plasma is the separate problem. In this case the pressure of the medium $p < 1\ Torr$. On the other hand the study of the nonlinear gasodynamical events when the pressure is medium ($1\ Torr < p < 100\ Torr$), is of great interest. In this case the medium is quite dense and the shock wave dynamics can be described by the classical theory [1,2], and, on the other hand, in this region of pressure it is possible to get the stable diffusive electric or ultra high frequency discharge. In this case it becomes also possible to compare the shock wave dynamics in ionised and nonionised medium under the same pressure.

Last time for the generation of laser radiation the possibility of the use of nonequilibrium medium in which there are excited the vibrational, electronical and other levels of atoms and molecules are investigated intensively. As for the dynamics of the perturbations, for example shock waves in such medium, it is studied very insufficiently. But these problems are very important from the point of view of the processes which take place in glow discharges of fast-flow lasers, for the investigation of generation processes etc. Generally, in weakly ionised low-temperature plasma, during passing of shock wave different nonlinear effects can appear by strong disturbance of nonequilibrium medium and wide range of own waves can be generated, which of course is of separate interest for different plasma devices.

Shock wave interaction with plasma when the pressure is the atmospheric has been described in the paper [3]. It must be mentioned that the laser discharge plasma discussed in this experimental work is quite difficult object for the study of the shock wave dynamics because of its strong turbulence. Still there is no answer on the question about the reason of the shock wave strong dissipation, which was already described in [4].

In the present paper the preliminary results of the experiments on the investigation of the shock wave dynamics under subatmospheric pressure in neutral gases and low temperature plasma are presented.

The aim of the work is the experimental study of the shock wave dynamics in the pressure region $1\ Torr < p < 100\ Torr$. Shock wave excitation takes place by means of electric spark discharge, which gives the possibility to imitate the single point explosion. Two configuration of the shock waves are studied: spherical, when the shock wave propagates in the unlimited medium, and plane, when the shock wave propagates along the cylindrical waveguide.

Experimental set-up and results

Scheme of the experiment is presented on the Fig.1. In the vacuum camera *1*, which is equipped with the systems of gas pumping *3* and gas puffing *2*, the shock wave generator *4* and movable piezosensor *5* are situated to the opposite of each other.

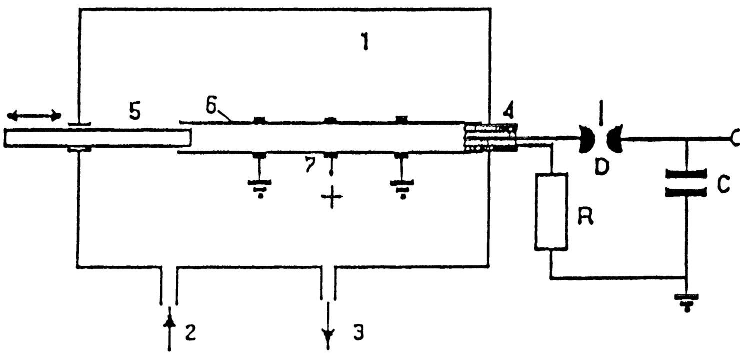

Figure 1: Experimental setup.

It is possible to place the waveguide *6* between them. The cilindrical waveguide is the glass tube with the diameter 1.5 *cm*. Weekly ionized low temperature plasma is created by electric discharge. For this purpose the ring-shaped electrodes *7* were inserted into the central part of the glass tube. Discharge current was changed up to 200 mA. Varying the neutral gas pressure and discharge current the density of plasma measured by the movable Langmuir probe was changing in the range $10^{10} - 10^{13}\ cm^{-3}$ and the electron temperature was $1 - 2\ eV$. The shock wave is excited by electric spark discharge, when the capacitor *C*, charged on the given voltage is discharged by switching the trigatron *D*. It is possible to create the atmosphere of various gases in the camera within the pressure region from 760 to 1 $Torr$. The capacity of the shock wave generator capacitor is 0.1 μF, the working voltage $U = 20\ kV$. R resistor is used for the concordance with the coaxial line. In such scheme 50% of the energy kept by the capacitor is released in the spark. The structure of the piezosensor gives the possibility to move it along the waveguide and place it on any distance from the shock wave generator. In the experiments it was measured the time, which is necessary for the shock wave to reach the piezosensor from the discharger under various pressure. In one case the gas pressure was changed under the fixed position of the piezosensor and in another case the distance from the sensor to the discharger was varied under the fixed pressure.

The preliminary results of the experiments on the investigation of shock wave dynamics under subatmospheric pressure in neutral gases and weakly ionized plasma can be summarized as follows:

1. When the neutral gas pressure decreases, the significant decrease of shock wave amplitude and change of pulse shape takes place, see the Fig.2.

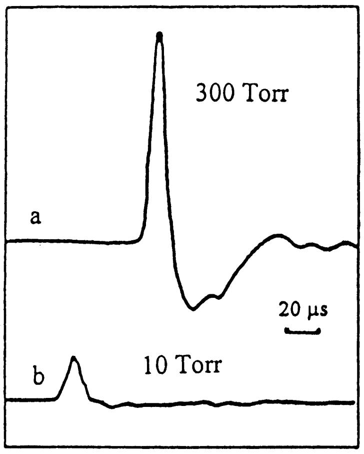

Figure 2: Spherical shock waves in neutral gas for (a) p=300 Torr and (b) p=10 Torr.

2. Decrease of the shock wave amplitude together with the decrease of pressure in case of different gases (air, helium, argon) takes place practically in the same way.
3. Under the constant pressure the spherical shock wave velocity decreases during increase of the distance from the source of shock wave. Such a change is not observed for plane shock wave and the wave velocity remains constant up to the distance $\sim$30 cm. On the other hand when the pressure decreases, the wave velocity increases, that is increasing of the Mach number takes place. On the Fig.3 the pressure dependence of the spherical (a) and plane (b) shock wave average velocities in the case of air are presented.

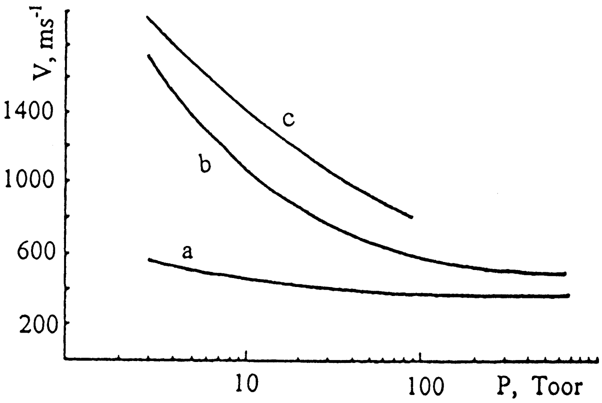

Figure 3: Velocity vs. pressure for (a) spherical and (b) planar shocks waves in neutral gas and (c) planar shock waves in plasma.

4. At the same time for the spherical shock wave the Much number magnitude increases from $M = 1.2$ ($p = 720$ $Torr$), up to $M = 1.6$ ($p = 3$ $Torr$), and for the plane shock wave in the waveguide - from $M = 1.5$ ($p = 720$ $Torr$), up to the value $M = 5.2$ ($p = 3$ $Torr$).
5. Under the same conditions (in comparison with neutral gas) in weakly ionised plasma significant decrease of plane shock wave amplitude and also the change of pulse shape

takes place, see Fig. 4. Significant blur of shock wave forward front and also the important broadening of backward front corresponding to the pressure of compressed gas behind the front of the wave, is observed.

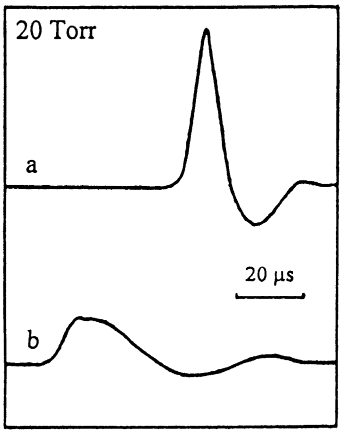

Figure 4: Planar shock waves for p=20 Torr (a) in neutral gas and (b) in plasma.

6. In plasma also the significant increase of plane shock wave velocity is observed, see the Fig. 3 (c). This increase can be linked with heating of gas in plasma. Really, the measurements of gas temperature by thermo coupler has shown that it reaches about 1000 K.

7. Both - increase of the shock wave velocity and change of the shape and amplitude of pulse strongly depends on discharge conditions. At low pressure, when discharge current density is about $1-2\ mA/cm^2$ plasma practically does not have an influence on the shock wave. By increase of current density this influence becomes more and more important.

Conclusion

We can conclude the following from our experiments:

a) the shock wave can be clearly fixed in gas by means of the piezosensor in the wide range of pressure and in the case, when the pressure $p = 1 - 10\ Torr$ it is possible to study the shock wave dynamics by means of this method.

b) in the given region of pressure the plane shock wave is quite stable and its velocity in the wide region (~30 cm) in the waveguide is practically constant.

The work performed will give the possibility in the future to study the shock wave dissipation mechanisms in the ionised medium.

Acknowledgement: Work was supported by the grant of AS Georgia 2.24

References

[1] Courant R., Friederichs L.O., Supersonic Flows and ShockWaves, N.Y. 1948
[2] Landau L.D., Lifshic E.M., Hydrodynamics, M., Nauka, 1986. (in Russian)
[3] Barkhudarov E.M., Mdivnishvili M.O., Taktakishvili M.I., Tsintsadze N.L., Chelidze T.Ia., ZhTF, 57, 2331, 1987. (in Russian)
[4] Barkhudarov E.M., Berezovskii V.R., Mdivnishvili M.O., Taktakishvili M.I., Tsintsadze N.L., Chelidze T.Ia., International Conference of plasma Physics, Lausanne, Switserland, P.32-1, p.396, 1984.