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Study of the interaction of non-thermal plasmas and organic liquids

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Abstract

Nowadays the study of the interaction of non-thermal plasmas and organic liquids have taken lot of attention because of its promising applications in medicine and environmental technologies. In addition, plasma treatment of liquid hydrocarbons is considered as promising approach to improve the crude oil quality and to produce valuable material and compounds. Being highly effective and environmental friendly, beam-plasma technologies are competitive with conventional ones of petroleum processing. The present study is devoted to the development of experimental techniques for studying of processes stimulated by non-equilibrium plasmas in liquid hydrocarbons. Two types of experimental setups were used, plasma chemical reactor based in electron beam and plasma chemical reactor based on Radio Frequency (RF) Discharge.

Technological Problem

According to [3], the world statistics shows that during the 90's decade the portion of crude oil of high density present in the world market has increased between 30 and 40 percent and the world reserves of nonconventional crude oil (oil with high viscosity and high content of paraffin and sulfur) duplicate the amount of light and conventional crude oil. Nonconventional crude oil requires the development of highly specialized technologies for its extraction, transport and oil refine processes, because of the difficulties that generates by its complex composition and high viscosity.

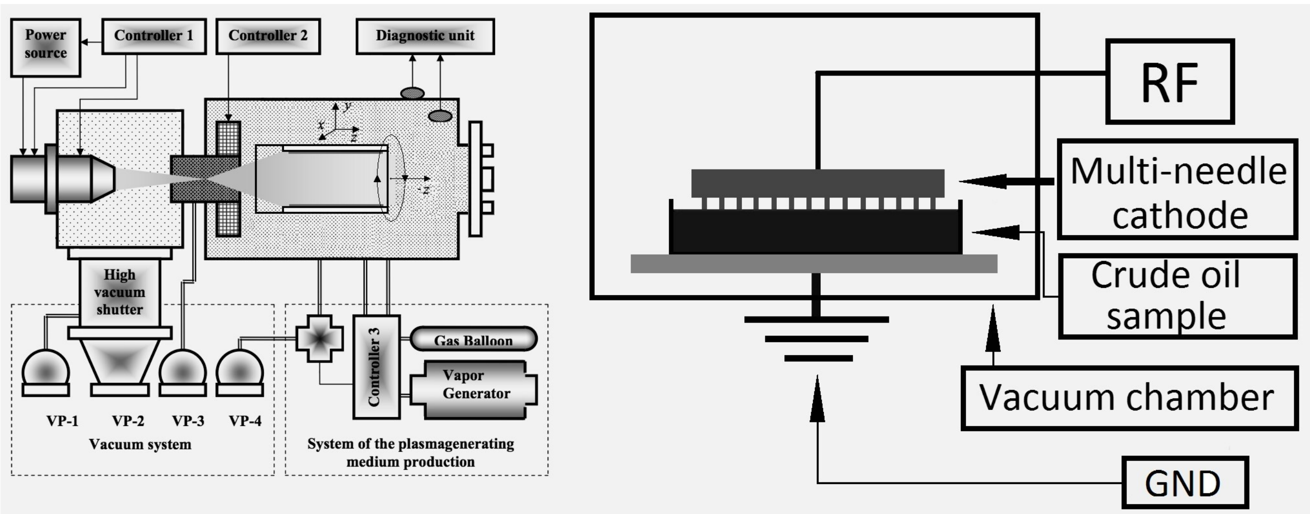

Fig.1. Experimental configuration for generation of non-thermal plasmas, on the left configuration for generation of electron-beam plasma, on the right configuration for generation of RF Discharge

The current work is devoted to study experimentally the effects of the interaction between non-thermal plasma with liquid hydrocarbon. In the study, two different configurations of Plasma reactor were used. In the first configuration non-thermal plasma is generated by the injection of fast electrons in a neutral gaseous media at low pressures, then newly appeared plasma cloud interacts with liquid hydrocarbon located in a rotational vessel during different periods of time. In the second configuration, Radio Frequency (RF) Plasma-Reactor were used, action of RF Plasma discharge, generated between multi-needle cathode and one circular anode behind the crude oil holder, both experimental configurations as shown in Fig 1.

Liquid hydrocarbons are mainly composed from long chains of molecules of carbon and hydrogen united by covalent bonds and is also mixed with different impurities. The longer the molecular chains, the higher is the viscosity. According to [2], one common way to upgrade crude oil is breaking down heavier molecules and obtaining high quality products.

Treatment of liquids hydrocarbons

Thermocatalytic methods produce excitation in translational modes of the molecules increasing the temperature to break the molecular chains. The main limitation of this technology is that, thermal energy is strongly coupled to translational, vibrational and rotational modes of the molecules and only small fraction is coupled to the electronic excitation, which is primarily responsible for molecular break. Thermocatalytic methods only break the weaker bonds according to [4], whereby a small portion of the supplied energy is harnessed. Conversely, the energy released from electrons to the molecules is absorbed almost completely according to [5], breaking the molecular bounds while viscosity is reduced with higher efficiency without increasing the temperature. According to [1] the output of light products from crude oil using Electron Beam technology is 25-50 % higher than the thermocatalytic ones.

Beam-Plasma treatment is a very suitable technology to drive chemical reactions to obtain different products in reproducible and reliable form. This allows combining different gases under controllable conditions of pressure, mixture of gases, electron energy, electron current and operation time. Its technology are reliable, controllable and repetitively approach for treatment of liquid hydrocarbon. This can be combined with another plasma generation method to produce hybrid-plasma systems. Beam-Plasma can induce changes in the viscosity of liquid hydrocarbons, it has been one of the more outstanding results obtained and that can be seen in the Fig 3.

Experimental technique

The experimental techniques for studying of processes stimulated by non-equilibrium plasmas in liquid hydrocarbons. Two experimental setups were developed, namely;

- Plasma chemical reactor in which the low-temperature non-equilibrium plasma is generated by the electron beam injection in a neutral dense gas.
- Plasma chemical reactor based on low-temperature non-equilibrium plasma generated by Radio Frequency (RF) Discharge.

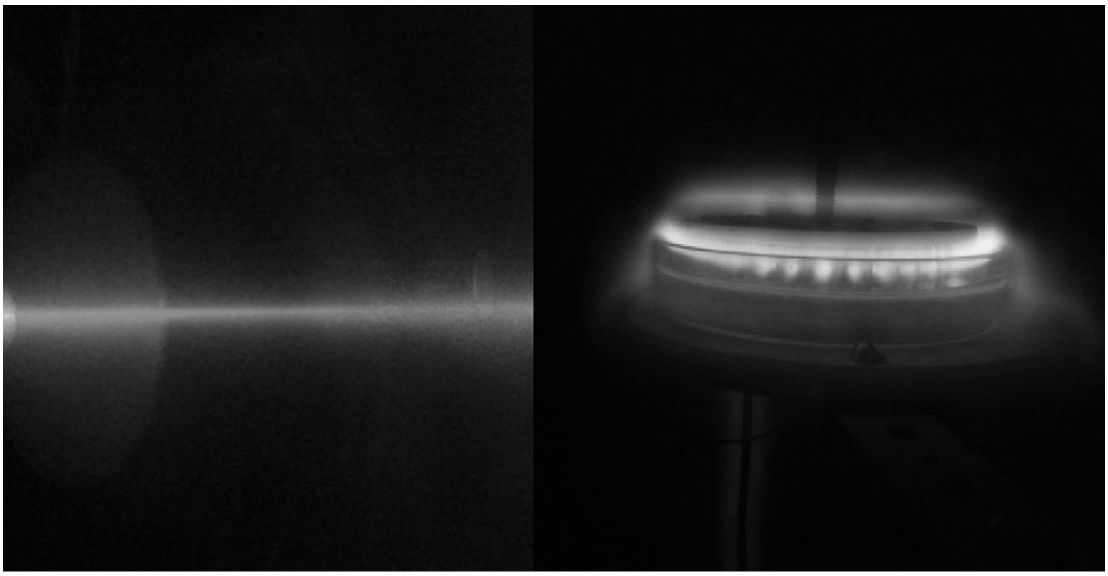

Fig.2. Experimental configuration for generation of non-thermal plasmas, on the left real operation of Electron-Beam Plasma, on the right real operation of Radio Frequency Plasma discharge.

During the experiment process, in Electron Beam Plasma Reactor, one current of 2,5 mA of fast electrons are injected in neutral gas chamber at 0,5 Torr of pressure, using a plasma gas to Methane (CH_4). The electrons cross the neutral gas generating ionization of it, excited particles generates during the process released photons of that can be seen in the left of fig 2, The beam of electrons and also the plasma generate for it do contact with the surface of the vacuum oil used during the experiment generating in it changes in its viscosity as can be seen in fig 3. In Radio Frequency Plasma Reactor, the multi-needle cathode was put in cotact with the surface of crude oil, Radrio Frequency was operated at one frequency of 13,56 MHz and a pressure of 0,5 Torr, and can be seen in fig 2 on the right. This configuration generate one intense cloud of plasma near to the liquid surface.

Experimental results

The viscosity of the samples of vacuum oil treated with Electron-Beam Plasma (in the left) and samples of crude oil treated with Radio Frequency discharges (right) are shown in the figure 2. For the measurement of the samples viscosity, viscometer was used. The viscosity is given by, the rate of shear rate (1/sec) and the shear stress (Pa). The more viscous liquids show low slope and the less viscous liquids show higher slopes. In figure 2, on the left, we can see that the dynamic viscosity tend to turn down slowly with three minutes of EB Plasma treatment when the shear rate is higher than (4 revolution/second), in the opposite form, on the right we can see that the treatment with RF on the liquid hydrocarbon increase its viscosity strongly as its time of treatment increase. One possible reason for the phenomena observed in samples treated with RF is that lighter fractions of hydrocarbon molecules may be evaporating in the process and then density of heavy molecules are increasing, which them increases the viscosity of the final sample.

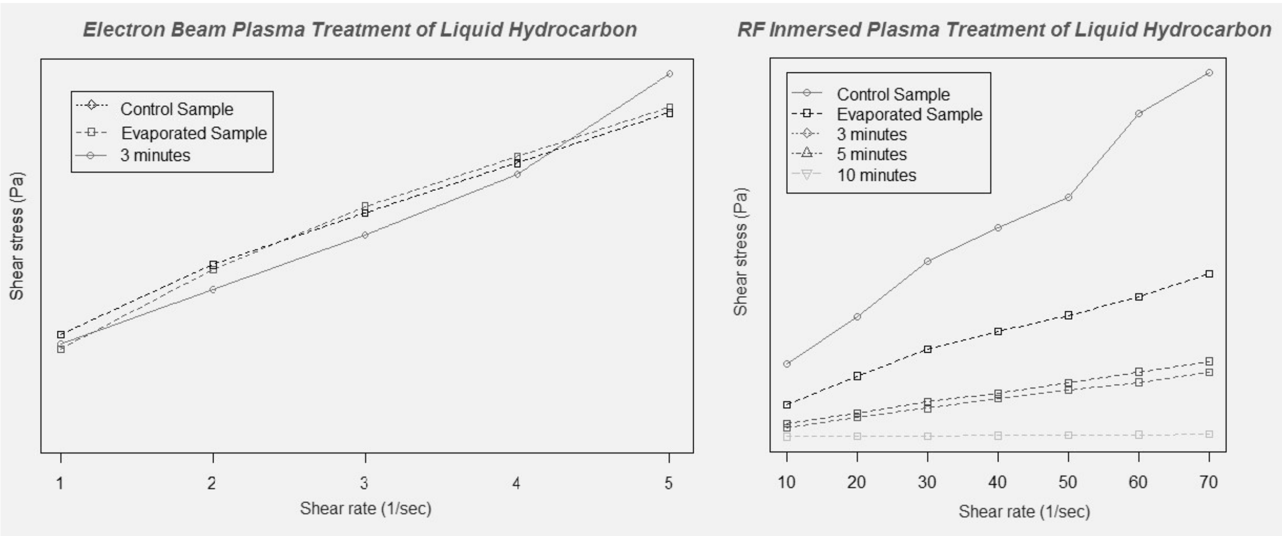

Fig.3. Viscosity of the hydrocarbons treated with non-thermal plasma, in the left samples of vacuum oil treated with Electron-Beam Plasma (EBP) and on the right samples treated with RF Plasma discharge.

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