Theoretical and computational study of collective effects in dusty plasmas revealed (1) formation of oscillatory wake potential behind a highly charged dust grain placed in the ion flow in the sheath (2) stable polygon structures formed by a collection of trapped dust particulates in the wake potential minima (3) low frequency oscillations of order 10Hz associated with the polygon plasma crystal structure (4) interaction of dust particulates and plasma particles through Hamiltonian formulation (5) low frequency lattice oscillations (-1Hz) described by Hamiltonian formulation (6) the attractive interaction between dust particulates through exchange of phonons (7) polarization of a dust grain in the order of a Debye length (8) the higher threshold of the dust ion-acoustic instability with the effect of dustcharging process, and (9) Buneman-type streaming instability in a dust plasma developed in a subsonic ion flow.
Final Technical Report on Study of Dusty Plasmas Grant No. F49620-97-1-0007

For the period of November 1, 1996 to October 31, 1999

Submitted to
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ABSTRACT

This progress report describes research work performed at Texas Tech University under AFOSR Grant No. F49620-97-1-0007 during the period of November 1, 1996 to October 31, 1999. Theoretical and computational study of collective effects in dusty plasmas revealed (1) formation of oscillatory wake potential behind a highly charged dust grain placed in the ion flow in the sheath (2) stable polygon structures formed by a collection of trapped dust particulates in the wake potential minima (3) low frequency oscillations of order 10 Hz associated with the polygon plasma crystal structure (4) interaction of dust particulates and plasma particles through Hamiltonian formulation (5) low frequency lattice oscillations (~1 Hz) described by Hamiltonian formulation (6) the attractive interaction between dust particulates through exchange of phonons (7) polarization of a dust grain in the order of a Debye length (8) the higher threshold of the dust ion-acoustic instability with the effect of dust-charging process, and (9) Buneman-type streaming instability in a dust plasma developed in a subsonic ion flow.
I. Objectives
To study the collective effects in dusty plasmas, focusing on the theoretical and computational study of dusty plasmas when plasma crystal is formed.

II. Status of the Research
The principal investigator, Professor Osamu Ishihara, in collaboration with Dr. Sergey Vladimirov of University of Sydney, conducted the research. Mr. Wu Zhang, a graduate student, completed his master degree in May 1999 on the topic of this research.

III. Accomplishments/New Findings
Our theoretical and computational study of collective effects in dusty plasmas has revealed
(1) formation of oscillatory wake potential behind a highly charged dust grain placed in the ion flow in the sheath, resulting in trapping of dust particulates in the potential minima provided by the wake potential
(2) stable polygon structures formed by a collection of trapped dust particulates in the wake potential minima, as a result of the force balance between ion drags, gravitational fields, and the sheath electric filelds
(3) low frequency oscillations of order 10Hz associated with the polygon plasma crystal structure
(4) interaction of dust particulates and plasma particles through Hamitonian formulation
(5) low frequency lattice oscillations (~1Hz) described by Hamiltonian formulation
(6) the attractive interaction between dust particulates through exchange of phonons
(7) polarization of a dust grain whose size is in the order of a Debye length
(8) the higher threshold of the dust ion-acoustic instability with the effect of dust-charging process
(9) Buneman-type streaming instability in a dust plasma developed in a subsonic ion flow.

IV. Publications
1. On Plasma Crystal Formation
   Wake Potential of a Dust Grain in a Plasma with Ion Flow
   Polygon Structures of Plasma Crystals
   Hamiltonian Dynamics of Dust-Plasma Interactions
   Instability due to Dust Particulate-Phonon Interaction
   Plasma Crystals - Structure and Stability
Wave Action in a Plasma with Coulomb Collisions
Buneman-type Streaming Instability in a Plasma with Dust Particulates
On the Realization of the Current-Driven Dust ion-Acoustic Instability

V. Presentations/Proceedings
1. On the Wake Potential of Dust Particles in a Plasma with Ion Flow, O.
   Ishihara and S.V. Vladimirov, IEEE Int. Conf. on Plasma Sci. (June 3-5, 1996,
   Boston, MA).
2. Effects of Plasma Fluctuations on the Evolution of Nonresonant Plasma
   Waves, S. V. Vladimirov and O. Ishihara, 1996 International Conference on
   by H. Sugai and T. Hayashi, vol. 1, pp.806-809 (Japan Society of Plasma
   Science and Nuclear Fusion, 1997).
   International Conference on Plasma Physics (September 9-13, 1996, Nagoya,
   (Japan Society of Plasma Science and Nuclear Fusion, 1997)
4. On Coulomb Crystallization in a Dusty Plasma, S.V. Vladimirov, O. Ishihara
   and M. Nambu, Plasma '97, the 21st Australian Institute of Nuclear Science
   and Engineering, Plasma Science and Technology Conference (February 17-
   18, 1997, Sydney, Australia).
5. Wake Potential due to a Pair of Dust Particles, W. Zhang, O. Ishihara, and S.V.
   Vladimirov, IEEE International Conference on Plasma Science (May 19-22,
   1997, San Diego, Ca).
6. Plasma Crystal Formation as a Result of Collective Effects in Dusty Plasmas,
   Perspectives of Collective Effects (November 10-14, 1997, Trieste, Italy).
   Invited lecture.
7. Propagation of a Wave in a Plasma with Coulomb Collisions, S. V.
   Vladimirov and O. Ishihara, IEEE International Conference on Plasma Science
8. Dust Particulate Phonon Interaction, O. Ishihara, Seventh Workshop on the
9. Dust Particulate-Phonon Interaction and the Resulting Instability, O. Ishihara,
   IEEE International Conference on Plasma Science (June 1-4, 1998, Raleigh,
   North Carolina).
10. Interaction Between a Pair of Dust Particulates, O. Ishihara, APS Division of
VI. Student Thesis.

Wu Zhang, MS May, 1999
Title: Plasma Simulation with a Dielectric Object in the Presence of an Ion Flow

Abstract:
Recent dusty plasma experiments have investigated the crystallization of dust grains near the edge of a plasma sheath. Some theories were proposed to explain the crystallization mechanisms. The purpose of this simulation work is to study the electrostatics of a dielectric object immersed in a plasma sheath where the ion flow velocity is greater than the ion acoustic velocity, utilizing the object-oriented particle-in-cell code called XOOPIC developed at UC-Berkeley. This simulation is designed to investigate the polarization in a charging process and the electrostatic traps downstream of an object caused by an ion flow in a plasma discharge. Both the polarization and electrostatic traps in the wake field are considered important factors in the formation of plasma crystals. In this thesis, the simulation model based on the XOOPIC code is established, and the simulation results on wake potentials and polarization are obtained and analyzed. This simulation work was completed on the Sun workstation in the department of electrical engineering at TTU.

VII. New Discoveries, Inventions, or Patent Disclosures
None
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