europhysics news
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Europhysics News in 1976

Europhysics News in 1976 will be a little bigger and we hope a little better.

Three Meetings issues will be published instead of two — in March, June and November. Moreover the June issue will be enlarged to include directory style information on the Society, its Divisions and Advisory Committees. The irregularity of the sequence is not accidental but has been chosen to correspond best with the inflow of information and the concentration of meetings which occurs in certain seasons.

Seven "green" issues will be published each of 12 pages instead of the traditional eight and will appear towards the end of the months of February (issue combining January and February) April, May, August (combining July and August), September, October and December.

Altogether EN will be publishing 112 pages of information in 1976 as against 100 in 1975.

Copies are distributed free of charge to Individual Ordinary Members who are asked to recognize that these are essentially personal copies carrying the copyright of the EPS. Members can help the EPS by encouraging their institutions to subscribe to the publication for display in their library. Contrast the subscription price of Fr. 75.— for a complete volume of green and yellow issues with the effort that has gone into, for example, the compilation of the meetings issues. Seventy five francs is about the salary of one person for one morning per year. Few libraries would refuse to put in that effort to produce the complete, checked out list of meetings that the EPS is now publishing.

As another encouragement to institutions to use EN more, an additional 25 % discount is to be allowed from January 1 on advertisements for situations vacant. Conscious of the increasing problems of employment in the world of science, EPS is making this gesture to help the flow of information on jobs.

Members are asked to draw the attention of their institutions to these changes and not to be hesitant in promoting the well-being of their society.

Condensation of Excitons into Electron-Hole Drops

M. Voos, Paris

Joint winner with V. S. Bagaev, L. V. Keldysh and J. E. Pokrovsky of the 1975 EPS Hewlett-Packard prize.

When a semiconductor is excited, for example with photons whose energy is larger than its band gap, it is well known that free electrons and holes (vacant electron states) are created in its conduction and valence bands respectively. At low concentrations the lowest electronic excitation in usual intrinsic semiconductors is the free exciton which is a two-particle complex analogous to positronium and resulting from the Coulomb binding of a free electron and hole. With increasing density the excitons interact and, if their mutual interaction is attractive, new bound states may be expected. The first one which was proposed is the excitonic molecule. This complex, which has perhaps been observed in several semiconductors (CdS, CdSe...), results from the binding of two excitons. The second one was introduced by Keldysh[1] in 1968 and is a kind of electron-hole "liquid" corresponding to the condensation of excitons into the so-called electron-hole drops (hereafter called EHD). This condensed phase looks like a liquid metal in many respects and is constituted by a neutral two-component plasma of free electrons and holes. The equilibrium density of electron-hole pairs in this plasma is perfectly well defined and the plasma energy is lower than that of excitons. The decrease of energy in the liquid phase comes from exchange and correlation effects between particles. Such a phenomenon can be viewed as a phase transition between gaseous excitons and liquid electron-hole drops analogous to ordinary gas-liquid transformations.

The first evidence for the existence of a new bound state in intrinsic semiconductors was the occurrence at low temperature of new radiative recombination lines observed first in Ge by Benoît à La Guillaume and Parodi[2]. As far as we know, it was only in 1969 that these lines were studied and reported again[3]. These new radiation peaks, which occur in the infra-red ($\sim$ 1.75 μ), arise below about 10 K and grow rapidly when the temperature is reduced. They are broader and lie at lower energy than the well-known emission lines due to the radiative recombination of free excitons. They have been attributed to EHD by Pokrovsky and Svistunova[3] who gave a very strong argument in favour of this interpretation. Indeed, it is easy to calculate the shape of these new lines if one assumes that they are due to the radiative decay of EHD, and the agreement between experiment and theory is very good. This yields also the equilibrium density n_0 of electron-hole pairs in a liquid drop which is typically for Ge 2×10^{17} cm^{-3} at 2 K.

Conclusive evidence for the exis-

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tence of EHD was given by two experiments proving their macroscopic character, namely the photovoltaic detection[4] of EHD in p-n junctions and the scattering[5] of 3.39μ light by EHD.

In the first experiment, a Ge p-n junction photodiode is immersed in pumped liquid helium at 2 K, and the n region is illuminated with a CW mercury lamp for instance. The new emission lines of Ge are easily seen to be present in these conditions of temperature and excitation. The fluctuations in the photovoltaic current are then analyzed with a rapid oscilloscope and are seen to have a spiky structure similar to that of the current from a photomultiplier. But at higher temperature ($\sim$ 10 K), this structure is not observed. Each current spike is interpreted as being due to the destruction in the junction electric field of an EHD containing N electron-hole pairs. By integrating the current under a spike, one easily gets N which is typically 10^7. This gives $r \sim 2\ \mu$ for the drop radius if we take $n_0 \sim 2 \times 10^{17}$ cm^{-3}. Investigations at liquid helium temperature of the scattering of 3.39 μ light by a crystal of pure Ge excited optically by a lamp or a laser also gave good proof of the existence of EHD. These experiments show that electron-hole drops are certainly spherical and, from the angular distribution of the scattered light, one gets their size which is of the order of some microns.

A lot of other data and arguments[6] have been put forward to support the existence of electron-hole drops, and it is generally admitted now that they have been observed in Ge, Si and Ge-Si alloys. More than 250 papers have been published in this field during the last six years, so it is not possible to give here an exhaustive list of all the investigations which have been done to understand this condensed phase. However it may be interesting to note that, at least in Ge, many of the most important EHD parameters have been measured. This is, for example, the case of the following ones : density of electron-hole pairs in the liquid phase[6] ($n_0 \sim 2 \times 10^{17}$ cm^{-3}), EHD binding energy[6] with respect to gaseous excitons ($\sim$ 2 meV), EHD lifetime[6] (40 μ sec), electric charge at the drop surface[7], surface energy[8] of drops ($\sim 2 \times 10^{-4}$ ergs/cm^2), critical temperature[9] (6.5 K). It should be pointed out that theory[10] and experiment are generally in very good agreement.

On the other hand, some interesting aspects of EHD are not yet well known or understood. Among others one can quote the following ones : the magnetic properties of drops have not yet been investigated ; it seems that EHD can move rather rapidly[6], but this is not explained ; the nucleation process (or processes) involved in drop formation is still unclear and raises very interesting and stimulating problems whose understanding might be helpful in other areas. One could also wonder whether this liquid phase may give rise, under conditions which are to be defined, to superfluidity or superconductivity. This may seem highly speculative, but the answer to this question is not clear.

To conclude, the existence of electron-hole drops in semiconductors is now well established. This liquid phase, which presents many interesting features, results from the condensation of gaseous excitons, and this phenomenon corresponds to a first order phase transition. Many aspects of EHD are now understood, but a number of challenging experimental and theoretical problems remain. Let us note that this condensed phase is probably the simplest example of liquid metal which is available at the present time. As such it provides a good opportunity to test theoretical methods of great interest in many body problems. Finally, it seems that this field remains very attractive for many solid state physicists and is in fact still developing.

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The Chemical Physics Section of the Atomic Physics Division

The recently-constituted Chemical Physics Section of the Atomic Physics Division will be holding its first conference from the 30th of August to the 1st of September 1976 in Amsterdam. The theme is "Exploring the chemical bond. New developments".

People interested in attending the meeting should contact Dr. R. Block, Congress Bureau (IBD) A-76, Vrije Universiteit, de Bœlelaan, 1105, Amsterdam, The Netherlands or the Conference Secretary, Miss A.-M. Bonino, Batelle Institute, Advanced Studies Center, 7, route de Drize, CH-1227 Carouge-Geneva, Switzerland.

On this occasion the Section will hold its first General Meeting and the Provisional Board has taken this opportunity to announce the creation of the Section to the various European Chemical Societies. Anyone interested in participating in the activities of the Section should contact either the Chairman of the Provisional Board Professor E.A.C. Lucken, Département de Chimie Physique, Sciences II, 30, Quai E. Ansermet, 1211 Geneva 4, Switzerland or the Secretary, Professor G. Wagnière, Département de Chimie Physique, Université de Zurich, Zurich, Switzerland.

The Provisional Board has decided to couple each of its meetings with a scientific lecture. It is particularly appropriate that the first of these will be given by Professor W. Kolos who, together with Professor L. Jansen, was largely responsible for the setting up of this Section. The title of the talk, to be given in the Physical Chemistry Department of the University of Zurich on the 16th of January 76 will be "Ab Initio Calculations on the Excited States of the H_2 Molecule".

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