Meetings

Vacuum: Sputtering, Desorption, and Surface Physics

Desorption and sputtering processes, which occur at the surfaces of vacuum chamber walls, are major sources of neutral gas in plasma experiments. Hence fundamental studies of surfaces provide a basis by which many mechanisms that produce impurities in plasma experiments can be quantitatively appraised. Both applied and basic physics of surface interactions were discussed by 45 scientists from 18 institutions at the annual Sherwood Vacuum Conference, held at the U.S. Atomic Energy Commission, Germantown, Maryland, 30–31 January 1964.

The attainment of low neutral particle densities and very pure plasmas in large volumes has always been the principal pursuit of the controlled thermonuclear research program (Project Sherwood). Such conditions have been achieved in several experiments. Base pressures of less than 10^{-9} torr in volumes of the order of 100 liters are now routinely produced in the ALICE and DCX-1 plasma experiments. In the model C plasma experiment, impurities have been reduced to about 0.05 percent of the plasma density, while base pressure of the order of 10^{-9} torr is produced in a volume of the order of 1000 liters. These successes cannot, however, be extrapolated uncritically to other plasma experiments. As plasmas continue to approach thermonuclear conditions, a new set of vacuum problems may replace those currently being overcome.

Since the scientists at the conference had varied backgrounds and interests, Stephen O. Dean (AEC) surveyed the energies of radiations expected near hot plasmas and discussed several materials of interest to the controlled thermonuclear research program. He indicated that the spectrum of expected energies is very broad, extending from impurity molecules of about 0.01 ev kinetic energy, through photons, ions, and electrons with energy of the order of thousands of electron volts, to fusion reaction products with energy of millions of electron volts. His survey showed, however, that the energy range of 0.1 to 20 kev is of great interest. Not only is this the particle energy range for many plasma experiments, but it may also be the energy range for plasma-generated bremsstrahlung photons.

Six physicists of the controlled thermonuclear research program described observations of surface interactions in plasma experiments. William E. Nexsen (Lawrence Radiation Laboratory) reported on a series of experiments called "Toy Top" in which a one order of magnitude background pressure rise in the plasma region was observed. A small portion of the initial plasma stream bombards the vacuum chamber wall and causes removal of loosely bound gas. The desorbed gas drifts into the plasma region and causes loss of plasma by charge exchange.

James A. Phillips (Los Alamos Scientific Laboratory) also presented evidence for desorption of gas. In the "Scylla" fast magnetic compression experiments, he ascribed the desorption in the aluminum oxide vacuum tube to ultraviolet bremsstrahlung photons. The Scylla experiments are performed so rapidly that the desorbed gas does not penetrate the plasma region during the time of plasma confinement. However, future experiments with longer confinement must take into account the presence of this desorbed gas.

Recent results on the model C Stellarator were noted by Amasa S. Bishop and Donald J. Grove (Plasma Physics Laboratory, Princeton). Bishop described the effectiveness of a magnetic field "divertor" in reducing (by a factor of 50) the level of impurities in the Stellarator. Under present conditions the impurity concentration is only about 0.05 percent of the density of the working gas, and the power emitted in impurity radiation is now totally negligible. Grove showed that the divertor, combined with pulsed gas feed, allowed differentiation between neutral and charged particle sorption at the stainless steel walls. Evidence indicates that sorbed neutral hydrogen atoms appear to stick to the vessel walls for roughly 5 to 8 milliseconds before returning to the discharge. Measurements were also made on stimulated neutral gas re-emission from the tube walls, caused by ion bombardment during the discharge.

Edward G. Apgar (Princeton) studied the O II radiation that resulted when 305 stainless steel, oxidized 305 stainless steel, Pt, Ti, Au, Be, and alumina "aperture limiters" were inserted across the hydrogen plasma column in the B-1 stellarator. The oxygen impurity observed at the limiter was interpreted as having originated at the walls and recycled at the limiter surface. Smaller O II signals for stainless steel, Ti, and Be were thought to be caused by the slower recycling rates for these surfaces which are "active" compared with Au and Pt. Observations were also made of decomposition of the alumina limiter and of oxide layer reduction on the stainless steel limiter.

Speculations were made by Alan C. England (Oak Ridge National Laboratory) on the effectiveness of hot electron "blanket" plasmas in preventing penetration of impurities into a hot ion region. Norman Milleron (Lawrence Radiation Laboratory) lightly criticized popular usage of the term "clean" when "stable" wall properties were desired.

Several discussions dealt with electron and photon desorption. Paul A. Redhead (National Research Council, Canada) reported on rates of desorption of ions and neutrals and on energy distribution of ions for electron bombardment (0 to 300 ev) of chemisorbed layers of O_2, N_2, H_2, and CO on polycrystalline molybdenum. He found that the ion desorption cross section was less than 10^{-24} cm^2 for N_2 and H_2. Gas desorption in electron storage ring tanks was described by Edward Garwin (Stanford Linear Accelerator). This desorption occurs when far ultraviolet photons from the accelerated electrons produce gas-desorbing photoelectrons at the wall. In an experiment designed to study electron desorption at the Stanford site, the apparatus allows study of six different metals at both normal and grazing incidence without breaking the vacuum (Norman Milleron). Further light was shed on this subject by Robert P. Madden and Bernard Waclawski (National Bureau of Standards) who reviewed available information on the "volume" photoelectric effect in the vacuum ultraviolet. A number of similar characteristics have been determined for a variety of dissimilar metals. For photon energies above 8 ev, there is a steep rise in photoelectric yield at about 10 ev, a broad maximum around 15 ev and a gradual decrease toward higher photon energies. The yields above 10 ev approximate 10 percent and exceed by 2 to 4 orders of magnitude those at 7 ev. The yields generally decrease by factors of 2 to 5 when the samples are heat-treated in vacuo.

Measurements of direct ultraviolet photodesorption of Co from Ni, W, Pyrex, and quartz were described by William J. Lange (Westinghouse Research Laboratories). In the case of tungsten, where the surface coverage was known, the cross section was of the order of 10^{-23} cm^2. Because thermal desorption of the alpha-phase becomes dominant as maximum coverage is approached, the above cross section applied to the first adsorbed, or beta, phase.

Other surface processes which occur in plasma experiments include thermal desorption and chemisorption. Lange reported on thermal desorption experiments which yielded a value of approximately 11 k cal/mole for the binding energy of the alpha-phase of CO on tungsten.

Richard A. Strehlow (Oak Ridge National Laboratory) reported on his experimental studies of gaseous desorption at low pressures and liquid nitrogen temperatures. He presented data for the heats of desorption over the temperature range of 80°K to 115°K for CH_4, Ar, H_2, and CO from a MO vapor-deposited surface at pressures of the order of 6×10^{-9} torr. Graphical integration of the desorption peaks indicated that the amount of gas desorbed was of the order of 10^{13} molecules per square centimeter—a small fraction of a monolayer.

Measurements of chemisorption of nitrogen on molybdenum films were described by Ralph A. Pasternak (Stanford Research Institute). He found that at room temperature the sticking probability is initially high (about one half) and then drops off gradually. At liquid nitrogen temperature, additional well defined sorption occurs. The amount sorbed is of the order of magnitude of a monolayer and is independent of pressure; the sticking probability is again about one half, but remains constant to almost saturation.

Angus L. Hunt (Lawrence Radiation Laboratory) presented data on the solubility of deuterium in titanium. He found that a deuteron flux of 3×10^{13} ion per cm^2 with an energy of 15 kev is totally captured, within the precision of the measurement, by a titanium sheet at −120°C. He further reported that evolution of methane and especially carbon monoxide, induced by the bombardment, is markedly reduced at low temperatures. This experience with titanium has been applied to the termination of the 30-milliampere, 20-kev neutral atomic hydrogen beam in the ALICE plasma experiment at Livermore. A reduction of one order of magnitude in the pressure increase in the beam termination chamber has been attained during beam injection by the use of a liquid nitrogen-cooled titanium target.

A provocative paper on exothermic charge exchange reactions (for example, $O^{++} + O^0 \rightarrow O^+ + O^+ + 21.5$ ev) was offered by J. Rand McNally, Jr. (Oak Ridge National Laboratory) who speculated that such reactions might occur at surfaces (for example, if the surfaces were bombarded by electrons or quanta whose energies were comparable to the energy required for double ionization). He stated that additional onsets would be possible at energies characteristic of the binding energies of electrons in the various shells (for example, K electron removal followed by Auger ionization). McNally stressed the speculative nature of his ideas because the surface processes proposed by him were based on much simpler atomic processes.

No vacuum conference is complete without a report on research related to understanding phenomena in pressure gauges. Edward E. Donaldson (Washington State University) reported on studies of positive ions emitted by hot tungsten filaments as a function of filament temperature and environmental gas type and pressure. He found that the positive ions consisted of Na^+, K^+, and ions of almost all alkaline metals. He also indicated that two kinds of processes give rise to these positive ion currents. The first is diffusion of impurities to the surface followed by evaporation; the second (which may be much larger than the first) is an uncovering process—either chemical sputtering or direct evaporation of surface atoms.

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Rheo-optics of Polymers

A conference on rheo-optics of polymers was held at the University of Massachusetts 24 August 1963. "Rheo-optics" is a new term designating the use of optical methods to study flow. The conference dealt with the use of several such methods to study the flow and deformation of polymers.

The dynamic birefringence technique, first described in a symposium at the University of Massachusetts last year [*Chem. Eng. News*, **40**, 56 (1962)], is now being employed in Japan and England as well as in several laboratories in this country. Masao Horio (Kyoto University), a pioneer in studies of the physical properties of polymers, presented a paper, written with Ryo Yamada (Nippon Rayon Company) and Shigeharu Onogi (Kyoto University), which described changes in the double refraction of polyethylene, polypropylene, and nylon subjected to vibration. Bryan Read (National Physical Laboratories, England) discussed the use of this method for studying the behavior of amorphous polymers in the vicinity of their transition temperatures. He showed how a combination of these optical methods with mechanical studies may elucidate the kinds of molecular motions occurring when such polymers are deformed and also such phenomena as the embrittlement of plastics at low temperatures.

Rodney D. Andrews (M.I.T.) demonstrated how the birefringence of a polymer is related to the stereoregularity of polymer chains. The birefringence of stretched polymethyl methacrylate (PMMA) changes from a negative to a positive value upon heating. The temperature of reversal of sign is uniquely dependent upon the tacticity of the sample, and is about 30°C for isotactic, 100°C for atactic, and 130°C for syndyotactic PMMA.

Several studies of light scattering from flowing and deforming systems