Treatise on Clean Surface Technology

Volume 1

EDITED BY

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Preface to the Treatise

This multivolume treatise is intended to provide a comprehensive source of information on clean surface technology. The impetus and justification for the treatise were provided by the excellent reviews received by the two-volume set on *Surface Contamination: Genesis, Detection, and Control* (published by Plenum in 1979). That set chronicled the proceedings of a symposium, held in Washington, D.C., in 1978, which was quite comprehensive in its own right. However, after the symposium it was felt that there was a definite need for a series of volumes containing state-of-the-art chapters on various aspects of surface contamination and cleaning written by experts and active practitioners. So this treatise was conceived, and when potential authors were initially contacted, the response was most gratifying. The general consensus was that the proposed treatise was both timely and needed.

The ubiquitous nature of surface contamination makes the subject of clean surface technology of paramount importance in many and diverse technologies, and all signals indicate that its importance is going to increase. Surface contamination has always been a *bête noire* to people working in areas such as adhesion, composites, adsorption, tribology, soldering, device fabrication, and printed circuit boards, and the proper level of cleanliness has always been a desideratum. For example, one commonly hears the statements ''cleanliness may be next to godliness, but it sure precedes adhesion'' or ''if it ain't clean, it won't stick.'' Also, in a world of shrinking dimensions, surface contamination and cleaning become of cardinal importance. A few years ago, a micrometer-size particle was considered innocuous (or at worst cosmetically unappealing), but in the era of submicrometer geometries in microelectronics, this same particle can be disastrous. So there is patently a need to understand why surfaces get contaminated and how to clean them and keep them clean.

In order to cover the subject of clean surface technology in a holistic manner, one must consider all of its essential aspects: sources, causes, and mechanisms of surface contamination; techniques for cleaning; techniques for characterizing the degree of cleanliness; kinetics of recontamination or storage of clean parts; and implications of surface contamination. All these ramifications are intended to be covered in this treatise. Both film and particulate contaminants will be addressed, and all sorts of surfaces (metal, alloy, glass, ceramic, plastic, and liquid) will be considered. The authors have been urged to cover the topic under consideration as completely as possible. In the references, the titles of papers have been included, so that one may be able to find something of interest merely by looking over the reference lists. For those chapters that discuss a technique, the recommended outline is: introduction (historical development), equipment needed (with all the requisite details to carry out experiments), results (showing the utility of the technique), potentialities and limitations, and directions for future development.

The intent and hope, over the course of this treatise, are to cover the topic of clean surface technology *in toto*. It may even be desirable, in a few years, to update selected volumes of the treatise.

The authors invited to contribute chapters are experts in their specialties and they hail from the groves of academia as well as from industrial and governmental research and development laboratories.

In closing, I feel very strongly that this treatise is both timely and needed, and that it should fill the lacuna in the existing body of literature on clean surface technology. These volumes should provide a rich source of information and should serve as a *vade mecum* for veterans as well as neophytes interested in the wonderful world of surfaces.

I now have the pleasant task of acknowledging the enthusiasm, efforts, and patience of the authors, without which this treatise would not have seen the light of day. I would also like to thank the appropriate management of IBM Corporation for allowing me to edit this treatise, and special thanks are due to S. B. Korin for his interest and support.

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Preface to Volume 1

This is the premier volume in the *Treatise on Clean Surface Technology*. The rationale for and scope of this treatise have been delineated in the Preface to the Treatise.

This particular volume contains thirteen chapters covering a number of topics, ranging from UV/ozone cleaning of surfaces to measurement of ionic contamination to implications of surface contamination to the application of pellicles in clean surface technology.

Since even a capsule description of each chapter would make this preface prohibitively long, only a few highlights of each chapter are noted.

The opening chapter by John R. Vig discusses the UV/ozone cleaning of surfaces. The author provides a comprehensive description of what this technique is, what it can do, and how to use it. In the last few years UV/ozone cleaning of surfaces has evoked a great deal of interest.

As pointed out in the Preface to the Treatise, the treatise will cover all kinds of surfaces, and so the next chapter by John C. Scott deals with techniques for cleaning liquid surfaces, which are very important in fluid mechanics and other areas. Robert Walker, in Chapter 3, discusses the Hydroson cleaning of surfaces and compares it with ultrasonic and megasonic techniques. Examples are cited to illustrate its commercial applications, and some recent developments are highlighted.

The measurement of ionic contamination on surfaces is discussed by Jack Brous in Chapter 4. Various techniques have been developed by a number of workers to monitor levels of ionic contamination, and the author discusses their potentialities and limitations. Chapter 5 by Tuan Vo-Dinh covers the characterization of surface contaminants by luminescence using UV excitation, and illustrates the application of this approach to the monitoring of a variety of contaminants on skin.

In a world of shrinking device dimensions, the importance of particle contamination is quite apparent, and Chapter 6 by Joseph R. Monkowski concentrates on particle surface contamination and device failures. The author cites examples of device failures attributed to particulates and emphasizes the need to keep these detrimental particles away from devices.

Chapters 7–12 deal with the effects or implications of surface contamination in various areas of human endeavor. Chapter 7 by David C. Jolly discusses the effect of surface contamination on the performance of HVDC insulators and test methods to evaluate insulator performance. Morton Antler in Chapter 8 covers the effects of surface contamination on electric contact performance. Contact resistance probes for the detection and characterization of contamination are also discussed. The role of surface contamination in solid-state welding of metals is the topic of Chapter 9 by J. L. Jellison, and mechanisms for the elimination of surface barriers during solid-state welding are also discussed. In Chapter 10, K. P. Homewood discusses how surface contamination can influence contact electrification, a topic of great importance in many technologies, for example, xerography.

Nowadays there is a great deal of interest in biomaterials (e.g., prosthetics in the human body) and the question of how their function and behavior are affected by surface contamination is quite important. Chapter 11 by Buddy D. Ratner reviews biomaterials contamination studies.

The redispersion of indoor surface contamination and its implications is the topic of Chapter 12 by Eric B. Sansone, and measurements of redispersion or resuspension factors are discussed. This chapter's emphasis is on radioactive contamination.

The volume concludes with a chapter by Pedro Lilienfeld on the application of pellicles in clean surface technology, and he cites examples to illustrate how pellicles can be effectively used to keep surfaces clean. If contamination can be prevented from depositing on a surface in the first place, then it will not be necessary to clean it. Preventive approaches and techniques are thus of great importance in clean surface technology.

As stated in the Preface to the Treatise, the treatise is intended to cover all aspects of clean surface technology, and the diverse topics covered in this premier volume set the tone for future volumes.

I sincerely hope that this first volume will receive a warm welcome by those involved in surfaces; their comments or suggestions would be most welcome.

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UV/Ozone Cleaning of Surfaces

JOHN R. VIG

1. Introduction

The ability of ultraviolet (UV) light to decompose organic molecules has been known for a long time, but it is only during the past decade that UV cleaning of surfaces has been explored.

In 1972, Bolon and Kunz[1] reported that UV light had the capability to depolymerize a variety of photoresistant polymers. The polymer films were enclosed in a quartz tube that was evacuated and then backfilled with oxygen. The samples were irradiated with UV light from a medium-pressure mercury lamp that generated ozone. The several-thousand-angstroms-thick polymer films were successfully depolymerized in less than one hour. The major products of depolymerization were found to be water and carbon dioxide. Subsequent to depolymerization, the substrates were examined by Auger electron spectroscopy (AES) and were found to be free of carbonaceous residues. Only inorganic residues, such as tin and chlorine, were found. When a Pyrex filter was placed between the UV light and the films or when a nitrogen atmosphere was used instead of oxygen, the depolymerization was hindered. Thus, Bolon and Kunz recognized that oxygen and wavelengths shorter than 300 nm played a role in the depolymerization.

In 1974, Sowell *et al.*[2] described UV cleaning of adsorbed hydrocarbons from glass and gold surfaces, in air and in a vacuum system. A clean glass surface was obtained after 15 hours of exposure to the UV radiation in air. In a vacuum system at 10^{-4} torr of oxygen, clean gold surfaces were produced after about two hours of UV exposure. During cleaning, the partial pressure of O_2 decreased, while that of CO_2 and H_2O increased. The UV also desorbed gases from the vacuum chamber walls. In air, gold surfaces which had been

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contaminated by adsorbed hydrocarbons could be cleaned by "several hours of exposure to the UV radiation." Sowell *et al.* also noted that storing clean surfaces under UV radiation maintained the surface cleanliness indefinitely.

During the period 1974–1976, Vig *et al.*[3-5] described a series of experiments aimed at determining the optimum conditions for producing clean surfaces by UV irradiation. The variables of cleaning by UV light were defined, and it was shown that, under the proper conditions, UV/ozone cleaning has the capability of producing clean surfaces in less than one minute. Since 1976, use of the UV/ozone cleaning method has grown steadily. UV/ozone cleaners are now available commercially.

2. The Variables of UV/Ozone Cleaning

2.1. The Wavelengths Emitted by the UV Sources

To study the variables of the UV cleaning procedure, Vig and LeBus[5] constructed the two UV cleaning boxes shown in Figure 1. Both were made of aluminum, and both contained low-pressure mercury discharge lamps and an aluminum stand with Alzak[6] reflectors. The two lamps produced nearly equal intensities of short-wavelength UV light, about 1.6 mW/cm^2 for a sample 1 cm from the tube. Both boxes contained room air (in a clean room) throughout these experiments. The boxes were completely enclosed to reduce recontamination by air circulation.

Since only the light which is absorbed can be effective in producing photochemical changes, the wavelengths emitted by the UV sources are important variables. The low-pressure mercury discharge tubes generate two wavelengths

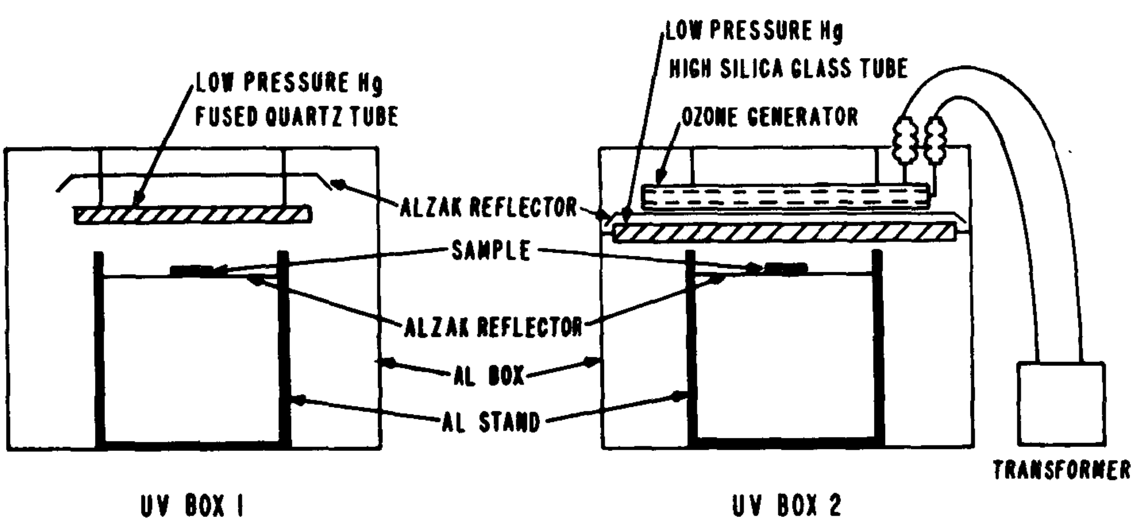

Figure 1. Apparatus for UV/ozone cleaning experiments.