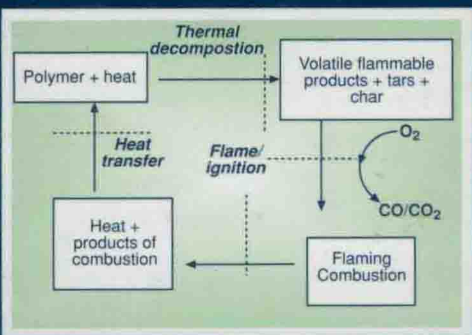
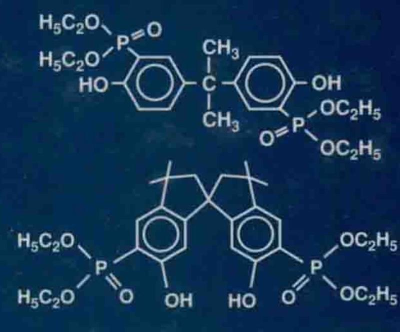
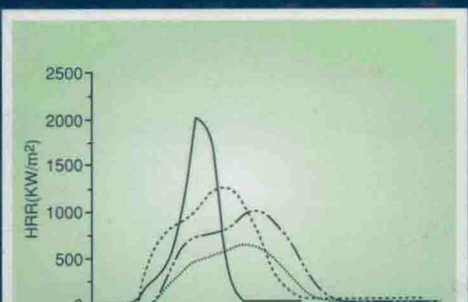
ACS SYMPOSIUM SERIES 922

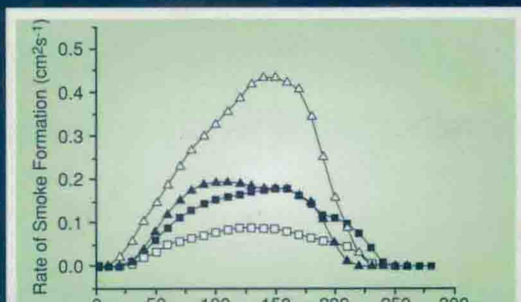
Fire and Polymers IV

Materials and Concepts for Hazard Prevention









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Fire and Polymers IV

Materials and Concepts for Hazard Prevention

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Foreword

The ACS Symposium Series was first published in 1974 to provide a mechanism for publishing symposia quickly in book form. The purpose of the series is to publish timely, comprehensive books developed from ACS sponsored symposia based on current scientific research. Occasionally, books are developed from symposia sponsored by other organizations when the topic is of keen interest to the chemistry audience.

Before agreeing to publish a book, the proposed table of contents is reviewed for appropriate and comprehensive coverage and for interest to the audience. Some papers may be excluded to better focus the book; others may be added to provide comprehensiveness. When appropriate, overview or introductory chapters are added. Drafts of chapters are peer-reviewed prior to final acceptance or rejection, and manuscripts are prepared in camera-ready format.

As a rule, only original research papers and original review papers are included in the volumes. Verbatim reproductions of previously published papers are not accepted.

ACS Books Department

Preface

In the United States we each have about a 40% lifetime probability of being involved in a fire big enough to cause the local fire department to arrive at our door. 1.6 million fires occur in the United States annually, resulting in $12.3 billion in damage. Although the United States has one of the highest rates of fire in the world, fire is a worldwide problem. Most fires involve the combustion of polymeric materials. Flame retardants continue to be the largest single class of additives sold for use in plastics and flame retardants alone constitute a $1 billion (plus) worldwide business. Thus, a clear need exists for a peer-reviewed book on the latest topics in fire science from a polymer perspective.

Because fire and polymers are an important social issue and because of the interest in and the complexity of fire science, a symposium was organized at the 228th American Chemical Society (ACS) National Meeting in Philadelphia, Pennsylvania. The symposium builds upon previous symposia in 1989, 1994, and 2000. Thirty-eight papers from the leading world experts were presented. From those presentations, 28 chapters were carefully selected for incorporation into this volume.

Acknowledgements

We gratefully acknowledge the ACS Division of Polymeric Materials: Science and Engineering, Inc. (PMSE) for providing the venue for the symposium. We acknowledge Cyndi Johnsrud for her extensive assistance with the myriad of details in preparation for the symposium and associated reception and in the preparation and organization of PMSE preprints from the symposium. We gratefully acknowledge Elementis Specialties, Astaris LLC, Great Lakes Chemical Corp., Isolatek International, Martin Marietta (Magnesia Specialties),

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Nanocor, Southern Clay Products, Inc., ATOFINA Chemicals, Inc., and Luzenac/Borax for their interest in the symposium, and in support of the associated reception and of international speaker travel.

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Fire and Polymers IV

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Chapter 1

Fire Retardancy in 2005

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Fire is a worldwide problem. It claims thousands of lives and causes significant loss of property every year. In the volume problems are discussed and solutions delineated. This peer-reviewed volume is designed to be representative of the state-of-the-art. This chapter places current work in perspective.

Introduction

In the United States every 20 seconds a fire department responds to a fire somewhere in the country. A fire occurs in a structure at the rate of one every 61 seconds. A residential fire occurs every 79 seconds. A fire occurs in a vehicle every 101 seconds. There is a fire in an outside property every 42 seconds. The result is 1.6 million fires per year (2003) attended by public fire departments. In 2003 those fires accounted for $12.3 billion in property damage and 3925 civilian fire deaths (one every 134 minutes) and 18,125 injuries (one every 29 minutes). Some 105 fire fighters died in the line of duty in 2003. Fires have declined over the period 1977 to 2003, most notably structural fires, from 1,098,000 to 519,500. Civilian fire deaths in the home (80% of all fire deaths) declined from 6,015 in 1978 to 3,145 in 2003. While those declines are

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progress, recent years have been static, and the United States still maintains one of the highest rates of fire in the world. Just as the U.S. has a high fire rate, the fire death rate in the US varies by state, from 37.9/million population in Arkansas to 3.1/million in Utah. Importantly, 70% of fire deaths in the U.S. occurs in homes without working smoke alarms, this despite years of effort to achieve a high penetration (1-3)

The higher rate of fire in the United States versus most industrialized countries is probably a product of five factors: (1) the U.S. commits fewer resources to fire prevention activities; (2) there is a greater tolerance in the U.S. for "accidental" fires (no one is at fault); (3) Americans practice riskier and more careless behavior than people in other countries (example, the use of space heaters); (4) homes in the U.S. are not built with the same degree of fire resistance and compartmentation as in some countries; and (5) most importantly, people in the U.S. have more contents or "stuff" than those in other countries (i.e., higher fire load) as well as a higher number of ignition sources (higher use of energy).

Polymers form a major part of the built environment. Fire safety depends upon those materials. Polymers are "enabling technology." Advances in numerous technologies depend on appropriate advances in polymers for success. While polymers are both natural and synthetic, this book focuses entirely on the fire safety aspects of synthetic polymers. Production of synthetic plastics resins totaled over 169 million metric tons worldwide in 2003 (4). The U.S. constitutes about one quarter of worldwide plastics consumption, the European Union only slightly less, and Japan about 9 %. In Table I one finds plastics production figures by resin for North America (5). In Table II one finds plastics use data by resin for North America (6).

All organic polymers are combustible. They decompose when exposed to heat, their decomposition products burn, smoke is generated, and the products of combustion are highly toxic. The prime toxic product is CO in concert with CO_2. Toxicity is made more complex by the pervasive presence of alcohol on the part of fire victims. Fire is not a single material property. Fire performance combines ease of thermal decomposition, ignition, flame spread, heat release, ease of extinction, smoke generation, toxic potency and other properties. Regulations use specific tests covering these properties with engineering assessments for materials and systems as deemed appropriate for a particular application. Thus, for example, it is appropriate in small appliances to only worry about ignitability by a Bunsen burner flame or a needle flame, since in the application, from an internal point of view, that is the size of a fire source possible in real appliance failures.

Table I North American Plastics Production[a] – 1999 and 2003 (millions of pounds, dry weight basis)

Resin	*1999 production*	*2003 production*
Epoxy	657	*578*
Urea and melamine[c]	2985	*3174*
Phenolics (gross wt)[c]	4388	*4442*
Total thermosets	8030	*8194*
LDPE[c]	7700	*7804*
LLDPE[c]	8107	*11137*
HDPE[c]	13864	*15709*
PP[c]	15493	*17665*
ABS[c,m]	1455	*1262*
SAN[c,m]	123	*121*
Other styrenics[c,m]	1644	*1596*
Nylon[c,m]	1349	*1279*
PVC[c]	14912	*14702*
Thermoplastic polyester	4846	*7587*
Total thermoplastics	75964	*85255*
Engineering resins[c]	2765	*2619*
All other resins	10702	*10913*
Grand total	97461	*106974*

Notes: [a] US, Canada and Mexico as noted, [c] Canada included, [m] Mexico included

Table II. Resins sales by major markets (millions of pounds)

Major market	*2003*	*%*
Transportation	4732	5.9
Packaging	27464	34.3
Building and construction	14495	18.2
Electrical/electronic	2862	3.6
Furniture and furnishings	3361	4.2
Consumer and institutional	14194	17.8
Industrial/machinery	962	0.8
Adhesives/inks/coatings	1170	1.5
All others	2021	2.5
Exports	9009	11.2
Total selected plastics[a]	80270	100.0

a versus Table I, including engineering resins but excluding thermoplastic polyester

This volume is about the latest research at the intersection of the fields of fire and polymers. Much work continues focused on improving the fire performance of polymers through a detailed understanding of polymer degradation chemistry. New and refined analytical techniques facilitate that analysis. Creative chemists continue to develop new approaches and new, more thermally stable structures. Mathematical fire models continue to become more sophisticated. Tests are becoming better understood.

There are many diverse approaches to enhancing the fire stability of polymers. In the past the most common approach involved the addition of additives. Fifteen years and more ago halogenated fire retardants (with antimony oxide) were the additives of choice to enhance the fire retardancy of many polymers. At this time there is a strong emphasis on non-halogenated fire retardants, and nano-scale additives in particular.

As one looks at previous Fire and Polymers volumes, topics have clearly changed over the years. In 1990 fire toxicity was the first section with six papers. In 1995 there again was a section on fire toxicity with seven chapters. In 2001 there was but one paper and in this volume, 3. In 1990 there was a section on cellulosics, in 2001 only 1 chapter, and in this volume none. In the 1995 volume there were twelve chapters on tests and regulations, in 2001, 2, and in this volume, none. In the current volume, half of the papers are on nanocomposites. Only two papers have a focus on halogen materials specifically. This is not to say that very traditional materials are not being used. Indeed, the use of halogen flame retardants continues to grow. However, this peer-reviewed volume is designed to represent the state of the art (7-9).

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