The Mission: Getting to know and understand silicone resins and their combinations – from the basics of the chemical structure which characterises their properties to the special features underpinning their use as binders in various application areas. This affords a way of gaining a current overview of this important class of raw materials. Essential for any formulator of competitive modern paint systems.

The Audience: Newcomers, career-changers, students and professionals wanting to broaden and deepen their knowledge and who seek key background information to assist them with the selection and use of modern silicones. For those wanting not only to consider the specifics of the underlying chemistry, but also to learn about the practical uses of silicones.

The Value: This completely revised and expanded new edition provides a deep insight into the most important aspects of the properties and applications of this class of binders. It offers a clear and vivid overview of the current status of the use of silicones and their combinations in various coating systems.
Wernfried Heilen and Sascha Herrwerth
Silicone Resins and their Combinations
Hanover: Vincentz Network, 2015
European Coatings Library

ISBN 978-3-86630-697-4

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Layout: Vincentz Network, Hanover, Germany
Printed by: Quensen Druck + Verlag GmbH & Co. KG, Hildesheim, Germany

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Foreword

Because of their molecular structure, silicone resins and silicone combination resins are used in numerous industrial applications, particularly as binders, for formulating coatings. The linking of silicon and oxygen atoms to form a stable basic framework, in which the free valencies of the silicon are saturated by hydrocarbon groups, results in outstanding properties which cannot be achieved with other products. The many possible combinations of the silicone building blocks are reflected in the impressive diversity of silicone chemistry and the resultant products.

The present book (2nd edition) is intended to provide a concentrated overview of the chemistry and technology of silicone resins and their use from an industrial viewpoint. It aims to report on current developments in the field of silicones for coatings and gives those approaching the subject an overview of the most important areas of application.

Since publication of the 1st edition of this book almost ten years ago, some areas of application have seen further technological developments and these have driven significant advances.

For example, silicone combination resins are being increasingly used in anti-corrosion coatings to cope with extreme weather conditions and temperatures.

Alkoxy-silyl functional urethane resins are used in high-tech coatings to increase scratch resistance.

New types of acrylic dispersions in combination with functional polysiloxanes enable the formulation of “below-critical” emulsion coatings with similar properties to “above-critical” silicone resin coatings.

These and further innovations are described in the 2nd edition of this book and reflect the current state of the art in this field.

Since this field will continue to develop, I am pleased that I have been able to win my colleague Dr. Sascha Herrwerth to join me as co-author for this new edition.

I would like to thank our colleagues Dr. Michael Ferenz, Dirk Hinzmann and Dr. Berendjan de Gans for numerous technical discussions.

Thanks are also due to Evonik for making available company literature and permission to reprint extracts as well as for technical and material resources.

Wernfried Heilen
Essen, July 2014
In line with the publisher’s guidelines, the authors have identified trademarked product names by enclosing them within quotation marks ““.”
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1 Introduction

The outstanding properties of silicone resins and silicone-containing combination resins in the form of solutions, liquid resins and emulsions make them extremely versatile. The versatility of silicone resins stems largely from the fact that the organo-siloxanes, on which they are based, can be modified in many ways and combined with numerous organic polymers and different functionalities. Thus the unique properties of the organo-siloxanes, such as high surface activity, chemical inertness and thermal stability can be combined with the properties of the chosen organic functionality or polymer. Applications range from impregnations and weather-resistant exterior coatings for building conservation, through heavy duty anti-corrosion protection to high temperature resistant coatings. Acrylic-functional silicone resins and epoxy-functional silicone resins are reactive resins, which are used as UV-curable coatings for paper and as additives for radiation curing printing inks and wood lacquers.

1.1 Organo-siloxanes and organo-polysiloxanes

The starting products required to manufacture silicones, $R_3SiOH$ (silanols), $R_2Si(OH)_2$ (silane diols), $RSi(OH)_3$ (silane triols) and $Si(OH)_4$, are obtained by hydrolysis of the corresponding halogen compounds $R_3SiCl$, $R_2SiCl_2$, $RSiCl_3$ and $SiCl_4$\[1\]. The latter can be prepared by addition of alkyl halides $RX$ to very pure silicon (> 98 %) in the presence of a copper catalyst\[2\].

This industrial process today generally known as Müller-Rochow Synthesis is also termed “direct synthesis” since organo-chlorosilanes are manufactured directly from elemental silicon (Figure 1.1). This process was discovered by

![Figure 1.1: Organo-chlorosilanes manufactured by Müller-Rochow-Synthesis](image-url)