Expert Level

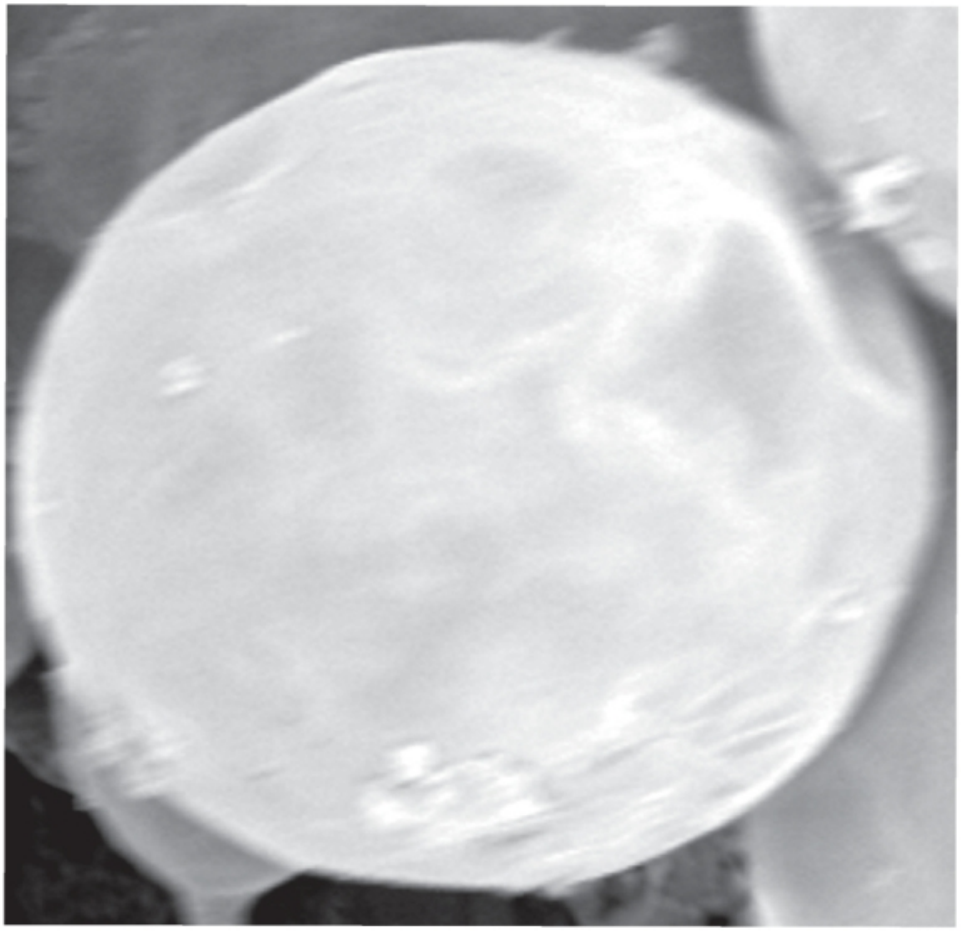
of

Dental Resins

Material Science & Technology

1st Edition

Ralf Janda



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Cover picture: SEM picture of a polymeric hollow bead

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The “Expert Level” is the third book of the series “Dental Resins - Material Science & Technology”. From a total data base of 8.198 references 1.707 were selected and used for this textbook. It comprises more than 1.000 manuscript pages, 384 figures and 124 tables. The Expert Level describes very accurately and comprehensively all details of material science and technology of dental resin polymers as well as their application and thus enormously extends the knowledge base of the Basic and the Advanced Level. This includes the disclosure of the

- raw/starting materials together with the disclosure of their chemical structure, CAS Numbers and manufacturers.
- amounts of the raw/starting materials usually used to formulate the finished products.
- important material and toxicological properties of the starting materials and the finished products.
- detailed description of the production processes of important starting materials such as the syntheses of important monomers, the silanization of inorganic fillers or the manufacturing of unfilled and filled splinter polymers.

- detailed description of the formulation of the finished products.

Furthermore, for many commercial finished products rather detailed formulations as well as the exact production processes are described.

Finally, I think that the Expert Level enables every scientist with a good chemical knowledge not only to understand how dental polymers function but also to develop and to formulate improved products.

Many thanks for your interest and best regards

Ralf

September 2022

Preface - Book Series

Resin materials are broadly used in dentistry for almost all indications and they will gain even more importance in future. Especially the increasing performance and efficiency of CAD/CAM technology and 3D-printing open possibilities to use resins not used up to now for dental applications. Besides of dentists, dental technicians, dental students, teachers of dental universities/schools, postgraduate students and PhD candidates there are many other specialists such as researchers, material scientists, industrial developers or experts of adjoining professional disciplines who are technically engaged in dental resins. Mainly three reasons are responsible for this interest:

a) many persons dealing with dentistry feel a large desire for deeper knowledge in dental resins

b) the knowledge of many different specialists is requested to develop, to investigate, to test and to evaluate dental resins

c) dental resins offer very sophisticated highly developed properties so that they are also used in other disciplines for other purposes or are the base to develop tailor-made products for other very special non-dental applications.

The idea of this e-Book is to present a three-level textbook dealing with material science and technology of dental resins:

a) The Basic Level addresses students, dental technicians, teachers or all those interested in dental resins. The Basic Level gives a comprehensive insight into chemistry, physics and toxicology of dental resins and their technical application.

b) The Advanced Level broadens the information of the Basic Level significantly and mainly addresses teachers of dental universities/schools, postgraduate students, PhD candidates, researchers, material scientists, industrial developers or experts of adjoining professional disciplines.

c) The Expert Level gives a very deep insight into the science of dental resins and mainly addresses scientists doing research on dental resins, industrial developers or scientists of adjoining professional disciplines who are very strongly interested to become also specialists in dental resin material science. The Expert Level describes also the industrial processes that are used to manufacture dental resins. Furthermore, some exact formulations for some dental products are given; this includes know-how that has never been published before as far as the author knows.

Contrarily to print books, it is the great advantage of e-Books that improvements, corrections, additions or enhancements can be done swiftly so that new improved editions can be produced and distributed rapidly and cheaply. Therefore, the e-Book is the ideal format to update the content

immediately whenever errors or mistakes must be eliminated or the scientific progress makes it necessary. It is the desired and planned scenario that the content of this e-Book will not become obsolete as fast as it usually happens with conventional print books but will be refreshed in shorter periods of time.

Illustrations and tables will increase in number with each level. The information they give is - hopefully - clear and understandable but certainly they will not become prettier or colored. This is a low-cost book and everything is done keeping costs to a minimum.

The author is aware that there will be errors, inaccuracies and ambiguousness but hopefully no incorrect or even misleading information in the text despite of all the care taken. The honorable readership is kindly asked for understanding and the author will be very grateful for any hints and proposals to improve the content of the book or the book at all. Therefore, every type of constructive criticism will be highly appreciated.

Having said all this, I hope you will enjoy the book and you will get the information that is helpful and valuable for you and your work.

Many thanks and best regards

Ralf

Literature/Trademarks/Other

Not all the literature used to write this book is specifically cited. Common dental, chemical or material science knowledge taken from textbooks is not specifically cited in the text. Such textbooks are

- dentistry and dental materials [1-20]
- chemistry [21-46]
- adhesives and adhesive technology [47-50]
- material science [50-52]

Also, information, figures or tables taken from the author's sole publications are not specifically cited; these are [53-79].

Information (terms, definitions, etc.) deriving from scientific organizations is not always specifically cited; these organizations are [80-83].

Specific information given is specifically cited.

Product names are not specifically marked as registered even if they are so. Principally brand names are only used when they are important in connection with the described subjects. This might be the case when only one product of a specific product category is available. Apart from that

representatives of product categories presented in tables or graphics are anonymized.

Introduction

Besides of metals, alloys and ceramics plastics and composite resins have become to one of the most important material categories in all areas of daily life such as engineering, electronics, building and construction industry, car industry and many other industries as well as in medicine and dentistry. In 1922 Hermann Staudinger discovered these high molecular compounds and called them macromolecules [84]. This was the start of a new until then unknown chemistry called polymer chemistry. The development of numerous polymeric materials and combinations thereof with other organic or inorganic substances or materials gave birth to a huge number of advanced materials with exceptional properties.

In the early years plastics were considered to be cheap and inferior materials but today composite resins and high-performance plastics are very valuable and indispensable in all industries. The most important aspect for the resin materials' breakthrough is certainly the fact that for nearly every usage custom-made, often also called tailor-made, products can be developed and finally provided. For sure, more and more new, until now unknown, resins or resin composites will be tailor-made for further or today even unknown applications in future.

Resin materials (plastics, composite plastics, composite resins, resin composites) are high molecular mass products (polymers). They are manufactured by transformation of naturally occurring or by synthesis from low molecular mass substances (monomers). These low molecular mass substances (monomers) are the smallest multiple recurring units building the high molecular mass substances (polymers). The properties of each of the resulting polymers depend on how the monomers are linked, on their chemical structure as well as on the spatial configuration of the formed macromolecules. Polymers or macromolecules do not have an exact but an average molecular mass because the single chains building the polymer/macromolecule are growing randomly and not in a well-defined manner.

Abbreviations and Chemicals

Abbreviations important in the context of this book or the dental literature are given in accordance with IUPAC [80-83]. Information given here is important for all levels of this book series.

Monomers

4-Met = 4-methacryloyloxypropyl trimellitic acid (Fig. 74b-2)

4-Meta = 4-methacryloyloxypropyl trimellitic anhydride (Fig. 74b-2)

AA = acrylic acid (Fig. 17b)

BADEP = N,N'-diethyl-1,3-bis(acrylamido)-propane (Fig. 63e)

BDMA = butanediol dimethacrylates (Fig. 18b-1a)

Bis-EDMA(2) = bis-EMA(2) = 2,2-bis[4(3'-methacryloyloxy)ethoxyphenyl)]propane (Fig. 18b-1)

Bis-GMA = 2,2-bis[4(3'-methacryloyloxy-2'-hydroxy)propoxyphenyl]propane (Fig. 18b-1)

BMDU = methylene-4,4'-N,N'-bis-cyclohexylamine carbamate of 3-methacryloyl-2- hydroxypropoxy benzene (author's knowledge) (Fig. 18b-1a)

BMP = bis-(2-methacryloyloxy)ethyl phosphate (Fig. 70e)

DiPEPA = dipentaerythritol monohydroxy pentaacrylate (Fig. 17b-1)

DDMA = 1,12-dodecandiol dimethacrylate (Fig. 18b-1)

EDMA = ethylene glycol dimethacrylate (Fig. 18b-1a)

EHA = 2-ethylhexyl acrylate (Tab. 2e)

EMA = ethyl methacrylate (Fig. 18ba-2)

Epoxy acrylate oligomer = 2,2-bis[acryloyloxy(2'-hydroxypropyloxy)phenyl]propane (Fig. 17b)

FurfurylMA = Furfuryl methacrylate (Fig. 18ba-2)

GDMA = glycerol dimethacrylate (Fig. 66e)

GPDM = glycerol phosphate dimethacrylate (Fig. 74b-1)

GPTA = glyceryl propoxy triacrylate = 3-[2,3-bis(3-prop-2-enoyloxypropoxy)propoxy]propyl prop-2-enoate (Fig. 17b-1)

HDDMA = 1,6-Hexanediol dimethacrylate (Fig. 18b-1)

HEMA = hydroxyethyl methacrylate (Fig. 18ba-2)

HPMA = hydroxypropyl methacrylate (Fig. 18ba-2)

HPPMA = 2-hydroxy-3-phenoxypropyl methacrylate (Fig. 73b)

i-BuMA = iso-butyl methacrylate (Fig. 18ba-2)

MA = methyl acrylate (Fig. 17b)

MASA = N-methacryloyl-5-aminosalicylic acid (Fig. 74b-2)

MDP = 10-methacryloyloxydecyl dihydrogen phosphate (Fig. 74b-1)