CHEMISTRY AND TECHNOLOGY OF CYANATE ESTER RESINS

Edited by I. Hamerton

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Chemistry and Technology of Cyanate Ester Resins

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Chemistry and Technology of Cyanate Ester Resins

Preface

After epoxy resins and polyimides, cyanate esters arguably form the most well-developed group of high-temperature, thermosetting polymers. They possess a number of desirable performance characteristics which make them of increasing technological importance, where their somewhat higher costs are acceptable. The principal end uses for cyanate esters are as matrix resins for printed wiring board laminates and structural composites. For the electronics markets, the low dielectric loss characteristics, dimensional stability at molten solder temperatures and excellent adhesion to conductor metals at temperatures up to 250°C, are desirable. In their use in aerospace composites, unmodified cyanate esters offer twice the fracture toughness of multifunctional epoxies, while achieving a service temperature intermediate between epoxy and bis-maleimide capabilities. Applications in radome construction and aircraft with reduced radar signatures utilize the unusually low capacitance properties of cyanate esters and associated low dissipation factors.

While a number of commercial cyanate ester monomers and prepolymers are now available, to date there has been no comprehensive review of the chemistry and recent technological applications of this versatile family of resins. The aims of the present text are to present these in a compact, readable form. The work is primarily aimed at materials scientists and polymer technologists involved in research and development in the chemical, electronics, aerospace and adhesives industries. It is hoped that advanced undergraduates and postgraduates in polymer chemistry and technology, and materials science/technology will find it a useful introduction and source of reference in the course of their studies.

Having completed my task as editor, it simply remains for me to express my sincere thanks to each of the chapter authors for their valuable contributions, and the spirit in which these were produced. I look forward to working with you again in the future.

I would also like to express my gratitude to my friends among the staff and students of the University of Surrey who have rendered either practical assistance or thought-provoking discussions during the preparation of this manuscript. Dr Elizabeth Lyon (George Edwards Library), Anni Read (AVS Graphics Department) and Noreen Kearney were particularly helpful.

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grateful. I would also like to say a special thank you to Shaaron Ainsworth who actively encouraged the concept of this work and helped to instil the confidence to pursue it further.

My thanks to the staff of Blackie A&P whose labours have transformed the roughly-edited manuscripts into the book of my original vision and to the Manufacturers who kindly responded to my requests for product data sheets. In the course of compiling this book some important literature references may have been omitted and I would welcome any correspondence from readers concerning these and future reference works. I hope that you enjoy the book.

I.H.

Notes

For ease of reference a general subject index and an index of compounds, as well as separate appendices of commercial monomers, prepolymers and resin systems are provided.

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Selected list of compounds

AcAc	Acetylacetonate
AN	Butadiene–acrylonitrile co-polymer
ATBN	Amino-terminated butyronitrile rubber
ATH	Aluminium trihydrate
BADCy	Bisphenol A dicyanate (2,2′-bis(4-cyanatophenyl)isopropylidene
BADGE	Bisphenol A diglycidgyl ether (2,2′-bis(4-glycidyloxyphenyl)isopropylidene)
BCB	Bis(benzocyclobutene)
BMI	Bismaleimide
BMI-MDA	Methylene dianiline-toughened bismaleimide (polyaspartimide)
BT	Bismaleimide–triazine (resin)
CE	Cyanate ester
Cl.PCy	4-Chlorophenyl cyanate
CPCy	2-(4-Cyanatophenyl)-2-phenyl-propane or (4-cumylphenylcyanate)
CSR	Core shell rubber
CTBN	Carboxy-terminated butyronitrile rubber
$Cu(acac)_2$	Copper(II) acetylacetonate
DCBA	Dicyanate ester of bisphenol A (2,2′-bis(4-cyanatophenyl(isopropylidene)
DCM	4,4′-diamino-3,3′-dimethyldicyclohexyl methane
DDS	Bis(4-aminophenyl)sulphone (4,4′-diaminodiphenylsulphone)
DGETBBPA	Diglycidylether of tetrabromobisphenol A
DMF	Dimethylformamide
DPEDC	Dicyanato-4,4′-diphenylethane
EMI	2-Ethyl-4-methyl imidazole
ETBN	Epoxy-terminated butyronitrile rubber
HTBN	Hydroxy-terminated butyronitrile rubber
MEK	Methyl ethyl ketone
METHYLCy	Bis(3,5-dimethyl-4-cyanatophenyl)methane
NFBN	Non-functional (unfunctionalized) butyronitrile rubber
OXOCy	Bis(4-cyanatophenyl)ether
PEEK	Poly(ether ether ketone)
PES	Poly(ether sulphone)
PGE	Phenyl glycidyl ether
PMI	Poly(methacrylimide)
PT	Phenolic-triazine (resin)

PTFE	Poly(tetrafluoroethylene)
PVC	Poly(vinyl chloride)
TGAP	*N*,*N*,*O*-Triglycidylamino-4-phenol
TGDDM	*N*,*N*,*N*′,*N*′-Tetraglycidyl diamino-4,4′-diphenyl methane
TGMDA-DDS	4,4′-Diaminodiphenylsulphone-cured tetraglycidyl methylene dianiline
THIOCy	Bis(4-cyanatophenyl)sulphide
Tp	Thermoplastic

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Selected list of abbreviations and terms

AO	Atomic oxygen (resistance)
ASTM	American Society for the Testing of Materials
bv	By volume
bw	By weight
CAF	Conductive anodic filament
CAI	Compressive strength after impact
CLTE	Coefficient of linear thermal expansion
CME	Coefficient of moisture expansion
CMOS	Complementary metal oxide semiconductor
CPC	Cloud point curve
CPU	Central processing unit
CSR	Core shell rubber
DMA	Dynamic mechanical analysis
DMTA	Dynamic mechanical thermal analysis
DSC	Differential scanning calorimetry
ECL	Emitter coupled logic
EFA	European fighter aircraft
FTIR	Fourier transform infrared spectroscopy
GC–MS	Gas chromatography–mass spectrometry
GPC	Gel permeation chromatography
HDT	Heat deflection temperature
HPLC	High performance (or pressure) liquid chromatography
HSCT	High speed civil transport
IC	Integrated circuit
ILSS	Interlaminar shear strength
IPN	Interpenetrating network
LCST	Lower critical solution temperature
LEO	Low Earth orbit
LOI	Limiting oxygen index
LSI	Large scale integration
MCM	Multichip module
NMR	Nuclear magnetic resonance spectroscopy
pbw	Parts by weight
PCB	Printed circuitboard
PFN	Prepreg flow number
phr	Parts per hundred parts resin
PWB	Printed wiring board
RAS	Relative hydrogen bond acceptor strength (referenced to benzonitrile)
RH	Relative humidity

RIM	Reaction injection moulding
RT	Room temperature
RTM	Resin transfer moulding
RV	Reduced viscosity
SEC	Size exclusion chromatography
SEM	Scanning electron microscopy
semi-IPN	Semi-interpenetrating network
SMC	Sheet moulding compound
TAB	Tape-automated-bonding
TBA	Torsional braid analysis
TEM	Transmission electron microscopy
TGA	Thermogravimetric analysis
T_gTP	Conversion–temperature–transformation
UCST	Upper critical solution temperature
UD	Unidirectional
VLSI	Very large scale integration
WLF	Williams–Landel–Ferry (equation)

Contents

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