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Dr. Bernhard Wunderlich at 70

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At the 29th NATAS Conference held in St. Louis, many of Dr. Wunderlich's students, colleagues and friends gathered to attend the symposium on "The Solid State of Macromolecules: A Symposium in Honor of Bernhard Wunderlich on the Occasion of his 70th Birthday." This symposium went on for 2 full days with 30 submitted papers. The audience and presenters were international with attendees coming from as far as Europe and Japan. Travel for many at this time, especially international travel, was very difficult since the conference was held less than 2 weeks after the terrorist attacks of 11 September. However, both the symposium and the panel discussion titled "DSC Theory and Applications: Conventional and Modulated" which Dr. Wunderlich participated in (and debated with Drs. Reading and Schick) were well attended. Still in our minds was the gathering of a large number of old and new students at Kemol's restaurant on the evening of 24 September. Not only were current interests discussed but also reminiscences of past times refreshed old memories.

Although Dr. Wunderlich's current research interests are to resolve reversible polymer melting and nanophase separation of macromolecules, which was discussed at the symposium, a look back at his life and research is called for.

1. Early life

Dr. Wunderlich was born in Brandenburg, Germany on 28 May 1931 [1,2]. Surviving both the bombing of his parent's house and the confiscation of his farm, he began his university study in 1949 at the Humboldt University in Berlin. Following the uprising in the German Democratic Republic in 1953, Dr. Wunderlich switched to the Goethe University in Frankfurt, where he married Heidi. After immigrating to the United States, Dr. Wunderlich found his way into the laboratory of Malcolm Dole at Northwestern University in Evanston, IL. At that time Prof. Dole was a pioneer in the calorimetry of polymers (and other physical chemistry subjects). Under Dr. Dole's guidance, he completed his thesis on the "Thermodynamics of the Copolymer System Poly(ethylene terephthalate-sebacate)." A large portion of his study required heat capacity measurements through the use of an adiabatic calorimeter on a number of polymers including polyethylene. It is very difficult for us now to appreciate how much calorimetry has advanced, use of an adiabatic calorimeter was highly time consuming and his measurements took months to complete. Dr. Wunderlich was later to redo his heat capacity measurements on polyethylene in a matter of weeks on the Perkin-Elmer DSC-1. After receiving his Ph.D., he lectured at Cornell University sharing his office space with the Baker Lecture Series Scholars, and spent time debating thermodynamics and its

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molecular interpretation with Peter Debye, Manfred Eigen, C.A. Coulson, Maurice Huggins, and Paul Flory.

2. Professional career

From his time with Malcolm Dole to the present, Prof. Wunderlich has worked in the thermal analysis field for over 46 years. The first 8 years, as previously mentioned, were spent at Northwestern and Cornell Universities. The next 25 years were at Rensselaer Polytechnic Institute (RPI), first in the old Walker building and later in the Materials Research Center (MRC). In 1980 advanced thermal analysis system (ATHAS) was founded and its first report released in 1981 with Dr. Umesh Gaur being its first director. Currently, Dr. Marek Pyda holds this position at the University of Tennessee.

After 25 years at RPI, Dr. Wunderlich retired in 1988. Following the example set by his thesis advisor, he did not stay in retirement but accepted a joint position at the University of Tennessee at Knoxville and Oak Ridge National Laboratory. Just before Dr. Wunderlich left RPI, Prof. Stephen Z.-D. Cheng, a former student and postdoctoral fellow of Dr. Wunderlich, initiated a second branch of ATHAS at the University of Akron in 1987. As of 29 June 2001, Dr. Wunderlich retired the second time and now enjoys emeritus status from both universities.

3. Research

With over 500 publications, a synopsis of Dr. Wunderlich's academic work is a momentous task and beyond the space allotted in this special journal issue. However, we would like to note a number of topics and achievements that have been made. We have also attached a listing of his papers for easy reference [2].

3.1. Heat capacity and the ATHAS database

Determination of a DSC baseline is always a problem, especially for semicrystalline polymers. For semicrystalline polymers, the melting transition is extremely broad while the glass transition can be asymmetric. Knowledge of the baseline from fundamental principles allows one to precisely define a baseline, taking the uncertainty out of the determination. Establishment of a database of heat capacities based on semi-empirical calculations is a cornerstone of the ATHAS laboratory. The database can be accessed from the ATHAS Website [3].

3.2. Organization of matter

Classification has always been an interest to Dr. Wunderlich. One of his earliest classification schemes was based on a molecule's ability to move from one phase to another. That is, one can separate molecules into small molecules which may be found as a solid, liquid or gas; flexible macromolecules which may be either liquid or solid; and finally rigid macromolecules which are solid only [4].

Another classification scheme also developed was for condensed matter. This classification scheme showed the interrelationship between the different ordering of a material's phases. Included in this classification is the identification of a different type of mesophase specific for flexible molecules, the conformationally disordered (condis) crystal and its associated glass. The disorder for the condis crystal is the molecule's ability to change conformationally [5]. Knowledge of this phase now allows us an explanation of how extended-chain crystals may form when passing through the condis crystal which permits sliding diffusion and gives the initially chain-folded macromolecule sufficient freedom to perfect itself.

3.3. Glass transition

Dr. Wunderlich has done extensive work towards our understanding of the glass transition. The rule of constant ΔC_p at T_g which estimates a heat capacity jump of 11 J/(K mol) of (small) mobile unit is widely used [6]. For example, polyethylene which has a mobile unit of CH_2 is close to this value in its change of heat capacity at its glass transition temperature.

Dr. Wunderlich is also noted for the theory that explains the hysteresis effect noted in the glass transition region in DSC traces [7,8]. Any difference between heating and cooling rates leads to hysteresis effects that show up as endotherms or exotherms in the glass transition region. Wunderlich explained this as resulting from the First Law of Thermodynamics

consideration towards the time dependence of the glass transition. For example, unfreezing of the glass transition resulting from a fast heating after a slow cooling would result in an endotherm since an apparent increase in the glass transition temperature would result in an apparent loss in enthalpy that is made up by the hysteresis endotherm since less time is allowed on heating for devitrification.

3.4. Rigid amorphous phase

It was also noted in Dr. Wunderlich's group that one can reduce the hysteresis effect by partially crystallizing the material [9]. Later through the use of temperature-modulated DSC, it was shown that the reduction of the hysteresis effect could be linked to the decrease in the activation energy in the devitrification process [10]. Additionally, for semicrystalline polymers it was found that adding the %amorphous with the %crystallinity, which can be determined through the ΔC_p and the heat of fusion knowing the 100% values for both, did not fully total unity [9]. This was explained by there being a rigid amorphous fraction in the interphase between the amorphous and crystalline regions, which makes up the difference [11]. This amorphous interphase is held rigid (unable to devitrify) due to the crystalline region.

3.5. Crystallization and melting

Dr. Wunderlich's initial work on crystallization occurred during his thesis study at Northwestern University. During this time he coined the term "cold crystallization" for crystallization that occurred after a polymer had been quench cooled from the melt [12]. Later in further studies on polymer crystallization, he developed the theory of macromolecular nucleation [13]. For small molecules it is generally accepted that crystallization is comprised of a nucleation process followed by growth. However, polymers show a higher degree of supercooling than that found for small molecules. This can be explained by an additional molecular nucleation step in which a polymer molecule must establish itself on the growing crystal. Today this concept helps to understand the reversible melting in metastable, semicrystalline polymers, as discussed in the present symposium.

Also noted in the DSC traces for many polymers are twin melting peaks. At first glance one may think this is just two different crystal phases, however, in many cases this is due to reorganization [14]. Reorganization is a process in which improvements or perfections of the initially metastable crystal occur. The lower peak represents the melting of the original crystals while the upper peak represents the melting of the crystals that have reorganized on heating. This was shown using variable heating rates where the upper peak grows proportionally at the expense of the lower peak as slower heating rates are employed.

For some polymers multiple melting peaks beyond two are observed. One example is extended-chain crystals of polymethylene, polyethylene and polyethylene fractions grown from the melt under elevated pressure [15]. Melting peaks on the low temperature side of the main melting peak were shown to be due to narrowly distributed, low molecular weight polymer segregated in extended-chain crystals. Superheating of crystals before melting increased with molecular weight and chain extension. The melting mechanism of extended-chain crystals was shown to be a successive peeling off of chains, which leaves the chain extension constant up to melting of the last crystal trace.

3.6. Modulated calorimetry

With the advent of temperature-modulated DSC, TMDSC (also known as modulated temperature DSC, MTDSC), a whole new area of calorimetry was born. Needed now is to develop the math and its understanding and apply it to the study of polymeric materials. This is currently a focus of the ATHAS lab.

4. Students and colleagues

Finally, as all who know Dr. Wunderlich will agree, recognition of his students is of importance to him. Below is a listing of the postdoctoral research associates, Ph.D. and Masters degree students, and finally research technicians and undergraduate assistants who have collaborated with him over the years at both RPI and UT [2]. Also attached as an appendix, is his current publication list [2].

5. Postdoctoral research associates

Dr. E.A. James, 1961–1962
Dr. H. Baur, 1963–1964
Dr. M. Sansone, 1970–1971
Dr. J. Bares, 1970–1972
Dr. K. Boehlke, 1971–1972
Dr. A. Mehta, 1973–1976
Dr. M. Altman, 1974–1976
Dr. K. Weber (Murphy), 1976–1978
Dr. H.-C. Shu, 1978–1979
Dr. J. Menczel, 1979–1980, 1985
Dr. J. Grebovicz, 1980–1985
Prof. M.-Y. Cao, 1982–1984
Dr. S.Z.-D. Cheng, 1985–1987
Dr. K. Loufakis, 1986–1987
Prof. A. Zhang, 1987 (jointly with Prof. Cheng, U. Akron, Akron, OH)
Dr. Yimin Jin, 1988–1993
Prof. Munehisa Yasuniva, 1988–1989
Dr. Nobuyuki Tanaka, 1991–1992
Dr. Jinlong Cheng, 1992–1993
Dr. Guanghe Liang, 1993–1994
Dr. Stefan Kreitmeier, 1994–1995
Dr. Reinhard Festag, 1995–1996
Mr. Iwao Okazaki, 1994–1996
Dr. Ge Zhang, 1996–1997
Dr. Yon Ku Kwon, 1996–1999
Dr. Renè Androsch, 1997–1999
Dr. Pawel Kamaza, 2000–2001
Dr. Alexander Buzin, 2000–2002
Dr. E. Hellmuth, 1963–1965
Dr. F. Hamada, 1966–1967
Dr. V. Baresova, 1970–1972
Dr. G. Treiber, 1971–1972
Dr. R. Iwamoto, 1972–1973
Dr. M. Mucha, 1973–1974
Dr. C.J. Lee, 1976–1977
Dr. R. Benkhoucha, 1978
Dr. U. Gaur, 1979–1981
Dr. Y. Cheban, 1980–1981
Dr. H. Suzuki, 1982–1984
Prof. Z.Q. Wu, 1986
Prof. H.-S. Bu, 1985–1987
Dr. M. Varma-Nair, 1988–1993
Dr. B. Sumpter, 1988–1992
Dr. A. Xenopoulos, 1990–1993
Dr. Yigang Fu, 1991–1995
Dr. Qiguang Wang, 1992–1994
Dr. Marek Pyda, 1994–1999. Since then, Research Professor at the University of Tennessee and Director of ATHAS
Dr. Martina Ralle, 1994–1996
Dr. Kazuhiko Ishikiriyama, 1995–1996
Dr. Wei Chen, 1996–1999
Dr. Andreas Boller, 1996–1997
Dr. Il-Kwon Moon, 1997–1999
Dr. Maria Laura Di Lorenzo, 1998
Dr. Wenbing Hu, 2000–2001
Dr. Jeong-Ihm Pack, 2001–till date

6. Ph.D. students

Dr. D.M. Bodily, 1964, Differential Thermal Analysis of High Polymers. The Glass Transition in Polystyrene and the Irreversible Melting of Ethylene Copolymers.
Dr. T. Arakawa, 1964, Extended Chain Polymer Crystals.
Dr. P. Sullivan, 1965, High Polymer Crystal Growth from Solution and Investigation of their Properties and Structure by Optical Interferometry.
Dr. M. Jaffe, 1967, The Solid State of Polyoxymethylene.
Dr. T. Davidson, 1967, Crystallization and Melting of Polyethylene under Pressure.
Dr. F. Liberti, 1968, The Solid State of Nylon 6.
Dr. R.B. Prime, 1968, The Equilibrium Melting of Homopolymers.
Dr. S. Wolpert, 1970, Dynamic Differential Thermal Analysis of the Glass Transition Region.
Mr. L. Melillo, 1967–1972, Morphology of Extended Chain Crystals of Polyethylene and Polytetrafluoroethylene (incomplete).
Dr. S. Kubo, 1971, Crystallization During Polymerization of Polyparaxylylene.
Dr. A. Weitz, 1974, The Thermal Analysis and Volume Relaxation of Glasses Formed under Elevated Pressure.
Dr. M. Coughlin, 1972, The Mechanism of Formation and the Morphology of Extended-Chain Crystals of Selenium.
Dr. A. Mehta, 1973, Molecular Rejection During the Crystallization of Polymers.

Mr. G. Czornyj, 1970–1975, Superheating During the Melting of Extended-Chain and Stirrer-Crystallized Polyethylene Crystals (incomplete).
Dr. C.J. Lee, 1976, Polymer Crystal Growth by Crystallization During Polymerization of Diphenylsilylene.
Dr. R. Benkhoucha, 1978, Crystallization During Polymerization of Lithium Dihydrogen Phosphate.
Dr. E.S.W. Kong, 1978, Synthesis of Extended-Chain Polymer Crystals of Polydiphenylgermylene by Transport Polymerization and Crystallization During Polymerization.
Dr. H.-C. Shu, 1979, Selenium, Its Thermodynamic Properties and Vapor-Phase Crystal Growth.
Dr. U. Gaur, 1979, Heat Capacities of Linear Macromolecules.
Dr. S.-F. Lau, 1982, Heat Capacity and Thermodynamic Properties of Linear Macromolecules.
Mr. N. Gjaja, 1975–1984 (evenings), Thermal Analysis of Crosslinked Systems (incomplete).
Dr. D.E. Kirkpatrick, 1984, Heat Capacity, Phases, and Phase Transitions of Poly-*p*-xylylene.
Dr. S.Z.-D. Cheng, 1985, Molecular Segregation and Nucleation of Poly(ethylene oxide) Crystallized from the Melt.
Dr. L. Judovits, 1985, The Thermal Properties of Polystyrene, Substituted Polystyrenes and Crosslinked Systems.
Dr. K. Loufakis, 1986, Advanced Thermal Analysis of Fluorinated and Chlorinated Polyethylenes.
Ms. W. Aycock, 1984–1987, Heat Capacities of Branched Polyethylenes (incomplete).
Dr. R.Y.L. Pan, 1987, Measurement and Computation on Heat Capacities of Polyesters and Other Linear Macromolecules.
Dr. M.-Y. Cao, 1987, The Thermal Properties of Copolymers with Anisotropic Melts.
Dr. J. Wesson, 1988, Mesophase Transitions of Polydiethylsiloxane.
Dr. A. Xenopoulos, 1990, Thermal Analysis of Polyamides.
Dr. K. Roles 1991, Heat Capacity Study of Solid Poly(amino acid)s.
Dr. Jinlong Cheng, 1992, Solid State ^{13}C NMR and Thermal Analysis of Conformation Motion and Disorder in Small and Large Molecules.
Dr. R.C. Bopp, 1993 (evening student), Differential Scanning Calorimetry of Brominated Poly(2,6-dimethyl-1,4-phenylene oxide) and its Solutions in Polystyrene.
Dr. L. Liang, 1993, A Study of the Atomic Details and Dynamics of Polymethylene Crystals via Molecular Dynamics Simulation.
Dr. Wei Chen, 1996, Characterization of the Thermotropic Mesophases by Thermal Analysis and Solid State ^{13}C NMR.
Dr. Ge Zhang 1996, Heat Capacities of Solid State Proteins.
Dr. Andreas Boller, 1996, The Thermal Analysis of Gel-Spun Ultra-High Molar Mass Polyethylene Fibers.
Dr. A. Michel, 1998–1999 (degree completed at U. Regensburg, Germany).
Dr. Jeong-Ihm Pack, 2001, Reversing Melting and Crystallization of Short and Long Chain Molecules by Temperature-Modulated Calorimetry.

7. Masters degree students

Dr. P. Sullivan, 1963 (Ph.D. from RPI)
Mr. W. Haney, 1970
Mr. A. Miyagi, 1971
Mr. N. Toyota, 1974–1976 (incomplete)
Mr. J.P. Walsh, 1979
Mr. W. Meesiri, 1981
Dr. L. Judovits, 1984 (Ph.D. from RPI)
Ms. V. Dann, 1985
Dr. R. Pan, 1985 (Ph.D. from RPI)
Ms. C.M. Cormier, 1965
Dr. A. Mehta, 1970 (Ph.D. from RPI)
Dr. R.C. Bopp, 1975 (Ph.D. from RPI)
Dr. U. Gaur, 1977 (Ph.D. from RPI)
Mr. T. Voll, 1981
Ms. J. Pathak, 1981
Ms. M. Palazoglu, 1984
Ms. S. Yao-Lim (Mesina), 1985
Dr. Jeong-Ihm Pack, 2000 (Ph.D. from UT)

8. Research technicians and undergraduate assistants

Mr. W.H. Kashdan, 1960
Mr. M.L. Stahl, 1962
Ms. T.-W. Shu, 1961–1962

Mr. G. Snyder, 1964–1965
Ms. C.M. Cormier, 1965–1967
Mr. R.C. Bopp, 1968–1973
Ms. B.A. Dean, 1972–1973
Mr. B.B. Wunderlich, 1977–1980
Ms. K. Wilson, 1983–1984
Ms. J. Woertman, 1986–1987
Ms. S. Gerdes, 1992–1993
Mr. D. Poland, 1960–1961
Mr. M.H. Kaplan, 1961–1962
Mr. J.M. Rankin Jr., 1964–1965
Mr. L. Melillo, 1966–1967
Mr. C.L. Gruner, 1967–1968
Mr. G. Czornyj, 1969–1970
Ms. C. Wunderlich, 1976
Mr. J. Berninger, 1980–1981
Mr. J. Reffner, 1983–1985
Mr. R. Jones, 1988–1989
Ms. M. Ribeiro, 1996

Appendix A. List of publications

A: Written at the University of Tennessee and Oak Ridge National Laboratory 1988–4/2002

A.1. To be published (19)

R. Androsch, B. Wunderlich, The specific reversible melting of polyethylene, J. Polym. Sci., Part B: Polym. Phys., submitted for publication.

B. Wunderlich, Reversible crystallization and melting in polymers, J. Macromol. Sci., Phys. Ed., in press.

B. Wunderlich, The thermal properties of complex, nanophase-separated macromolecules as revealed by temperature-modulated calorimetry, Thermochim. Acta, in press.

J. Pak, M. Pyda, B. Wunderlich, Rigid amorphous fractions and glass transitions in poly(oxy-2,6-dimethyl-1,4-phenylene), Macromolecules, in press.

A.I. Buzin, E.V. Kosyreva, M. Pyda, B. Wunderlich, New integrated approach to the ATHAS databank of heat capacities of polymers, in preparation.

J. Pak, B. Wunderlich, Reversible melting of gel-spun fiber of polyethylene, J. Polym. Sci., Part B: Polym. Phys., in preparation.

R. Androsch, B. Wunderlich, I. Kolesov, The specific reversibility of crystallization and melting of polymers, J. Polym. Sci., Part B: Polym. Phys., submitted for publication.

M.L. Di Lorenzo, B. Wunderlich, Melting of polymers by non-isothermal, temperature-modulated calorimetry: analysis of various irreversible latent heat contributions to the reversing heat, Thermochim. Acta, submitted for publication.

B. Wunderlich, Reversible crystallization and the rigid amorphous phase in semicrystalline macromolecules, Prog. Polym. Sci. 28/3 (2002) 383–450.

R. Androsch, B. Wunderlich, Heat of fusion of the local equilibrium of melting of isotactic polypropylene, Macromolecules 34 (2001) 8384–8387.

J. Pak, M. Pyda, B. Wunderlich, Temperature-modulated calorimetry of hexacontane and oligomer fractions of poly(oxyethylene) and poly(oxytetramethylene), Thermochim. Acta, in press.

P. Kamasa, M. Pyda, A. Buzin, B. Wunderlich, Frequency dependence of the heat capacity of polystyrene by multi-frequency infrared temperature-modulated DSC in the glass transition region, Thermochim. Acta, in press.

B. Wunderlich, The three reversible crystallization and melting processes of semicrystalline macromolecules, Thermochim. Acta, in press.

P. Myśliński, P. Kamasa, A. Wasik, M. Pyda, B. Wunderlich, Characterization of the ceramic coating of iron with TiN by temperature-modulated thermomagnetometry, thermal dilatometry, and DTA, Thermochim. Acta 392/393 (2002) 187–193.

B. Wunderlich, The solid state of semicrystalline macromolecules, the first nanophase material for industry—temperature-modulated calorimetry, the first experimental method to study the phase-behavior of polymeric nanophases, in: Proceedings of the 10th International Symposium on Polymer, Werkstoffe, Halle, Germany, 25–27 September 2002, pp. 15–22.

P. Kamasa, M. Merzlyakov, M. Pyda, J. Pak, C. Schick, B. Wunderlich, Multi-frequency heat capacity measured with different types of TMDSCs, Thermochim. Acta 392/393 (2002) 195–207.

B. Wunderlich, Thermophysics of Polymers. II. Experiments, Springer, Berlin, in preparation (for vol. I, Theory, see H. Baur, Springer, Berlin, 1999).

M. Pyda, B. Wunderlich, Melting using temperature-modulated calorimetry, analyzed by high-speed infrared thermometry, J. Therm. Anal. Calorim., in preparation.

B. Wunderlich, The application of MTDSC to polymer melting, in: M. Reading (Ed.), Basic Theory and Practice for Modulated Temperature Differential Scanning Calorimetry (MTDSC), Kluwer Academic Publishers, Dordrecht, The Netherlands, in press.

A.2. 2002 Publications (11)

B. Wunderlich, Reversible crystallization and melting in polymers, in: Proceedings of the International Symposium on Polymer Crystallization, Mishima, Japan, 9–12 June 2002, pp. 74–77.

M. Pyda, A. Buzin, R.C. Bopp, B. Wunderlich, Morphology of poly(lactic acid) by AFM and calorimetry, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 30th NATAS Conference, vol. 30, Pittsburgh, PA, 24–26 September 2002, pp. 463–468.

J. Pak, M. Pyda, B. Wunderlich, Rigid amorphous fraction in poly(phenylene oxide) detected by temperature-modulated calorimetry, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 30th NATAS Conference, vol. 30, Pittsburgh, PA, 24–26 September 2002, pp. 345–350.

J. Pak, B. Wunderlich, Reversible melting of polyethylene extended-chain crystals detected by temperature-modulated calorimetry, J. Polym. Sci., Part B: Polym. Phys. 40 (2002) 2219–2227.

A.I. Buzin, M. Pyda, K. Matyjaszewski, B. Wunderlich, Calorimetric study of block-copolymers of poly(*n*-butyl acrylate) and gradient poly(*n*-butyl acrylate-co-methyl methacrylate), Polymer 43 (2002) 5563–5569.

R. Androsch, B. Wunderlich, T. Lüpke, A. Wutzler, The influence of deformation on irreversible and reversible crystallization of poly(ethylene-co-1-octene), J. Polym. Sci., Part B: Polym. Phys. 40 (2002) 1223–1235.

M. Pyda, B. Wunderlich, Analysis of the residual entropy of amorphous polyethylene at zero Kelvin, J. Polym. Sci., Part B: Polym. Phys. 40 (2002) 1245–1253.

M. Pyda, Conformational heat capacity of interacting systems of polymer and water, Macromolecules 35 (2002) 4009–4016.

P. Kamasa, A. Buzin, M. Pyda, B. Wunderlich, The use of infra-red light-modulated temperature in DSC by application of pulse-width modulation, Thermochim. Acta 381 (2002) 139–146.

A.I. Buzin, P. Kamasa, M. Pyda, B. Wunderlich, Application of Wollaston wire probe for quantitative thermal analysis, Thermochim. Acta 381 (2002) 9–18.

B. Wunderlich, Heat capacity of polymers, in: S.Z.-D. Cheng (Ed.), Handbook of Thermal Analysis and Calorimetry. III, Elsevier, Amsterdam, in press.

A.3. 2001 Publications (20)

M. Pyda, B. Wunderlich, Quantitative thermal analysis of biomaterial-water systems, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 76–81.

J. Pak, M. Pyda, B. Wunderlich, Critical chain length for the growth of crystals of oligomers of oxyethylene and oxytetramethylene without supercooling. A study with temperature-modulated calorimetry, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 329–334.

W. Hu, A. Buzin, J.-S. Lin, B. Wunderlich, Annealing behavior of gel-spun fibers of polyethylene, J. Polym. Sci., Part B: Polym. Phys., in press.

P. Kamasa, M. Pyda, A. Buzin, B. Wunderlich, Frequency dependence of the heat capacity of polystyrene by multi-frequency infrared temperature-modulated DSC in the glass transition region, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 600–604.

P. Kamasa, A. Buzin, M. Pyda, B. Wunderlich, The use of infra-red light-modulated temperature in DSC by application of pulse-width modulation, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 323–328.

A.I. Buzin, P. Kamasa, M. Pyda, B. Wunderlich, Application of Wollaston wire probes for quantitative thermal analysis, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 649–654.

B. Wunderlich, The three reversible crystallization and melting processes of semicrystalline macromolecules, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 32–37.

R. Androsch, B. Wunderlich, Reversible crystallization and melting at the lateral surface of isotactic polypropylene crystals, Macromolecules 34 (2001) 5950–5960.

W. Hu, B. Wunderlich, Data analysis without Fourier transformation for sawtooth-type temperature-modulated DSC, J. Therm. Anal. Calorim. 66 (2001) 677–697.

B. Wunderlich, W. Hu, Temperature-modulation with standard DSC, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 594–599.

M.L. Di Lorenzo, M. Pyda, B. Wunderlich, Reversible melting in nanophase-separated poly(oligoamide-*alt*-oligoether)s and its dependence on sequence length, crystal perfection, and molecular mobility, J. Polym. Sci., Part B: Polym. Phys. 39 (2001) 2969–2981.

M.L. Di Lorenzo, M. Pyda, B. Wunderlich, Reversible melting in nanophase-separated poly(oligomer amide-block-oligomer ether)s probed by temperature-modulated calorimetry, in: K.J. Kociba, B.J. Kociba (Eds.), Proceedings of the 29th NATAS Conference, vol. 29, St. Louis, MO, 24–26 September 2001, pp. 132–137.

J. Pak, B. Wunderlich, Melting and crystallization of polyethylene of different molar mass by calorimetry, Macromolecules 34 (2001) 4492–4503.

M. Pyda, M.L. Di Lorenzo, J. Pak, P. Kamasa, A. Buzin, J. Grebowicz, B. Wunderlich, Reversible and irreversible heat capacity of poly[carbonyl-(ethylene-co-propylene)] by temperature-modulated calorimetry, J. Polym. Sci., Part B: Polym. Phys. 39 (2001) 1565–1577.

R. Androsch, B. Wunderlich, Reversibility of melting and crystallization of indium as a function of the heat conduction path, Thermochim. Acta 369 (2001) 67–78.

B. Wunderlich, Temperature-modulated calorimetry of polymers with single and multiple frequencies to determine heat capacities as well as reversible and irreversible transition parameters, in: A.T. Riga, L. Judovits (Eds.), Material Characterization by Dynamic and Modulated Thermal Analytical Techniques, ASTM STP 1402, American Society for Testing and Materials, West Conshohocken, PA, 2001, pp. 3–16.

Y.K. Kwon, R. Androsch, M. Pyda, B. Wunderlich, Multi-frequency sawtooth modulation of a power-compensation differential scanning calorimeter, Thermochim. Acta 367–368 (2001) 203–215.

M. Pyda, Y.K. Kwon, B. Wunderlich, Heat capacity measurement by sawtooth modulated standard heat-flux differential scanning calorimeter with sample-temperature control, Thermochim. Acta 367–368 (2001) 217–227.

J. Pak, B. Wunderlich, Heat capacity by sawtooth modulated, standard heat-flux differential scanning calorimeter with close control of the heater temperature, Thermochim. Acta 367–368 (2001) 229–238.

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A.4. 2000 Publications (24)

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