Crystal Growth Problems Solved by Hans J. Scheel

1958 Chromatographic separation, purification and crystallization of Brazilian Curare alkaloids (for structure determination, product development of Hoffmann La Roche; with Prof. Paul Karrer at Chemical Institute of University of Zurich).

1959 γ – Quinacridone & other organic pigment dyes:
These dyes are stable to about 400°C, not soluble in any solvent, not melting; problem for chemical pigment industry that no crystals could be grown for determination of the structure.
Solution: Long-time sublimation (90 to 200 days) in optimised temperature gradient.
(with H. Koyama, K. Ogawa and F. Laves).
Naturwiss. **53**(1966)700; 701; Z. Krist. **130**(1969)405-419.
(1989 HJS was welcomed by Hoechst/Frankfurt as "Mr. Quinacridone").

1960 – 1964 Secret of Corning-Ware (Pyroceram/Vitroceram-Type Glass):
Simulation with a low-melting model system showed relation of phase separation to nucleation and crystallisation of pyroceram-type glasses, explained Pyroceram Mechanism.(with G. Bayer, O.W. Flörke, W. Hoffmann).
Glastechn. Berichte **39**(1966)242-261.

1964 – 1971 Setting up crystal growth laboratories at ETH Zurich & IBM Zurich Research Laboratory; design of versatile Verneuil furnace for flame-fusion growth.

1968 Size of ferromagnetic $NaCrS_2$ crystals increased 500 times by new Na_2S_x-solvent which then allowed growth of ZnS, CdS, FeS_2, CoS_2, $NaInS_2$, etc.
J. Crystal Growth **24/25**(1974)669-673; patents.

1970 – 1972 Size of GdAlO3 crystals increased 145x by novel stirring technique in sealed crucibles, the Accelerated Crucible Rotation Technique ACRT. This allows to control nucleation, to achieve high stable growth rates (inclusion-free growth), and to solve the striation problem. Forced convection instead of popular reduced convection.
(First Award of Swiss Crystal Growth Association 1972,
Outstanding Contribution Award & Invention Award from IBM;
now ACRT is widely applied in research and in industrial production for YIG, CdTe & III-V solid solutions, Si, $LiNbO_3$). J. Crystal Growth **13/14**(1972)560-565: Selected as a classical paper of crystal growth in the 20th century.
Theoretical analysis of ACRT by E.O. Schulz-DuBois: J. Crystal Growth **12**(1972)81.

1972 The maximum stable growth rate for growth of large inclusion-free crystals from high-temperature solutions derived (with D. Elwell). J. Crystal Growth **12**(1972)153.

1972 – 1976 Invented and developed a slider-free liquid phase epitaxy method (MultiLPE) for multilayers and superlattices and achieved the transition from misoriented macrostep-surface to a facet which was proven by scanning
1980 tunnelling microscopy and by Nomarski differential-interference-contrast
1982 micrographs to be atomically flat and
1995 also theoretically explained.
J. Crystal Growth **42**(1977)301-308; Appl. Phys. Lett. **37**(1980)70-73;
J. Crystal Growth **60**(1982)199-202 (with G. Binnig and H. Rohrer);
J. Crystal Growth **149**(1995)187-195 (with A. Chernov). Patents.

1976 – 1979 Designed a Super- Glovebox with less than 0.03 ppm O_2 and humidity (with P. Dill).
Invited lecture at AACG Workshop on "Purification of Materials for Crystal Growth and Glass Processing", Pajaro Dunes/Watsonville, California May 14-17, 1985.

1976 Flame-fusion (Verneuil) growth of $SrTiO_3$ (with J.G.Bednorz, his master thesis).
J. Crystal Growth **41**(1977)5-12; Ferroelectrics **13**(1976)507-509.

1977 Growth of dislocation-free SrTiO3 from high-temperature solutions (with P.Dill).
Invited at EMF-3 in Zurich Sept. 22-26, 1975;
Ferroelectrics 13(1976) Nos. 1-4, 507-509.

1982 – 1983 & 2001	The "inherent" crystal growth problem of striations theoretically and experimentally solved by forced convection (with D. Rytz, J. Sommerauer, R.H. Swendsen). J. Crystal Growth **59**(1982)468-484; **62**(1983)291-298; **233**(2001) 609-617.
1982 2001	Distribution coefficient k = 1 achieved in crystal growth from high-temperature solutions (with R.H. Swendsen). J. Crystal Growth **233** (2001) 609 - 617.
1985 – 1986	Discovery of Taylor vortices in Czochralski melts from analysis of special dimension-less numbers (with J. Sielawa). Proceedings of the International Sympos. High-Purity Materials (Dresden May 6-10, 1985) 232 - 244.
1987 1988 1989	First "free" crystal of $YBa_2Cu_3O_{7-x}$ and thick YBCO crystals grown. (with F. Licci, W. Sadowski). Invited at First Internatl. Conference on High-Temperature Superconductors and Materials & Mechanisms of Superconductivity Interlaken Feb.28-March 4, 1988 in Physica C **153-155**(1988) 44 - 49, 431 - 432; J. Less-Common Metals **150**(1989)219-217; **151**(1989)199-211; Mat.Res.Bull. **19**(1994)26-32.
1989	Leading-Edge Growth (LEG) mechanism discovered which explains the growth of the majority of thin platelets (with Ph. Niedermann). J. Crystal Growth **94**(1989)281-284.
1992 1993	Liquid Phase Epitaxy of YBCO and "atomically flat" surfaces (with F.-K. Reinhart, H.P. Lang, C. Klemenz, H.-J. Günterodt) at ICCG-10 San Diego Aug. 16-21, 1992 and J. Crystal Growth **129**(1993)421-428; Appl. Phys. Lett. **65**(1994)901-903; Physica C **265**(1996)126-134.
1996	Growth of colourless high - quality anatase (TiO2) crystals by chemical vapour transport (with L. Kavan, M. Graetzel , S.E. Gilbert, C. Klemenz). J. Amer. Chem. Soc. **118**(1996)6716-6723.
1996 2000	Liquid Phase Epitaxy of Gallium Nitride GaN (with C. Klemenz). Electrochem. Soc. Proc. Vol. **96-11** (1996)20-36; at ACCG-11 (1999) and J. Crystal Growth **211**(2000)62-67. H.J. Scheel and D. Elwell "Liquid Phase Epitaxy of Gallium Nitride", Chapter 7 in "Liquid Phase Epitaxy of Electronic, Optical and Optoelectronic Materials", editors P. Capper and M. Mauk, Wiley & Sons 2007, p. 203 - 225.
1997	Control of Epitaxial Growth Modes for High-Performance Devices Definition and interrelation of 8 epitaxial growth modes and their occurrence as function of supersaturation and misfit. Proceedings First Internatl. Symp. on Lasers and Nonlinear Optical Materials (Singapore Nov. 3 - 5, 1997), editor T. Sasaki, Data Storage Institute Singapore 1997, 10-18; H.J. Scheel "Control of Epitaxial Growth Modes for High-Performance Devices", Chapter 28 in "Crystal Growth Technology", editors H.J. Scheel and T. Fukuda, Wiley, Chichester UK 2003, paperback 2004, 623-644; H.J. Scheel "Introduction to Liquid Phase Epitaxy", Chapter 1 in "Liquid Phase Epitaxy of Electronic, Optical and Optoelectronic Devices", editors P. Capper and M. Mauk, Wiley, Chichester UK 2007, 1-19.
1975	Book "Crystal Growth from High - Temperature Solutions" by D. Elwell and H.J. Scheel, Academic Press, London-New York 1975, "reprint" (with Chapter 11 on „Crystal Growth and Liquid Phase Epitaxy of High-Tc Superconductors", Appendix A. „Growth of Striation-free Crystals", Appendix B. „Epitaxy and the Importance of LPE" on the website of HJS).
1972, 1976, 1988 &1995	Patents on Growth of CdS, on MultiLPE, and on Co-Rotating Ring Czochralski Method (CRCZ) for growth of homogeneous crystals from melts and for a nearly convection-free zone (in front of growing crystal) surrounded by a mixed melt.