50 Years of SID Symposia – Nurturing Progress in Liquid Crystal (LC) Technology

1960's

Image Generation
1964 Guest-Host (Heilmeier) mode **RCA**

1966 Dynamic Scattering Mode **RCA**

1968 RCA demonstrates their LCD technologies **RCA**

LC Materials
1967 **RCA** develops room temp, apolar Schiff base mixtures

1967 Demus publishes concept of eutectic mixure formulation

1969 MBBA - 1st room temperature single component LC **Hoechst**

Manufacturing Milestones
Passive-Addressing Milestones
RCA developes CMOS technology

Product Milestones

1970's

Image Generation
1970 Schadt & Helfrich start collaboration on field effects at **Roche** and file Swiss TN patent

1970 Fergason independently conceives TN and files US TN patent later bought by Roche

1971 Vertical alignment LCs **Schiekel & Fahrenschon, Kahn**

1972 Raynes eliminates reverse twist and tilt domains in TN

1972 Berremann uses 4x4 matrix to model LCD configurations **Bell Labs**

1972 1st and 2nd TN minimum understood **Gooch & Tarry**

1973 **Soref** proposed transverse field effect (similar to IPS) LCD

1974 **White-Taylor** cholesteric guest-host display **Bell Labs**

LC Materials
1970 Demus apolar esters

1970 Room temp azoxy compounds **Hoechst**

1971-1973 First commercial alkyl cyano Schiff base and cyano ester TN mixtures **Roche**

1972 Stable biphenyl liquid crystals by Gray, Harrison and Nash

1973 Demus alkyl-alkoxy cyclohexane esters

1974 Commcercial production of biphenyl mixtures (E7, E8 etc) BDH

1975 Meyer discovers ferroelectric LCs

1976 1.5 volt pyrimidine TN mixtures **Roche**

1976 Cyano-phenyl cyclohexanes and their mixtures **Merck**

Manufacturing Milestones
1970-1975
- Hermetic glass frit sealing, SiO alignment, and vacuum fill cell fabrication - High temp. process*
- Rubbed Polyimide (PI) alignment*

1972 Janning develops alignment by oblique evaporation*

1975-1980 PI alignment, epoxy seal, vacuum fill based low temp. batch process (7"-14" mothers glass)

1975
- Low temp. drop fill cell frabrication (thermoplastic gasket, PVA alignment)
- Batch processing*
- Distributed glass fiber spacers*
- Ion barrier layer on soda lime glass*

Passive-Addressing Milestones
1973-1974 Kawakarni and Alt-Pleshko independently develop optimized MUX drive

1975-1976 Low level intrinsic multi-plexing applied in TN products

1979 Nehring & Kmetz publish "Ultimate limits for matrix addressing"

Product Milestones
1973 **Sharp** EL-805 pocket calculator using DSM

1973 **Brown Boveri** makes first commercial TN displays (Casio watches)

1973-1980 TN LCDs were introduced in clocks, calculators and numerous other applications

1975 Hughes develops LC Light valves

1980's

Image Generation
1980 Kmetz proposed single polarizer TN display **Bell Labs**

1980 Surface Stabilized Ferroelectric LCD **Clark & Lagerwell**

1981 Berreman-Heffner 360 bistable cell **Bell Labs**

1982 Waters and Raynes Super-twisted guest-host mode **RSRE**

1983 **Brown Boveri** develops STN display

1984 Bos proposed pi-cell **Tektronix**

1987 **Seiko-Epson** develops DSTN

1988 Stretched retarder film compensated STN developed **Sharp & Seiko-Epson**

LC Materials
1980 Alkenyl LCs enabling large STN mux ratios and short TFT response **Roche**

1980s Fluorinated, TFT-TN compatible LCs **Merck, Chisso**

Manufacturing Milestones
1985 "Touched polished" no alkali flat glass **Corning**

1985 Pixilated color filters for color displays

1987 Mechanically stretched optical retarder films **Nitto Denko**

Passive-Addressing Milestones
1988 Ruckmongathan publishes IHAT technique

Product Milestones
1983 Monochrome TN panel used in Data General portable computer

1988 Monochrome STN panel for computer notebooks

1990's

Image Generation
1991 Yang demostrates multidomain TN **IBM**

1992 Baur et al present IPS mode

1993 Cholesteric bistable reflective display **KSU/KDI**

1993 Uchida proposed OCB mode **Tohoku University**

1993 Lien demonstrated multi-domain homeotrophic (VA) LCD **IBM**

1995 **Hitachi** presents IPS display

1995 Single-polarizer reflective modes for low power and LCOS **Hughes & Sharp**

1996 Wu proposed MTN mode LCD **Hughes**

1996 E-ink Displays

1997 MVA mode LCDs **Fujitsu**

1998 Lee develops FFS LCDs **Hydis**

LC Materials
1990 Difluoro substituted materials with large negative dielectric anisotropy **Merck**

1990-2000 Many types of LC mixtures got perfected for TFT applications **Merck, Chisso**

Manufacturing Milestones
1990-2000 LC materials, processes and equipment for large area AM LCD manufacturing got perfected.

1991 Gibbons et al publish LC photo-alignment

1992 Schadt et al. develop stable optical alignment and its patterning by LPP.

1995-2000 LC photo-alignment

1995 BEF & DBEF multi-layer brightness enhancement films **3Mv**

1997 **FujiFilm** develops discotic wide view film for TFT-TN displays

1998 **Samsung** manufactures PVA LCDs

1995-2005 LC mother glass sizes kept on increasing significantly (Gen. 3-8)

Passive-Addressing Milestones
1991 MLA/MLS addressing independently **InFocus/Asahi Glass**

1990 "Frame response" found by **Citizen Watch Co.**

Product Milestones
1992 "Dual scan" color STN panels (notebook computers)

1993 **Kent Display Ind.** commercializes ChLCDs

1990 Stacked STN panels used in subtractive color mode LCD projector color

1992-1995 AMLOCDs introduced in Notebook and Desktop computers.

1996-2006 Various types of LCDs (TN, IPS, MVA, OCB & Blue Phase) introduced in TVs, mobile phones and many other applications

2000-2012

Image Generation
2002 Polymer-stabilized blue-phase LC Concept **Kikuchi**

2008 Polymer-stabilized blue-phase LCD **Samsung**

Manufacturing Milestones
2001 LC (one) drop filling and cell mating in vacuum for large size LCDs

2009 Sharp's Generation 10 plant using photo-alignment

Product Milestones
2001 LCDs start gaining significant TV market from CRTs.

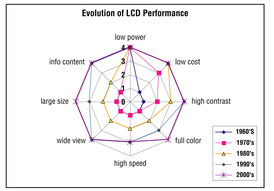
2002 CSTN cell phone displays with single-chip MLS drivers introduced

2004 LCD becomes the largest display techology

2007-2010 3D LCD TVs

2010 LCDs constitute > 85% of all the display sales. CRTs are almost extinct.

LCD performance improvements created new display markets



Note: In 2006, with the high speed achieved,we have a near perfect display!

SID Award Recipients for Liquid Crystal (LC) Technology

Fellow of the SID

Koichi Miyaji	1977
Peter Pleshko	1978
Frederic J. Kahn	1981
Lawrence Tannas, Jr.	1983
Werner E. Haas	1984
P. Andrew Penz	1984
Cornelius J. Gerritsma	1985
Allan R. Kmetz	1985
Paul M. Att	1986
Tomio Wada	1986
Shunsuke Kobayashi	1987
Dwight W. Berreman	1988
Martin Schadt	1992
E. Peter Raynes	1994
Tatsuo Uchida	1994
Hideaki Kawakami	1996
Günter Baur	1997
James L. Fergason	1997
Shoichi Matsumoto	1999
Terry J. Scheffer	1999
William Doane	2000
Eiji Kaneko	2000
Shin-Tson Wu	2001
Kei-Hsiung Yang	2001
Philip J. Bos	2002
Shohei Naemura	2002
Katsumi Kondo	2004
Anthony Lowe	2004
Masataka Matsuura	2004
Adi Abileah	2005
Gregory Crawford	2005
Hoi-Sing Kwok	2005
Paul Drzaic	2005
Deng-Ke Yang	2007
Kenji Okamoto	2007
Vladimimir Chigrinov	2008
Seung Hee Lee	2008
Sung Tae Shin	2011
Hiap L. Ong	2012

Special Recognition

George H. Heilmeier	1975
C. J. Gerritsma	1978
Paul M. Att	1980
Dwight W. Berreman	1987
Eiji Kaneko	1987
Jürgen Nehring	1987
E. Peter Raynes	1987
Martin Schadt	1987
Akio Sasaki	1988
Terry J. Scheffer	1987
Noel A. Clark	1989
Sven T. Lagerwall	1989
Karel Kuijk	1992
Birendra Bahadur	1993
Tatsuo Uchida	1994
Satoshi Okazaki	1995
Georg Weber	1997
Bernhard Scheuble	1997
Rudolph Kiefer	1998
Katsumi Kondo	1998
Joseph A. Castellano	2000
Shohei Naemura	2000
Shin-Tson Wu	2001
Haruhiko Okumura	2004
Hiap Ong	2005
Deng-Ke Yang	2005
Alex Henzen	2007
Sang Soo Kim	2007
Hiroyuki Mori	2008
Hirotsugu Kikuchi	2009
T.N. Ruckmongathan	2009
Michio Kitamura	2010
Hyun Chul Choi	2011
Takahiro Ishinabe	2011
Kyeong Hyeon Kim	2011
Hyang Yul Kim	2012
Seung Hee Lee	2012
Seok-Lyul Lee	2012

Frances Rice Darne Memorial Award
James L. Fergason

Karl Ferdinand Braun Prize
George W. Gray 1906
Martin Schadt 1992
Richard Williams 2008
Frederic J. Kahn 2010
Rudolf Eidenschink 2011

Jan Rajchman Prize
Terry J. Scheffer 1993
William Doane 1998
Shunsuke Kobayashi 1995
Tatsuo Uchida 2004
Shin Tson Wu 2008
E. Peter Raynes 2009
Dwight Berreman 2010

Slottow-Owaki Prize
William Donae 2007
Tatsuo Uchida 2008
Philip J. Bos 2010
Shin-Tson Wu 2011

Contributors to initially generating (2003) and in 2010/12 revising/updating this Milestone Technology Chart

2003 - **Allan Kmetz (architect)** and others gratefully acknowledged
2010/12 Revision - **Birendra Bahadur (chair)**, Allan Kmetz, Martin Schadt, Shin-Tson Wu