

SECOND INTERNATIONAL CONFERENCE ON CRYSTAL GROWTH
Birmingham, England, July 14-19, 1968

As is by now well known, the First International Conference on Crystal Growth was held in Boston during the summer of 1966. At that time it was decided that a Second Conference was appropriate and England was chosen as the venue. Under the aegis of an able British Organizing Committee, Co-chaired by W. Bardsley of the Royal Radar Establishment, Malvern, and A. D. McQuillan, of the University of Birmingham, the Second Conference took place at the University of Birmingham, July 14-19, 1969. Following a plenary lecture on "The crystals we need" by Professor K. Hoeselitz, Director of Physics of Mullard Research Laboratories, the Conference was divided into two and at times three parallel sessions devoted to

- 1) Vapor growth
- 2) Melt growth
- 3) Flux growth
- 4) Hydrothermal and high pressure growth
- 5) Electrocrystallization and gel growth
- 6) Nucleation and equilibrium
- 7) Morphological stability
- 8) Nonmetallic solution growth
- 9) Eutectics
- 10) Dendritic growth
- 11) Segregation and convection
- 12) Polymers and organics
- 13) New technologies
- 14) Assessment and polytypes
- 15) Growth from metal solutions
- 16) Ternary semiconducting compounds.

Review papers were presented at the beginning of each session. For these lectures, two of the lecture halls were linked by closed-circuit televisions. At the end of the review papers, the conference continued with separate sessions in two or three lecture rooms. The conference committees are to be congratulated for having many of the review papers presented by young workers in the field. The review papers set the stage well for the subsequent papers in each session. Review papers were presented by:

- J. H. E. Jeffes, "The physical chemistry of transport processes"
- R. Roy and W. B. White, "High temperature solution (flux) and high pressure solution (hydrothermal) crystal growth"
- B. A. Joyce, "Growth and perfection of chemically deposited epitaxial layers"
- B. Cockayne, "Developments in melt-grown oxide crystals"
- R. F. Sekerka, "Morphological stability"
- J. D. Hunt, "Developments in eutectics"
- D. C. Bassett, "The growth of polymer crystals"
- N. P. Luzhnaya, "Growth from metal solution".

Obviously no two people could give adequate coverage to the more than 200 papers presented (total attendance exceeded 500) so that what follows can be little more than a sampling biased to some extent by our predilections and research interests. Most of the papers, presented will appear in a special issue of the "Journal of Crystal Growth" to be published this winter.

We will first discuss techniques of crystal growth and the growth of specific materials. Perhaps the most interesting trend here is the continual push to extend melt growth to materials with higher and higher vapor pressures. J. B. Mullin and co-workers at Royal Radar (U.K.); S. J. Bass and P. E. Oliver at Services Electronic Research Laboratories (U.K.); and G. S. Meiling and R. Leombruno of Ion Physics and Corning Glass (U.S.A.), among others, presented papers on liquid encapsulation techniques. Among the materials grown, GaAs, GaP, InAs, InP and ZnTe were reported. The most common liquid encapsulant is 0203 and systems capable of routinely containing 40-50 bar inert gas pressure were regularly in use. Both A. D. Little (as reported by J. F. Wenckus and P. R. Doherty (U.S.A.)) and licensees of Royal Radar (who showed equipment in the meeting exhibition area) have pressure pulling equipment commercially available which; in some cases extends to the 200 bar range.

ICCG-2 Birmingham, 1968

The second trend observable in the technique related papers was the beginning of a wedding (or perhaps it would be more accurate to say a cautious courtship) of theory and practice. This trend was epitomized by B. Cockayne's (Royal Radar) paper on developments in Li_2O crystal growth and D. T. J. Hurle et al. (Royal Radar) on "Striated solute distributions produced by temperature oscillations during crystal growth from the melt. It appears now that the fluid dynamicists really do have something to teach the, practical crystal growers, especially the laser and nonlinear optical crystal growers plagued by optical inhomogeneities in their crystals.

An additional theme which reoccurred in a number of papers and which should emerge as of ever increasing importance in the future is, the necessity of accurate knowledge and control of stoichiometry in crystals. Here, P. Lerner et al. of CGE, Marcoussis, France, had interesting results to report on LiNbO_3 which to the surprise of some has been shown, not to have its maximum in melting point at 50 mole % Li_2O in the melt and whose liquidus-solidus curves have at last been determined. Stoichiometry control by the control of the partial pressure of vapor species was emphasized in three papers on CdS growth by P. D. Fochs et al. of A.E.I., Rugby (U.K.); L. Clark and J. Woods of Univ. of Durham (U.K.); and L. Hildisch of Physico-Technical Institute (Berlin).

One of the highlights of the Conference was the Cine Film Session at which R. Kaishev (Institute of Physical Chemistry, Bulgaria) presented his outstanding movie on electrolytic growth. Dislocation-free silver can be grown in capillary tubes under appropriate conditions. Dislocations, if present, can be revealed using a current pulse which produces a pit or hillock depending on the sign of the pulse. When the crystal surface is perfect, new layers can be initiated by an appropriate pulse and conditions can be adjusted so that a single monolayer is triggered by each pulse.

R. F. Strickland-Constable (Imperial College, London) showed a movie of salol growing in a capillary. The salol slows down as it grows along the capillary and there is strong evidence (presented later in a paper with D. Kirtisinghe and P. J. Morris) to show that this is because dislocations are growing out of the salol. When the salol reached the end of the capillary it suddenly grew very rapidly as though it had picked up many defects right at the end of the tube.

H. E. C. Powers (London) showed a spectacular movie of crystal growth in sugar and other materials.

In a paper entitled "On the equilibrium form of pure-metal single crystals", M. Dreschler and A. Müller (Fritz-Haber Institute, Berlin) showed that the observed shape of field emitter crystals in the field-ion microscope could be explained quite well using the Mie potential, but not using a Morse potential or bondcounting. At the same session, on nucleation and equilibrium morphology, R. L. Schwoebel (Sandia Laboratory, U.S.A.) presented an analysis of step motion during vapor growth.

In the session on dendritic growth, G. R. Kotler (Ford, U.S.A.) and L. A. Tarshis (G. E., U.S.A.) applied the Temkin analysis of dendritic growth to ice, and found good agreement with experiment. R. O. Ramseier (Cold-Regions Research and Engineering Laboratory, U.S.A.) discussed the preferred orientation found in columnar ice. W. B. Hillig (G. E., U.S.A.) presented an analysis of the edgewise growth of a platelet.

The role of constitutional supercooling during vapor growth was emphasized by T. B. Reed et al. of M.I.T. who have evidence for diffusion boundary layers as wide as 1 cm under conditions which are probably in practical use by vapor growers. J. H. E. Jeffes of Imperial College, London, reported on his interesting extensions and modifications of Schäfer's criteria for useful vapor transport reactions.

There were several theoretical papers on interface stability. Significant contributions were made by D. E. Coates and J. S. Kirkaldy (McMaster Univ., Canada) who discussed stability in ternary systems; by R. T. Delves who discussed stability stirred melts; by D. T. J. Hurle and E. Jakeman (Royal Radar, U.K.) who discussed stability in lamellar eutectics; and by S. O'Hara, L. A. Tarshis et al. (Stanford Univ. and G. E., U.S.A.) who discussed stability in semitransparent materials. Of special note was the paper by S. C. Hardy and S.R. Coriell (Bureau of Standards, U.S.A.) who compared measurements of the breakdown of a cylinder of ice in undercooled water with stability theory. These are very pretty experiments indeed, and they provide direct experimental confirmation of stability theory.

Some interesting eutectic morphologies were discussed in the papers on eutectics although much of the recent work on eutectics was not presented at this Conference, because it had been presented at the recent conference at Brighton.

In the hydrothermal sessions, V. A. Kuznetsov's (Institute of Crystallography, Moscow) report of the use of NH_4F as a transport reagent for TiO_2 , ZrO_2 and HfO_2 and A. A. Chernov's (Institute of Crystallography, Moscow)

ICCG-2 Birmingham, 1968

correlation of the growth rate of inclusion free quartz with the competition between step velocity and the desorption rate of adsorbed material were of particular interest.

In the flux growth sessions, R. C. Linares (Perkin-Elmer, Norwalk, U.S.A.) gave results which indicate that epitaxial films of garnet may be capable of preparation by tipping processes analogous to those used for semiconductors: This work has the potential, of extending flux growth to the preparation of layers of controlled composition. M. Kestigian and W. W. Holloway (Sperry Rand, Sudbury, Mass., U.S.A.) in a flux growth paper on substituted yttrium aluminum garnet introduced the concept of size compensation. They postulate that for instance substituents with poor lattice fits because their atomic radius is too large may be included with respectable distribution constants if they, are "size compensated" by the simultaneous substitution of impurities whose atomic size is smaller than the lattice size.

A L. Gentile and O. M. Staffsudd (Hughes and Univ. of Cal., U.S.A.) reported on the pulling of proustite by a method which may have considerable utility for other materials with high vapor pressure. Pulling took place through the annulus of a floating ring on the melt surface which repressed volatilization.

Perhaps the only disappointment with the meeting was the paucity of reports on new materials. It is our view that crystal growers are the prime well of new electronic materials and the health of a large number of related fields and technologies depends upon their not forgetting this. The English Organizing Committee is to be complimented on the facilities, arrangements and social amenities of the meeting and commiserations are in order for the weather.

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