Ajit Ram Verma (1921–2009)

Ajit Ram Verma an eminent scientist, teacher par excellence and an able administrator died on 4 March 2009.

Verma was an outstanding scientist with a deep knowledge of the fundamentals. He would only pick up problems with strong impact on the understanding of physical phenomenon. As a teacher he was endowed with an extraordinary quality of communicating difficult concepts in an understandable, simple language. He made valuable contributions in school education as well as higher education. He had inspired three generations of researchers in the three schools established by him, as well as scientists in general in national laboratories and academic centres. Verma was a person with a deep spiritual base. His humility and understanding of human nature and treating even the junior-most colleagues with respect and dignity endeared him to all. His administrative capability was of immense value to the growth of the National Physical Laboratory (NPL), New Delhi as an internationally reputed centre. His experience and wise counsel benefitted the numerous national organizations, institutions and universities with which Verma had been associated as chairperson or member of the governing or advisory bodies.

Verma was born on 20 September 1921 at Dalmau near Lucknow. His father Hans Raj Verma was a Railway official and his mother Devi Rani was a pious lady whose nature had left a lifelong influence on him. After early education at several places, including Allahabad and Meerut, Verma enrolled in Allahabad University and passed his B Sc (1940) and M Sc (1942, gold medalist) from there. Even though he was a topper in M Sc (Physics), Verma opted to pursue a career in research rather than the administrative services. After a short period as a research scholar at Allahabad, he was appointed as Lecturer in Physics at University of Delhi in 1947. During 1950–55, Verma worked at the University of London and made well-known contributions on the observation and study of unimolecular growth spirals on the surfaces of silicon carbide crystals. He was awarded a Ph D in 1952 and D Sc in 1969 (University of London). After serving as a Reader in Physics for four years (1955–59) at the University of Delhi, Verma moved to Banaras Hindu University (BHU), Varanasi as Professor and Head of the Department of Physics in 1959. In 1965, he was appointed as Director, NPL, a post he served till 1982. Thereafter, for three years, Verma served as Visiting Professor, IIT Delhi and as a Jawaharlal Nehru Fellow. Later, he was Emeritus Scientist of CSIR and INSA Senior Scientist at NPL.

Verma established three active schools of research in crystallography, one each at the University of Delhi, BHU, and NPL. In 1951, using phase contrast microscopy, the first unequivocal experimental evidence in support of screw dislocation theory of crystal growth of millimetric sizes was provided by Verma. He used phase contrast microscopy to study the crystal surfaces of SiC and photographed these 'nearly invisible' molecular growth spirals. Using multiple-beam interferometric technique, these molecular growth spirals were shown to be growth hills. The step height for 6H, SiC crystal was measured to be 15 ± 1 Å, which still stands in the scientific literature. The lattice c-parameter for type 6H SiC as measured by X-rays is 15.079 Å, which shows that the measured step-height is equal to the relevant unit cell dimension. Hence, these spirals were shown to be unimolecular growth spirals originating from screw dislocations. Further, the shapes of these spirals were shown to be completely in accordance with the theory. This work showed the power of phase contrast microscopy and Zernicke, who had developed this technique nearly twenty years before these studies, was awarded the Nobel Prize in Physics in 1953. The Nobel Presentation speech by E. Hulthen states: 'Zernicke's phase plate serves as an indicator, which locates and measures small surface irregularities to a fraction of light wavelength. This sharpness is so great that it penetrates to the point at which atomic structure of substances begins to become manifest'.

The correlation of the step-heights of growth spirals with the dimensions of X-ray unit cell had helped in explaining the phenomenon of polytypism by the screw dislocation theory propounded by F. C. Frank. Verma had also made valuable contributions in the pioneering work on direct measurement of metric thicknesses of Blodgett–Langmuir molecular films. At NPL, in collaboration with Krishan Lal, Verma made several original contributions in the field of crystal growth and study of lattice imperfections.

As Director, NPL from 1964 to 1982, Verma's efforts were focused on bringing Indian National Standards of Physical Measurement to international level. Also, in place of artefact standards, work on quantum standards was undertaken. Verma laid the foundation of several new areas at NPL. These include: quantum metrology; materials science, including work on electronic materials like silicon and advanced materials like carbon fibres; high pressure and high temperature synthesis of materials; phosphorus and piezoelectric materials, and consolidation of advanced materials characterization activities. Under his leadership, NPL made strong impact at the national and international level. Further, in collaboration with Krishan Lal, Verma worked on the growth of crystals and study of lattice imperfections. Some of the important results are summarized in the following.

(a) Investigation of growth and lattice imperfections in vapour-grown whisker crystals:

In the 1960s, growth of whisker crystals was an outstanding problem. The observed rates of growth of whiskers from vapour phase at low super saturations were found to be several orders of magnitude faster than theoretically expected rates on the basis of layer-by-layer growth mechanism. Also, the mechanical strengths of whisker crystals were close to the theoretically expected limits, which was not the case in most of the other materials. The growth of the whiskers was thought to be either on the basis of the screw dislocation theory or the vapour liquid solids (VLS) mechanism. At NPL, a number of whiskers of cadmium, copper, silver, etc. were prepared from the vapour phase and investigated using a high-resolution X-ray Laue technique. This technique was considerably developed at NPL and through a rigorous analysis it was shown that there was no tilt of equatorial Laue spots indicating the absence of axial screw dislocations. It may be mentioned, Webb and co-workers had claimed to have observed tilts of equatorial Laue spots in the case of α-Al_2O_3 whiskers.

(b) Establishing X-ray diffraction topography facilities and their applications in studies related to defects in crystals:

In 1970, it was decided by NPL to establish an X-ray diffraction topography system and within a year, an indigenously developed X-ray diffraction topography system similar to a Lang camera started functioning. This was first employed to investigate whisker crystals. These experiments also demonstrated the absence of axial screw dislocations in vapour-grown whisker crystals. This system has been used for investigation of dislocations and other defects in α-Al_2O_3 single crystals grown by different techniques and several other crystals, including garnets and semiconductors.

(c) High-resolution diffuse X-ray scattering studies on understanding the origin of diffuse X-ray scattering and its application in the study of crystal defects:

A high-resolution three-crystal X-ray diffractometer was designed, fabricated and established at NPL to investigate diffuse X-ray scattering from nearly perfect single crystals close to reciprocal lattice points. For the first time, diffuse X-ray scattering measurements were made around diffraction peaks having half width of only ~5 arc sec with silicon single crystals. Detailed investigations made on crystals having different Debye temperatures as well as measurements made at different temperatures clearly established that at and near room temperature diffuse scattering was primarily due to defects and not due to thermal vibrations of the lattice, as was an established concept till then. This technique was used to investigate point defects and their clusters in a number of crystals, including silicon and alkali halides and is now one of the well-established techniques for this purpose. In recent times, it is widely employed as reciprocal lattice mapping.

(d) High-resolution X-ray diffraction investigations of natural diamond crystals:

Using the high-resolution X-ray diffraction techniques developed at NPL, it has been possible to directly observe and record a forward diffracted beam in the case of diamond crystals even when these were 'thin' ($\mu t << 1$). The degree of perfection of some of these crystals was rather low as shown by broad diffraction curves. According to conventional dynamical diffraction theory, a forward diffracted beam is expected only when the crystals are perfect and thick ($\mu t \geq 10$). Further, it has been possible to demonstrate that there is a loss in absorption at and around the diffraction maxima in Laue geometry in the case of these 'thin' diamond crystals having varying degrees of perfection.

(e) Investigation of zeroth-order diffraction maxima in single crystals:

Zeroth-order diffraction in single crystals promises to reveal new and interesting phenomenon. This was one of the problems in which Verma was deeply interested during the last phase of his life.

Verma had authored six books, published more than 100 research papers in refereed journals and contributed numerous invited papers and book chapters. His two books on crystal growth have been translated into Russia.

Verma was the recipient of several honours and awards. Notable among these are: British Council Scholar (University of London), 1950–52; I.C.I. Fellowship (University of London), 1952–1955; Fellow, the Indian Academy of Sciences, Bangalore, National Academy of Sciences, Allahabad, and Indian National Science Academy, New Delhi; Member, Board of Editors – *Solid State Communication*, Pergamon Press (Charter Member since inception, retired in 1990); Elected member of International Committeee on Weights and Measures, Paris, 1966–82; Formerly Member of Commission on Symbols, Units and Nomenclature of International Union of Pure & Applied Physics; Shanti Swarup Bhatnagar Prize in Physics, 1964; Padma Bhushan, 1982, and Atma Ram Puraskar in Hindi by Kendriya Sansthan Agra, 1984.

Verma was a person with many extraordinary qualities. He established strong human bonds with people. Spiritually, he was strongly influenced by the teachings of the *Geeta*, *Upanishads* and Sant Kabir.

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