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INVITED: RECENT ADVANCES IN OPTOELECTRONIC DISPLAYS AND MATERIALS

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Electronic systems containing solid state light emitting display elements are now making a sizeable impact on the public at large. Important embodiments already exist in scientific instrumentation of all types, ranging from NIM systems, through magnetometers, lock-in amplifiers to pressure gauges in advertisements in the recent 25th Anniversary issue of Physics Today. It is clear that most scientific measuring instruments will be given digital readouts in the near future. The display form already established for these instruments, involving simple indicator lamps and a few digits, < 10 with character height between a few mm and a couple of cm, involves adaptation of the solid state light emitting diode (LED). Light emitting diodes are already impinging on a much wider consumer group, at the moment mainly as the display element in electronic calculators covering an appreciable range of computational sophistication, size and cost. It is now certain that solid state displays represent a major growth area for the electronics and lamp industries in the next few years. Unfortunately, commercial competition is already so intense that it is becoming difficult for further device development to occur in a scientifically natural manner.

Marketable LED devices have emerged in the early 1970s as the fruit of major research and development programmes, mainly from the 1960s, on 'optoelectronics' in the sense of radiative and competing non-radiative recombination processes in semiconductors. Much of the work was performed on the Group IV (elemental and compound-SiC) and, particularly on the III-V compound semiconductors and their alloys, although the II-VI compound semiconductors and their alloys received appreciable attention in a number of major centres. Most of the present commercial LEDs are made from Ga(AsP) or GaP, although hybrid devices involving a GaAs infra-red emitting LED and a so-called 'upconverting' or 'double photon' phosphor are also marketed on a pilot scale. Commercial interest in these III-V based LEDs has had a dual effect on research on II-VI semiconductor lamps. Some laboratories have largely abandoned their earlier interest in favour of III-V devices, while others, some of which previously had a mainly academic interest in II-VI semiconductors, have intensified their efforts to produce practical II-VI LEDs.

The present talk is restricted to a discussion of active, ie light emitting devices, with no coverage of the many forms of passive, ie light subtractive, scattering or reflective optical display, including liquid crystals. The passive displays, though generally less well developed at present, ultimately may prove particularly suitable for certain situations, for example in high light ambients and also in small battery powered equipment. The field can be divided into the small scale/complexity devices already cited and large area displays, perhaps > 1000 cm^2. Problems connected with current technical performance limitations of displays falling into these two categories will be stressed, rather than problems of economic large scale production, where more direct contact than this author possesses is required to establish competent opinions. At small sizes, existing LEDs lack colour coverage in the blue-green and, perhaps rather less urgently, require greater efficiency over the available colour range, particularly in the yellow-green. Recent research developments of GaN, ZnS LEDs and upconverter phosphors for blue light will be discussed, as well as N-doped Ga(AsP) and (GaIn)P for the yellow-orange, a topic to be covered later in detail by N Holonyak. It is clear from recent work that further significant improvements in red and, particularly green-yellow GaP lamps will be obtained only from better general control of the background impurities which usually dominate the minority carrier recombination. The same is probably true for Ga(AsP) direct gap LEDs. In this context, very recent work on the identification of residual shallow donors and acceptors in refined GaAs through low temperature optical spectroscopy is significant. Particularly relevant are the deeper levels which can provide unwanted carrier recombination at $300^{\circ}K$. Techniques for identifying these levels will be reviewed briefly. Recent developments in large area, matrix-addressed panels designed to exhibit > 30 alpha-numeric characters in variable format will be discussed. Solid state embodiments will be emphasised, particularly ZnS:Mn d.c. electroluminescence, rather than the plasma discharge variety.