Preface

Over the last forty years, plasma supported processes have attracted ever increasing interest, and now, all modern semiconductor devices undergo at least one plasma-involved processing step, starting from surface cleaning via coating to etching. In total, the range of the treated substrates covers some orders of magnitude: Trenches and linewidths of commercially available devices have already passed the boundary of 100 nm, decorative surface treatment will happen in the mm^2 range, and the upper limit is reached with surface protecting layers of windows which are coated with $\lambda/4$ layers against IR radiation.

The rapid development of the semiconductor industry is inconceivable without the giant progress in the plasma technology. MOORE's law is not carved into stone, and not only the ITRS map[1] is subject to change every five years but also new branches develop and others mingle together.

Moreover, the quality of conventional materials can be improved by plasma treatment: Cotton becomes more crease-resistant, leather more durable, and the shrinking of wool fibers during the washing process can be significantly reduced.

To cut a long story short: More than 150 years after the discovery of the sputtering effect by GROVE, plasma-based processes are about to spread out into new fields of research and application [1]—no wonder that the market for etching machines kept growing by an annual rate of 17 % up to the burst of the internet bubble, and it took only some years of recovery to continue the voyage [2].

To realize a multi-color flat panel display measuring 16 square feet, a total of 300 000 LEDs is required. 1994, just in front of the launching of the blue LED, the fraction of LEDs (which effectively emit in the visible range) amounted to about $^1/_3$ of the total compound semiconductor market of $4.4 billion. Four years later, the fraction of so-called high-brightness LEDs had been grown by 64 % (total market 1997: $7.1 billion), and the number of substrates which were subject to epitaxial processes to produce LEDs had been increased by almost 300 % (Fig. 1). This was conservatively updated to an estimated amount of

[1] **I**nternational **T**echnological **R**oadmap for **S**emiconductors

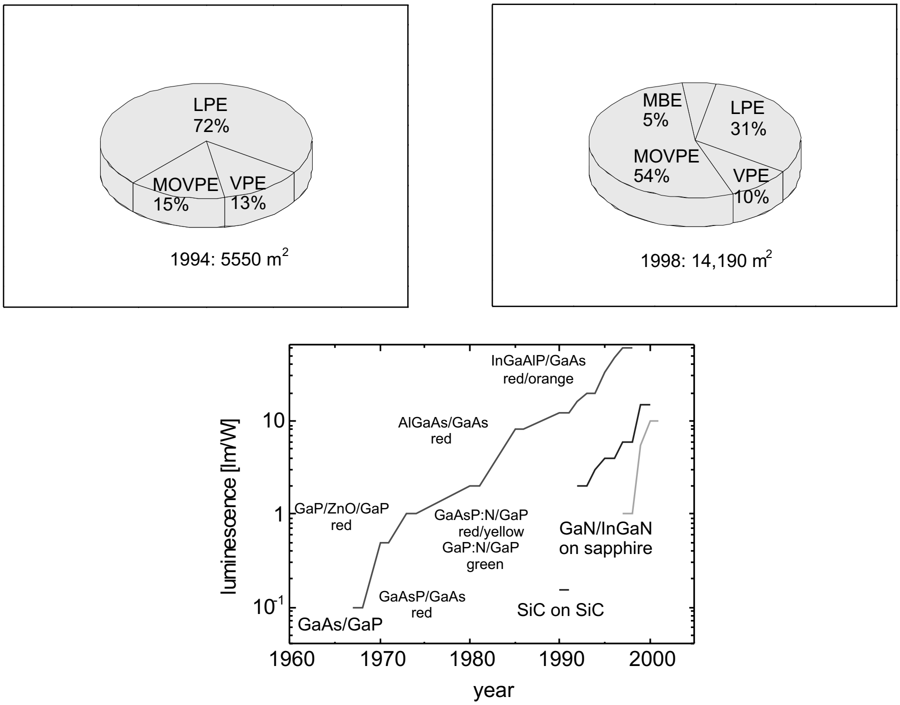


Fig. 1. From 1994 to 1998, the area which had been epitaxially grown for LEDs rised by about 300 % from 5 550 m^2 to 14 190 m^2 (about $1^1/_2$ soccer pitches). Simultaneously, the main interest moved from relatively simple techniques (liquid-phase epitaxy) to highly sophisticated gas-phase epitaxy. The etching techniques covered the whole palette from sewing via wet etching up to dry etching methods, and here from hard gunfire by an argon ion beam to subtle etching by generating a reactive plasma of high density but consisting of ions with relatively low energy. This is associated with a steep increase in colorful brillance or efficacy.

$1 billion in 2003 [3]. Despite the deep crisis which was even aggravated by the assassination on Sep 11, the market had recovered. Alone the market for high-brightness LEDs has hit the volume of the total LED market of 1997 [4] (in numbers of LEDs shipped: 20 billion units in 2004, 30 billion units in 2006), and the next landmark has been reached just now: Almost every third LED is used for automotive purposes, most of them belong to the category high-brightness [5]. (Figs. 2).

Progress is made most obvious by a flashback. In 1978, the costs for a complete wafer fab amounted to about $20 mio., the narrowest geometries were about 2 and 3 microns, and the yield remained at ridiculous 10 %. Some statements from the first number of *Semiconductor International* from the year 1979:

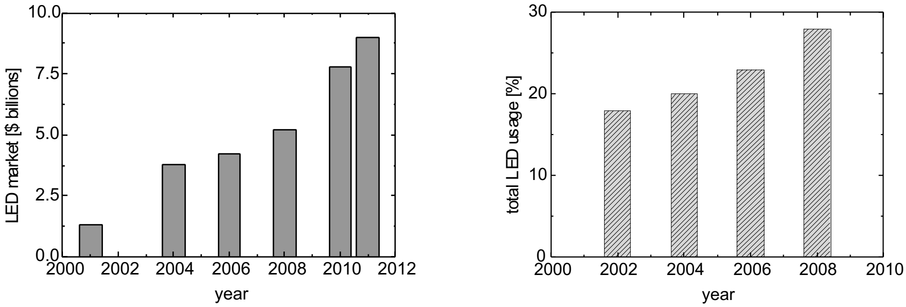


Fig. 2. 2007, the market for LEDs alone has hit the total volume of III/V compound semiconductors of 1997. In particular, the market for automotive LEDs has grown by more than 30 % in the last five years. By the end of 2008, almost every third LED is expected to be part of an automotive illumination with a growing fraction of high-brightness LEDs [4] [5].

- Progress in the area of photoresist and masks provided, deep-UV lithography will be the next technological step [6].
- Plasma etching will become a very important technology for pattern transfer, and plasma deposition shows the same auspicious propects . . . [7].
- Many of the problems what design is concerned can get over provided
  - a less efficient chip is accepted by the market,
  - test functions are integrated on the chip,
  - which is synonymous not to strive for the highest packing density [8].

This was 1978 [9]:

- minimum of the structures by about 2.5 μm;
- the design was at a maximum of eight masks;
- clean room class between 100 and 1 000;
- first application of steppers for processing of 4" wafers;
- gate electrodes with doped polysilicon;
- first operation of lasers for annealing purposes;

- minimum gate oxide thickness: 100 Å;
- wet etching still dominates, plasma etching as high-end technology is operated only in areas where undercut is not tolerable.

For the public, the computer market was entirely dominated by dinosaur computers, but the first programmable calculators were offered by Hewlett-Packard and Texas Instruments, the overwhelming part of light was generated by EDISON' evanescent bulb, and "cold light" was just a dream of some scientists.

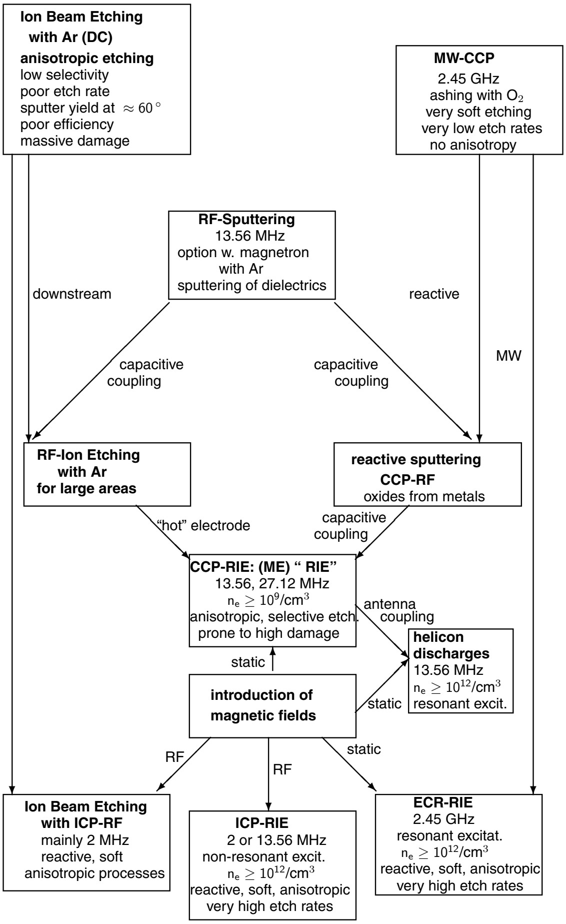


Fig. 3. Flow Diagram for Mutual Development of Excitation Methods and Reactive Processes

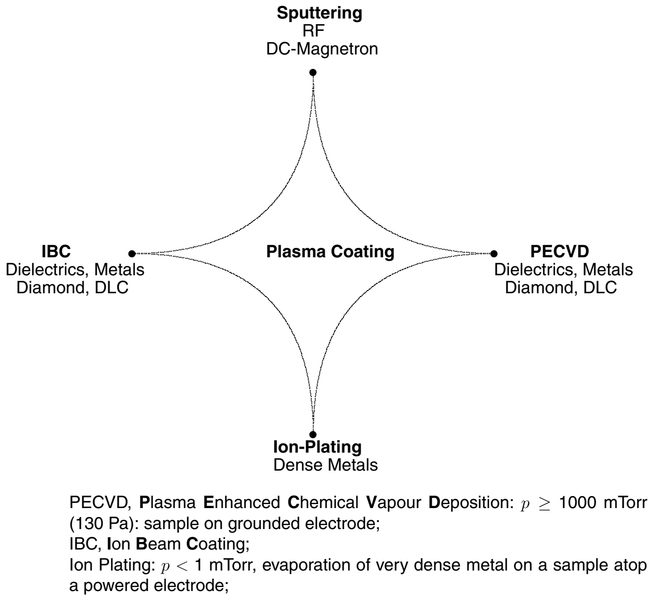
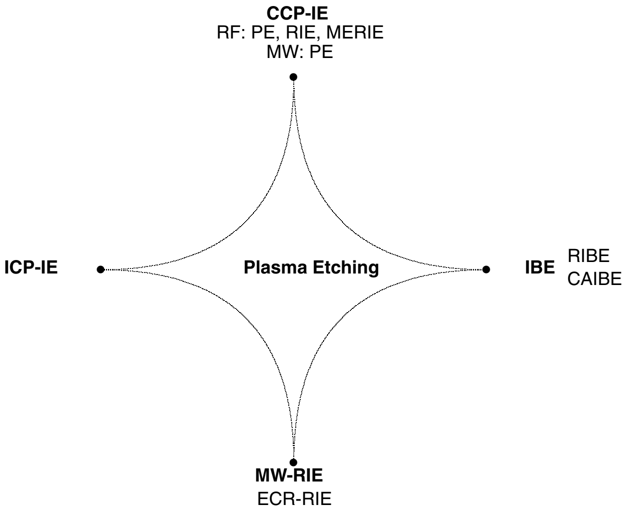


Fig. 4. Various dry etching methods. They mainly differ in the excitation method.

Today, the line widths of the most advanced devices are less than 1 000 Å, but the main issues in nanometer devices are still the patterning of the gate (MOS devices) or the mirror or facet (semiconductor lasers). The end of the common planar technology although further miniaturized is predicted to be reached by less than a decade. But perhaps the prognostic power will be comparable with the score of the prognosis for the world-wide oil deposits which should be depleted always "in the next fifteen years", who knows?

Therefore, we consider to address again a broad readership for the next edition of this book. After a short phenomenological introduction, the various methods to generate charged carriers are extensively discussed, keeping in mind that low temperature plasmas have been subject of intense research for now more than a century which comprises the methods to characterize the plasmas. In the second half, the technological techniques of surface refinement are discussed in two lengthy chapters, and we become again aware of the mutual challenges of surface treatment and plasma technology. Detailed derivations are compiled in a special chapter, including the detailed but tedious algebra. It has become customary to spell acronyms which are introduced just recently in capitals which are gradually transformed to small letters, and it is a matter of taste to decide whether this time is already passed by. Since this book is mostly directed to plasma beginners, I preferred to apply capitals throughout.



CCP, **C**apacitively **C**oupled **P**lasma;
ECR, **E**lectron **C**yclotron **R**esonance, downstream;
ICP, **I**nductively **C**oupled **P**lasma, downstream;
MW, **M**icro **W**ave (2.45 GHz);

PE, **P**lasma **E**tching: $p >$ 75 mTorr (10 Pa): sample on grounded electrode;
IE, **I**on **E**tching,
RIE, **R**eactive **I**on **E**tching: $p <$50 mTorr (7 Pa), sample on powered electrode;
IBE, **I**on **B**eam **E**tching;

MERIE, **M**agnetically **E**nhanced **R**eactive **I**on **E**tching: RIE; electrons are suppressed to reach the sample's surface by means of a magnetic field;
CAIBE, **C**hemical **A**ssisted **I**on **B**eam **E**tching;
RIBE, **R**eactive **I**on **B**eam **E**tching.

Fig. 5. Various dry coating methods. They mainly differ in the excitation method.

It is simply impossible to name all the collegues who discussed certain issues extensively or courteously passed me figures and micrographs (cf. Chap. 15). For more than a decade, I am now used to meet most of them during the annual conference of the AVS, feeling the reality of the scientific community. But in particular, I would like to thank Peter Awakowicz, Rod Boswell, Francis Chen, John Coburn, Vince Donnelly, Demetre Economou, David Graves, Michael Klick, Michael Lieberman, Ivo Rangelow, and Peter Unger.

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