Chapter 8
Operation of Micropattern Gaseous Detectors

ABSTRACT

This chapter is dedicated to the physics of the operation of micropattern detectors. The authors analyze in more detail what causes discharges in these detectors. The chapter shows that, at low counting rates, the breakdowns appear due to the Raether limit and in some specific cases due to surface streamers. In some particular detectors (e.g., combined with high-efficient photocathodes or operating in very clean noble gases) the discharges may appear via a feedback mechanism. At high counting rates, the maximum achievable gain drops with the counting rate due to avalanches overlapping in space and time, and also due to a contribution from explosive electron emission. Detailed studies of the problems that micropattern detectors, in particular GEM, may experience while operating in cascade mode are presented. A better understanding of these effects has allowed researchers to make a further step in the development of micropattern gaseous detectors in recent years.

1. INTRODUCTION

The main advantage of micropattern detectors is that they can be manufactured by conventional microelectronic technology, which offers high granularity and consequently an unprecedented 2D position resolution (20–40 μm). This makes them attractive for many applications such as tracking of charge particles, visualization of X-ray and UV photons and many others (see Chapter 12).

However, the fine structure of the electrodes, and the small gap between them, makes micropattern detectors electrically rather “weak.” In fact, their maximum achievable gain is usually not very high compared to traditional detectors, and without special precautions and measures they can easily be destroyed by sparks which may occur during their operation. This is not the case of traditional wire-type and parallel-plate type detectors which normally withstand sparks. Experience show that at least in high energy experiments sparks are always happening, although their probability may be low enough (10^-5–10^-8 per passing particle) to allow micropattern detectors to operate for a long enough time without being seriously damaged (Procureur, 2010, 2011).

In the previous chapters, we identified two main reasons for these breakdowns:
1. In poor quality detectors sparks appear due to various imperfections like sharp edges, tips, dust particles, dirt etc.;

2. In high quality detectors, in which the imperfections have only minor contribution, the breakdown appears due to the Raether limit (see formula 2.1).

In practice, often imperfection is the limiting factor to create breakdowns in micropattern detectors. Figure 1 identifies some of the most common imperfections which may cause breakdowns in a GEM. Similar imperfections may trigger discharges in other type of micropattern detectors like MSGC, MICROMEGAS etc.

To minimize the effect of imperfections, various sophisticated cleaning procedures are used and micropattern detector assembly is usually performed in dust free laboratories. These efforts to maximize the cleanliness of the micropattern detectors reduces the probability of breakdowns, but one still cannot reach gas gains comparable to traditional gaseous detectors. The maximum achievable gas gain for most micropattern detectors is about $10^4$ measured with 6 keV photons. This was an intriguing puzzle which stimulated intensive investigations (Bouclier, 1995; Bressan, 1999; Bachmann, 2002; Bay, 2002). Systematic studies reveal that in a perfect micropattern detectors breakdowns appear when the total charge in an avalanche reaches some critical value (see formula 2.1) (Fonte, 1998b; Fonte, 1999; Ivaniouchenkov, 1999; Peskov, 2001; Iacobaeus, 2002). This is similar to the limit identified earlier by Raether in the case of the PPAC (see formula 1.36 in Chapter 1). However, the absolute value of this critical charge in micropattern detectors is 2-3 orders of magnitude lower than the Raether limit of a PPAC. Typically $q_{\text{max}} \sim 10^6$-10$^7$ electrons for most micropattern detectors.

Let’s recall the physics behinds the Rather limit. It is the critical charge in an avalanche $q_{\text{max}} = A_{\text{max}} n_0$ (where $n_0$ is the number of primary electrons which initiate the avalanche) which starts modifying the electric field around the avalanche and causes formation of streamers. The value of $q_{\text{max}}$ depends on the geometry of the amplification region and the gas, especially its density and concentration of impurities.

Figure 1. A schematic representation of various imperfections which can crate breakdowns in a GEM