VLSI TECHNOLOGY

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CHAPTER
EIGHT

DRY ETCHING

C. J. MOGAB

8.1 INTRODUCTION

Resist patterns defined by the lithographic techniques described in Chapter 7 are not permanent elements of the final device but only replicas of circuit features. To produce circuit features, these resist patterns must be transferred into the layers comprising the device. One method of transferring the patterns is to selectively remove unmasked portions of a layer, a process generally known as etching.

As the title of this chapter suggests, "dry etching" methods are particularly suitable for VLSI processing. Dry etching is synonymous with plasma-assisted etching[1] which denotes several techniques that use plasmas in the form of low-pressure gaseous discharges. These techniques are commonly used in VLSI processing because of their potential for very-high-fidelity transfer of resist patterns.

The earliest application of plasmas to silicon ICs dates back to the late 1960s, when oxygen plasmas were being explored for the stripping of photoresists.[2] Work on the use of plasmas for etching silicon was also initiated in the late 1960s and was signaled by a patent[3] detailing the use of CF_4-O_2 gas mixtures. At that time, there was no universal endorsement of dry methods which were largely novel replacements for existing wet chemical techniques.

This early work set the stage for an important period in the evolution of IC technology. From 1972 to 1974, workers at several major laboratories were heavily involved in the development of an inorganic passivation layer for MOS devices. The preferred passivation turned out to be a plasma-deposited silicon nitride layer. While this material exhibited many desirable characteristics, there was one immediate difficulty. No suitable wet chemical etchant could be found to etch windows in the nitride in order to expose underlying metallization for subsequent bonding. This problem was circumvented by the use of CF_4-O_2 plasma etching.[4] Concurrently, CF_4-O_2 plasma etching was developed for patterning CVD silicon nitride layers being used as junction seals.[5] These efforts marked the first significant applications of plasma etching in IC manufacture and the beginning of large-scale efforts to develop plasma etching techniques.

Not long after this, an awareness of the potential of plasma techniques for highly anisotropic etching evolved. In particular, there were many observations of a vertical etch rate that greatly exceeded the lateral etch rate when etching through a layer of material. As will become apparent, anisotropy is necessary for high-resolution pattern transfer. The significance of etch anisotropy was recognized by researchers who were hoping to achieve ever larger scales of integration by designing circuits with ever smaller features. By the mid-1970s, therefore, most major IC manufacturers had mounted substantial efforts to develop plasma-assisted etching methods. These methods were no longer seen as merely novel substitutes for wet etching, but rather as techniques having capabilities uniquely suited to meeting forseeable requirements on pattern transfer.

8.2 PATTERN TRANSFER

"Pattern transfer" refers to the transfer of a pattern, defined by a masking layer, into a film or substrate by chemical or physical methods that produce surface relief.

8.2.1 Subtractive and Additive Methods

In the *subtractive* method of pattern transfer shown in Fig. 1a, the film is deposited first, a patterned masking layer is then generated lithographically, and the unmasked portions of the film are removed by etching. In the *additive* (or lift-off) method shown in Fig. 1b, the lithographic mask is generated first, the film is then deposited over the mask and substrate, and those portions of the film over the mask are removed by selectively dissolving the masking layer in an appropriate liquid so that the overlying film is lifted off and removed.

The subtractive methods collectively known as dry etching are the preferred means for pattern transfer in VLSI processing today. The lift-off process is capable of high resolution, but is not as widely applicable as dry etching.

8.2.2 Resolution and Edge Profiles in Subtractive Pattern Transfer

The resolution of an etching process is a measure of the fidelity of pattern transfer, which can be quantified by two parameters. Bias is the difference in lateral dimension between the etched image and the mask image, defined as shown in Fig. 2. Tolerance is a measure of the statistical distribution of bias values that characterizes the lateral uniformity of etching.

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