UNITED STATES DISTRICT COURT

DISTRICT OF NEW MEXICO

STC.UNM,

Plaintiff,

v.

INTEL CORPORATION,

Defendant.

Case No. 10-CV-01077-RB-WDS

DECLARATION OF BRUCE SMITH IN SUPPORT OF INTEL'S OPENING BRIEF ON CLAIM CONSTRUCTION

1. I, Bruce Smith, declare as follows:

2. I have been a professor in the College of Engineering at the Rochester Institute of Technology (RIT) since 1988. I am currently the director and a professor of Microsystems Engineering within the College of Engineering. I received my B.S., M.S., and Ph.D. degrees from RIT in the fields of optics and imaging science and have been involved in semiconductor processing and microlithography for over 25 years. In addition to my teaching and research experience at RIT, I have held development engineering positions in the semiconductor industry. I have published widely in the field of lithography with over 100 publications, over 40 invited presentations, and several textbook chapters. I am a Fellow of the International Society for Optics and Photonics ("SPIE") and a Senior Member of the Institute of Electrical and Electronics Engineers ("IEEE"). I hold over 20 patents in the field of lithography and semiconductor patterning and have licensed my technology world wide. I have personal knowledge of the facts set forth herein and if called to testify as a witness thereto could do so competently under oath.

3. Manufacturing semiconductor chips often requires forming patterns into various layers on a semiconductor substrate (such as a wafer) to represent the circuitry of a microelectronic device. Such devices are referred to as integrated circuits or ICs. The patterning or printing process is known as microlithography or simply "lithography," and it typically involves transferring a geometric pattern from a photomask to a layer on a substrate by (1)

coating the layer to be patterned with a layer of light-sensitive compound called "photoresist"; (2) using the photomask to selectively expose the photoresist to an appropriate wavelength of light; (3) "developing" the photoresist to form a pattern; (4) using a chemical (such as an acid) or a plasma (an ionized gas) to etch into the underlying layer wherever photoresist has been removed; and (5) removing the photoresist to reveal the patterned layer on the substrate. Lithography becomes more challenging and more complicated as engineers strive to pack more features into a given area to keep up with the scaling requirements of ICs (commonly referred to as "Moore's law" scaling). Some ways in which the industry has been able to continually reduce the size of IC features is by reducing the wavelengths of the laser light used to draw the patterns, developing more advanced photoresists, and trying a variety of other resolution enhancement techniques such as customized illumination and phase-shift masking.

4. Interferometric or interference lithography (IL) is a lithography method used to create dense and periodic patterns stretching over a large field. The technique involves the overlapping or "interference" of two beams of light that are nearly identical in wavelength and are also in phase (or in sync) as they travel through space. This is often accomplished by splitting a laser beam in two and optically recombining the beams with an angular separation between them. An interference pattern occurs where the beams overlap, which results in a periodic variation in intensity, like a sine wave. This sine wave can be used to expose photoresist to make dense, identical, periodic patterns. Because IL is ideal for creating patterns of densely packed identical lines, it has been used to make gratings for various applications. It is rarely used as the lithography method for commercial IC manufacturing however because actual semiconductor devices involve much more complex patterns, shapes and sizes than mere dense lines.

5. The '998 patent appears to describe and claim particular methods of double patterning semiconductor chips in order to increase the "spatial frequency content" of the patterns on the chips. "Double patterning" refers to using two exposures of photoresist to pattern a single layer, rather than just one. The concept is basic and was known in the semiconductor industry before 1997. It can be understood in the context of conventional lithographic printing.

Specifically, if you want to print a particularly complex, dense pattern with elements that are very close to one another, it may be easier to use two printing steps, with each print step including only part of the overall pattern. Methods of creating two lines out of a single exposed line are also referred to as double patterning. Approaches to accomplish this generally include separating the edges of a single feature into two distinct patterns, referred to as sidewall double patterning, among other things.

6. In the early 1800s, French mathematician Joseph Fourier explained that a pattern, signal, or object can be broken down or "transformed" into a sum of sine waves having different frequencies, phases (lateral positions), and amplitudes (weights). Mathematically, this process is known as the Fourier Transform. Thus, the Fourier Transform is the mathematical representation of a pattern, where the concept of "spatial frequencies" is a principal aspect. This approach of representing an object in terms of its frequency components can be applied to many fields. For example, although a musical chord is heard as a single sound, and is a complex sound wave, it is possible to take that complex sound and break it down into a sum of constituent notes, such as the notes appearing on the score for that chord. Each note has itself a sound wave at a certain frequency, with a certain phase, and with a certain amplitude. Separating these individual notes as separate frequencies of the chord is akin to taking its Fourier transform. Similar examples can be found with electrical signals, vibration signals, and images. In imaging, the frequencies of the component sine waves are indicative of the basic pattern structure. These are referred to as "spatial frequencies" to indicate their distribution in space rather than in time, as would be the case for signals such as sound. Spatial frequency is measured in units of reciprocal distance (per millimeter for example) and indicates how frequent the component sine waves repeat over a given distance. The amplitude of each component wave is called the "coefficient" of the spatial frequency.

7. To completely represent a pattern, one needs to have all spatial frequency terms, from the lowest to the highest. The lowest spatial frequency terms for a given pattern represent its basic, shape, location, and periodicity. These terms may be sufficient to image the basic structure of a pattern. The higher spatial frequency terms represent the finer feature detail, such

as the sharp edges. As a pattern becomes more dense (i.e. the features within the pattern become closer together), the range of spatial frequency terms (from lowest to highest) is increased.

8. The trend of IC fabrication is to reduce the size and density of semiconductor device patterns so that more features can be put on a chip. All things being otherwise equal, the more features that are in a given chip area, the higher the spatial frequency of those features. By analogy, a 10-foot long picket fence with 20 slats has a higher spatial frequency of slats than a 10-foot long picket fence that has only 10 slats.

9. Describing spatial frequencies in the vertical *z* direction (perpendicular to the *x-y* plane) is somewhat more complicated. When a mask pattern is imaged by an optical lithography system, most of the component sine waves cannot be transmitted; typically the single lowest frequency sine wave gets through. As a result, a photomask pattern that had sharp edges (transitions from light to dark) to begin with will produce a fuzzier image of that pattern at the substrate (i.e. the image plane). The sharp transitions on the photomask from light to dark become low contrast shades of grey in the exposure image. One way to solve the problem as the pattern is exposed is to use a high contrast photoresist. By 1997, it was well known that the inherent properties of high contrast photoresist exposure and development result in an image sharpening effect that can recover sharp light-to-dark transitions from a low contrast image. This occurs because the photoresist essentially has just two states: "off" and "on." If an exposure amount is sufficient, the photoresist turns "on"; otherwise it remains "off." The end result is that the photoresist recovers much of the image fidelity that was lost by the optical system. In spatial frequency terms, the photoresist has restored some of the lost spatial frequencies in the vertical *z* direction.

10. STC's construction of "high spatial frequencies" is inaccurate, specifically as to the clause "resulting in sharp corners, smaller features or higher pattern density." In the context of the '998 Patent, while higher spatial frequencies in the *x-y* plane do result in higher pattern density in that plane, higher spatial frequencies do not necessarily result in "sharper corners" or "smaller feature size." For example, as stated by the applicants during prosecution history, a feature that is square shaped can have the same spatial frequencies as a feature that is round,

even though the square has sharper corners in the x-y plane than the round feature. (1/14/99 Response at 9). Moreover, features of larger size can have the same or greater spatial frequency than smaller features. Feature size alone, without knowledge of pattern density, is not enough to ascertain spatial frequency content of a pattern.

11. A "mask" as used in the fields of lithography and semiconductor patterning is for purposes of shielding. A photo-mask is something that blocks part of an exposure of light. A photoresist pattern is also referred to as a mask and is used to protect an underlying layer from etching or other processing. In order to provide such protection, the photoresist does not react to the etching chemicals as does the underlying layer. A "hardmask" is a mask made of a hard material such as silicon dioxide (not photoresist) that remains in place even when the photoresist is removed. Thus the hard mask does not react to either the chemicals used to etch the underlying materials or the chemicals used to develop or strip the photoresist. Its purpose is to shield portions of the substrate from etchants in order to transfer the desired pattern into the layer(s) below.

12. One can use various combinations of steps and layers of materials to transfer a double pattern into a semiconductor substrate.

a. Most simply, one could use two photoresist layers and no hardmask layer. One way to do so would be to deposit, expose, and develop the first photoresist layer to form a first pattern in that layer; then to deposit expose, and develop the second photoresist layer to form a second pattern in that layer; and then use the combination of the patterned first and second photoresist layers as a mask to pattern the layer underneath the first photoresist layer (e.g., with an etchant).

b. Alternatively, one could use one hardmask layer and two photoresist layers. For example, one could first deposit the hardmask layer (sometimes called a "sacrificial" layer); then deposit, expose, and develop a first photoresist layer; then transfer the resulting pattern to the hardmask layer; then deposit, expose, and develop a second photoresist layer; and then use a combination of the patterned hardmask and patterned second photoresist layer to pattern the layer underneath the hardmask layer.

c. Alternatively, one could use a single hardmask containing both patterns. For example, one could deposit the hardmask layer; deposit, expose, and develop a first photoresist layer to form a first pattern; transfer that first pattern into the hardmask; deposit, expose, and develop a second photoresist layer to form a second pattern; then transfer that second pattern into the hardmask; and then use the hardmask alone to transfer both patterns into the layer below.

d. Alternatively, one could use a separate hardmask for each of the patterns. For example, one could deposit the first hardmask layer; deposit, expose and develop a first photoresist layer to form a first pattern; transfer that first pattern into the first hardmask layer; then deposit a second hardmask layer; deposit, expose, and develop a second photoresist layer to form a second pattern; then transfer that second pattern into the second hardmask layer; and finally use both hardmask layers in combination to transfer the two patterns into the layer beneath the first hardmask layer.

These are just some examples of transferring a double pattern into a semiconductor substrate. All of the methods described above are distinct, and are used for different purposes.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Dated: June 21, 2011, at Rochester, NY.

By ____________________

BRUCE SMITH