Toward Automated Pattern Inspection and Defect Characterization for Patterned Media Lithography

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The ever-growing demand for hard drives with increased data storage density has motivated a technology shift from continuous magnetic media to patterned media hard disks, which are expected to be implemented in future generations of hard disk drives to provide data storage at densities exceeding 10^{12} bits per square inch. Realization of this technology transition will require industrial-scale lithography at unprecedented levels of feature resolution, pattern precision, and cost efficiency. Step and Flash Imprint Lithography (S-FIL) technology is currently being developed to address these manufacturing requirements.

Development of a manufacturable lithography process is contingent upon the ability to inspect patterned substrates at levels of resolution and throughput that are sufficient to obtain meaningful statistics on device yield; this metrology facilitates the feedback loop that is essential for process optimization. For the integrated circuit (IC) industry, this inspection requirement has led to the development of highly specialized tools that are capable of identifying sub-50 nm defects embedded in arbitrarily complex patterns. The inspection requirements for patterned media lithography are very different from the requirements for semiconductor lithography. Patterned media layouts include regions that contain sub-50 nm structures for data storage, as well as regions containing larger-scale servo structures that enable the drive to precisely locate the position of the head on the disk surface for read/write operations (Fig. 1). One patterned media substrate might contain more than eight trillion individual structures, but a disk drive is generally much more tolerant of lithography defects than a semiconductor device. A low level of small, isolated defects can reduce the area that is available for data storage, but the overall performance of the disk drive is not affected. However, defects within the servo patterns can be much more problematic because these defects can impair the function of the drive head.

This work presents a methodology for automated pattern inspection and defect characterization for imprint-patterned media. Candela CS20 and 6120 tools from KLA-Tencor map the optical properties of the disk surface, producing high-resolution grayscale images of surface reflectivity, scattered light, phase shift, etc. We have developed software that analyzes these images and identifies defect pixels distinctly from the pixels that correspond to data storage structures or servo patterns (Fig. 2). Defects that have been identified in this manner are further classified according to the morphology of the defect pixels as well as the defect location on the substrate (Fig. 3). Complementary metrology techniques (e.g. SEM and AFM) have been used to determine the physical structure of a number of characteristic defects that were identified by the optical inspection described above. This study has produced a set of Boolean relationships that can be useful in quickly determining the physical structure – and thereby the root cause – of each defect. For example, a 3-nm variation in feature height does not cause significant light scattering, but will produce a local deviation in the optical phase shift that can be mapped by a Candela tool and subsequently detected by the software. These procedures provide a quantitative framework for causal analysis of process defectivity.

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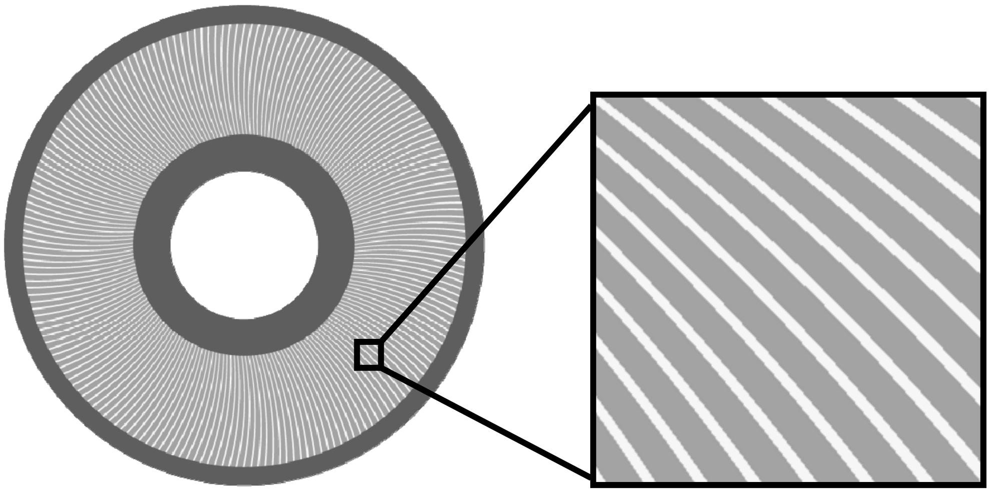

Figure 1. Typical layout for a patterned media application on a disk substrate (65 mm OD). The pattern layout includes regions that contain nanoscale data storage structures (dark shading) and regions that contain larger-scale servo patterns (light shading).

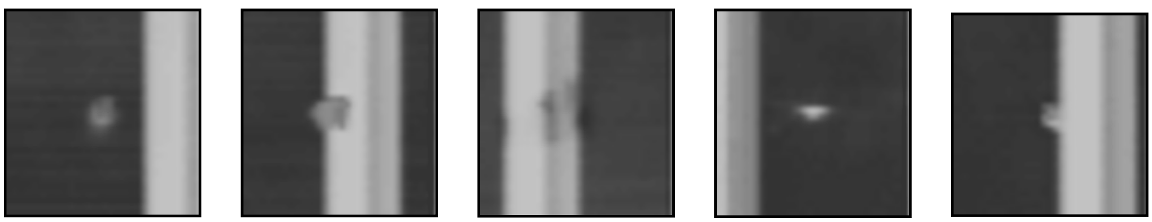

Figure 2. Optical images of several defects identified by the custom software. The detection algorithm identifies intensity variations caused by defects; the software then classifies the defects according to morphology and location.

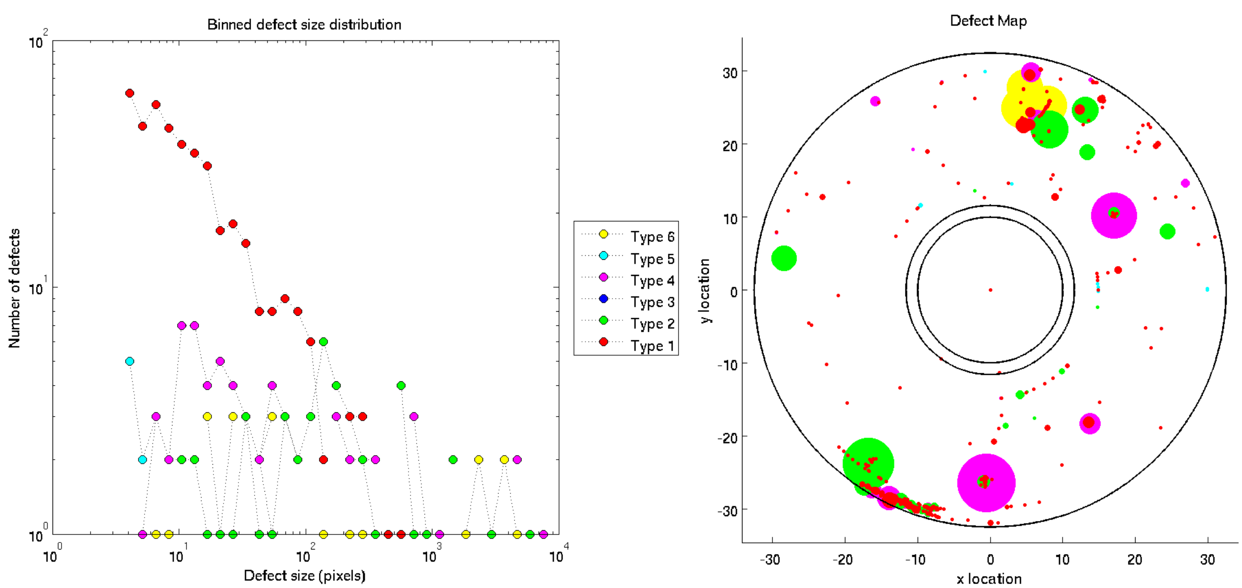

Figure 3. Bin classification of defects and defect mapping facilitate root cause analysis of process defectivity.