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Development nano-Moiré method with high-resolution microscopy at FML

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Abstract

Some novel nano-Moiré methods have been developed at failure mechanics lab in the Tsinghua University, recently. This paper offers an introduction of these new methods, which can be realized under the atomic force microscope, scanning tunneling microscope, as well as the transmission electron microscope. These nano-Moiré methods are able to offer quantitative analysis to nano-deformation of object. The measurement principles and experimental techniques of these methods are described in detail. A new digital nano-Moiré technique is proposed. Some typical applications to these methods are discussed. The successful experimental results demonstrate the feasibility of these methods and also verify that the methods can offer a high sensitivity for displacement measurement with nano-meter spatial resolution.

Keywords: Electronic microscope; Nano-Moiré; Nano-metrology; Crystal lattice

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1. Introduction

The Moiré method introduced by Weller [1] is a full-field optical method for in-plane deformation measurement that has been widely used in experimental stress analysis [2,3]. Displacement measurement sensitivity of the Moiré method is decided by the frequency of a grating used. However, because the gratings in the Moiré method have a frequency lower than 100 lines/mm, this method can only be applied to large deformation measurement.

Moiré interferometry developed by Post [4] offers a unique combination of high sensitivity and excellent contrast, range and spatial resolution. Since the frequency of specimen grating is normally 1200 lines/mm or 2400 lines/mm, this considerably improves the sensitivity of the Moiré method and extends its application to the field of meso-mechanics. Further increase in the frequency of grating is limited by the wavelength of laser used. More sensitive measurement comes from electron beam Moiré developed by Kishimoto [5]. In his works, an electron beam was used to write very fine lines and to measure micro-deformation. A grating up to the frequency of 10,000 lines/mm can be produced by this technique, which represents the highest sensitivity for the Moiré method at present.

In 1993, Dally et al. [6] proposed the scanning Moiré method. In this method, the scanning lines in the SEM monitor or CCD video camera were used as the reference grating to form scanning Moiré fringes. The method provides a new way to improve the resolution and sensitivity for the microscopic Moiré method.

The micro-mechanical behaviors of engineering materials in nanoscopic range have aroused general concern in recent years. To understand the rule of these behaviors, the experimental technique with nanometer sensitivity and spatial resolution are required. However, the methods mentioned above obviously cannot meet such requirements.

In 1999, Xing et al. [7] proposed a nano-Moiré method in which high-resolution electron microscopy (HREM) image of crystal lattices acted as a specimen grating is superposed onto a unidirectional geometric grating as a reference one. Xie et al. [8] developed a new scanning Moiré method in which Moiré fringes are formed by the overlap between scanning lines of the CRT in the atomic force microscope (AFM) system and atomic lattices of the mica.

Asundi et al. [9–11] proposed a digital Moiré method including logical Moiré, shadow Moiré, arithmetic Moiré and projection Moiré. The logical Moiré used the logical operators (AND, OR, XOR) to generate Moiré fringes from two 1-bit binary gratings within a computer.

2. Formation of nano-Moiré and measurement principle

2.1. Atomic force microscope (AFM) nano-Moiré method

2.1.1. Formation principle of nano-Moiré fringe and measurement principle

Under an AFM, the probe tip of the flexible force-sensing cantilever is controlled in such a way that it scans over the surface of a specimen. The atomic force between