Superlattices and Microstructures 93 (2016) 122–127

Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlattices

Fabrication of photonic quasicrystalline structures in the sub-micrometer scale

Shuai Wang [a], XiaoHong Sun [a, *], WenYang Li [a], Wei Liu [a], Lei Jiang [b], Juan Han [b]

[a] Henan Key Laboratory of Laser and Opto-electric Information Technology, Zhengzhou University, Henan 450052, China
[b] Center for Bioengineering and Biotechnology, China University of Petroleum, 66 Changjiang West Road, Qingdao, Shandong 266580, China

ARTICLE INFO

Article history:
Received 18 January 2016
Received in revised form 27 February 2016
Accepted 27 February 2016
Available online 3 March 2016

Keywords:
Photonic quasicrystal
Top-cut prism
Holographic interferometry

ABSTRACT

Compared to periodic crystals, photonic quasicrystals (PQC) have higher point group symmetry and are more favorable in achieving complete band-gaps. In this report, a top-cut prism interferometer is designed to fabricate ten-fold photonic quasicrystalline structures in the sub-micro scale. Based on the difference of production conditions, a variety of quasicrystals have been obtained in the SU8 photoresist films. Scanning Probe Microscopy and laser diffraction are used to characterize the produced structures. The corresponding theoretical analysis is also provided to compare with the experimental results. This will provide guidance for the large-area and fast production of ten-fold quasicrystalline structures with high quality.

1. Introduction

Quasicrystals are structures exhibiting long-range aperiodic order and rotational symmetry [1,2].Mesoscale quasicrystals may possess photonic bandgaps (PBG) [3,4] that are more isotropic than conventional photonic crystals and, hence, they may have more complete PBGs leading to interesting properties of light transmission [5], wave guiding and localization [6], increasing the flexibility of these materials for many photonic applications. So recently, a growing number of researchers are engaged in the research on quasicrystals.

However, because quasicrystals lack translational symmetry, it is complicated and difficult to fabricate quasicrystalline structures. Especially, it is challenging to fabricate the quasicrystals in large area and in the visible range with sub-micro scale. In recent years, some scientists found that laser holographic lithography can not only be used to fabricate periodical photonic crystals [7–10], but also to obtain quasicrystals [11–16].

In this article, a top-cut prism interferometer is designed and optimized for PQC [19]. By changing the exposure conditions, different quasicrystalline structures can be obtained. At the same time, Scanning Electronic Microscopy (SEM), Scanning Probe Microscopy (SPM) and laser diffraction methods were used to characterize the fabricated structures. By comparing the experimental results with the theoretical calculations, a good agreement is obtained. This will guide the fabrication process of quasicrystalline structures with high quality and large area.

* Corresponding author.
E-mail address: iexhsun@zzu.edu.cn (X. Sun).

http://dx.doi.org/10.1016/j.spmi.2016.02.047
0749-6036/

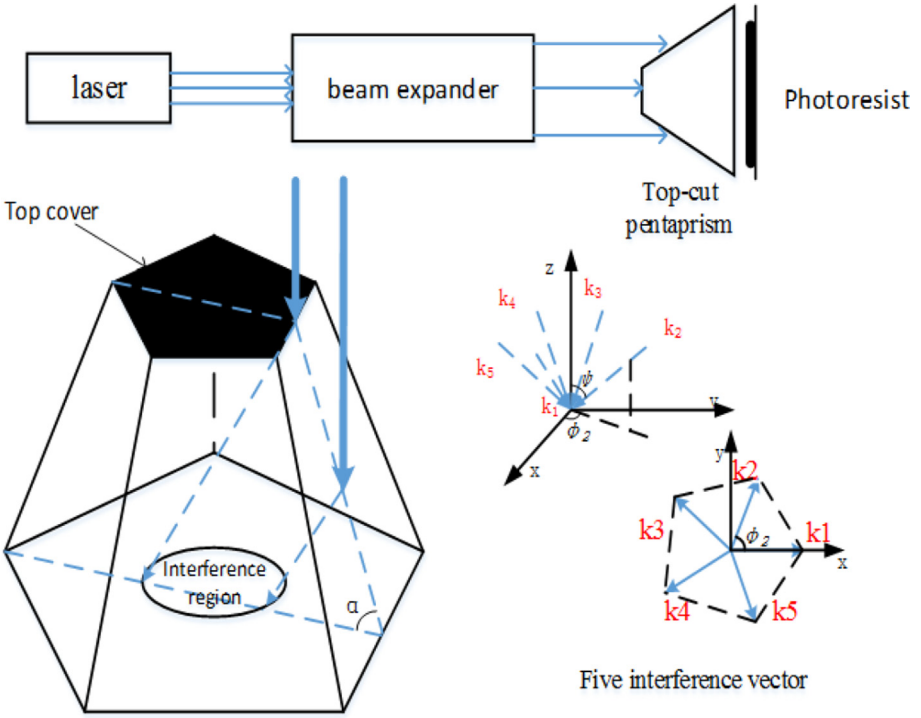

Fig. 1. The schematic diagram of the top-cut prism interferometer.

2. Quasicrystalline structures

2.1. Material and writing system

The material used in this work is SU-8 photoresist, a high contrast, epoxy based photo-resist resin from MICRO CHEM Cop. First, glass substrates were subjected to a piranha etch/clean (H_2SO_4 &H_2O_2) for 30 min at room temperature, followed by a thorough rinse of deionized water and dehydrated at 100 °C for an hour in an oven. SU-8 photo-resist resin was first spin-coated on the pretreated substrate at 300 rpm for 5 s, then coated at 3000 rpm for 60 s, to ensure that the thickness of the SU8 was uniform. The total thickness of the SU-8 film was about 10 μm. Then the film was baked on an oven at 85°Cfor 25 min.

The basic element of the writing system is the top-cut prism interferometer, comprising five identical side faces and two parallel different sized pentagonal bases, as shown in Fig. 1. The top-cut prism is the main optical element and made of quartz with refractive index of 1.47. A 355 nm beam from a triple-frequency Nd:YAG laser (YG980, Quantel Co. France) was expanded and collimated to irradiate the sample film through the designed prism. The film was exposed with 20–40 mJ/cm^2 dose for about 4s. After exposure, it was post-baked at 85 °C for 30 min, developed in Propylene Glycol Monomethyl Ether Acetate (PGMEA, $C_6H_{12}O_3$) for 50 min followed by rinsing in isopropanol and drying with a blower.

A collimated plane wave is normally incident from the top small base and is split into five umbrella-like beams. The angle between the side and central beam is $\phi = \alpha - \arcsin(\sin\alpha/n_\omega)$, where $\alpha = 54.7°$ is the cutting angle of the top-cut prism and

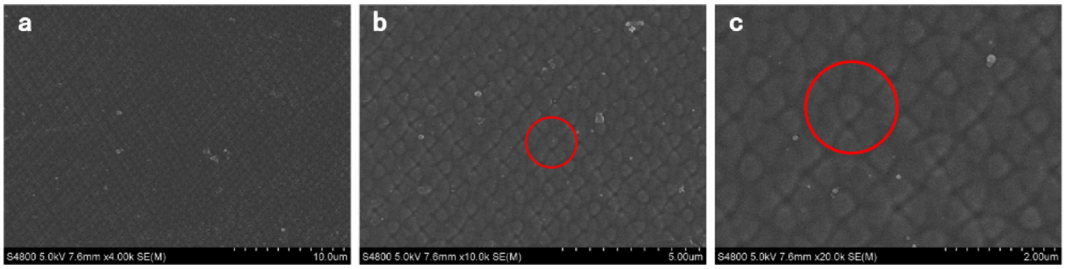

Fig. 2. Different magnification of SEM micrograph of PQC structure with the same intensity of different beams.