Optical Method to Determine the Orientation of Monocrystalline Silicon Wafers

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Abstract

In this work, an optical method was used for the determination of the crystalline orientation of the chemically etched silicon surfaces in the (111), (110) and (100) planes. This method depends on the light patterns of laser beam reflected from the monocrystalline surfaces. The optical method submits acceptable measuring accuracy and well-distinguished folded patterns.

Keyword: Crystalline orientation, Crystallographic orientation ,Optical reflectogram technique.

طريقة بصرية لتحديد الاتجاهية لشرائح السيليكون احادية البلورات

الخلاصة

في هذا البحث ، استخدمت طريقة بصرية لتحديد الاتجاهية البلورية لسطوح سيليكونية منمشة كيماويا باتجاه المستويات (111) و (110) و (100). تعتمد هذه الطريقة على الأنماط الضوئية التي تكونها حزمة الليزر المنعكسة عن السطوح أحادية التبلور. توفر هذه الطريقة البصرية دقة قياس مقبولة وأنماط متميزة بشكل واضح والاستغناء عن الفحوصات بالاشعة السينية.

Introduction

A few decades ago, single crystals represented a backbone for the modern technology as they form the base of optics and semiconductor lasers and optoelectronics [1]. In the 50's of the past century, the fabrication of electronic devices and solar cells depended on the single-crystal semiconductors. The most important semiconductor is single crystal silicon due to its availability in the earth (25%) and the processing techniques of silicon fabrication are the most practical and economic with respect to other semiconductors.

The polycrystalline silicon wafers were used for solar cells fabrication achieving efficiencies no more than 10%, meanwhile this efficiency might reach 20% when monocrystalline silicon wafers were used. Therefore, researches and workers tend towards the development of crystal growth techniques. Czochralski technique was used extensively to form large sized rods of monocrystalline silicon with good quality and short times when compared to other crystal growth techniques [2].

As most physical properties of semiconductors – especially silicon – depend on the crystal orientation, more care should be given to the orientation of silicon rod during seeding procedure. Silicon wafers of (100) orientation are preferred for

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use in solar cells fabrication while the (111) wafers are the most commonly used in devices fabrication such as transistors [3].

Etching is a result of the interaction between solid surface and the enchants and such interaction determines crystallographic orientation, lattice imperfections and chemical composition. There are two nominations; preferential and non-preferential, often used to describe the effect of chemical solution on the appearance or absence of a certain crystalline orientation [4].

The most common techniques used for etching of solids are chemical etching, molten metal etching, anodic dissolution, electrolytic etching and ion bombardment [3-4]. The chemical etching includes chemical and autonomous reactions between the solid and etchant. Accordingly, stigmas and dislocations appear in certain geometric configurations due to the surface orientation [5].

Experimentally, all visual observation methods require advanced experiences in crystal growth technology to determine the features of the growth facets or to show stigmas and cracks. Although X-ray diffraction is an effective NDT technique and does not require such experiences, it consists in complexity in equipment and instruments.

An optical method, is often used in orienting crystal for cutting since it is extremely simple and cheap. The method has been described by Schwutte[6].One apparatus, consists merely of beam of light which is reflected from the surface of crystal onto a screen[7].The crystal surface must be referentially etched first. An imperfection in the surface will act as site for this type of action, and the result is a surface containing a number of etch pits. The inside faces of the pits are actually facets parallel to some important crystal plane. They act as tiny mirrors and reflect the light to form characteristic patterns. Those for the(111),(100) and(110) plane,in germanium are sketched in [8] and represent perfect alignment .

Experiment

An optical system was designed and used for the determination of the crystal orientation of 500 m-thick silicon wafers in (111), (110) and (100) planes. Because the wafer may easily be broken, it was maintained on a brittle support before grinding and polishing. The wafers were ground and polished to remove any cutting deformations and obtain the planes parallel to wafer surface. Emery papers of (5-30) mm range were placed on a rotor disk and the sample is maintained normally and moved manually in a 8-shaped path for (15-30) min. diamond paste was used to polish the wafer surface until a mirror-like was obtained. Wafers were then rinsed in the deionized water and dried by air. They were etched chemically using three different etching solutions as explained in Table (1).

The optical reflectogram technique was considered in this work to determine the crystal orientation of silicon wafers by introducing the patterns of the reflected laser beam.

The optical system designed and constructed in this work consists of a 0.9mW CW 0.6328 m He-Ne laser. Laser beam was focused on the silicon wafers using a lens of 80mm focal length. The wafers were maintained on a stage moving in two manners; angular and oblique. All elements were maintained on a standard optical bench. The light patterns were shown on a white screen in a dark room then recorded by high-sensitivity digital camera. The instruments given light patterns of very high intensity have been assembled in physics laboratory. This shows in Fig. (1) and Fig.(2) shown the shape of expected reflections from geometrical considerations.

Results and Discussion

A Si crystal can be etched “preferentially” in such a way that its surface is crowded with etch pits of microscopic size .These pits are bounded by minute facets of the crystal lattice and are, therefore, oriented with respect to the crystal structure. A beam of light reflected from such a surface will be split into two or more components, the number being equal to the number of bounding plane comprising one single etch pit. These planes behave as tiny mirrors whose orientation with respect to the incident beam is the same for all etch pits. If the reflected beam is intercepted by a screen, a light pattern, or reflectograms is seen .

This pattern shows the symmetry of the crystallographic direction along which the light beam incident as shown in Fig. (3),(4) and (5). Fig. (3) shows the pattern for the (111) plane thus shows three fold symmetry, Fig.(4) shows and the pattern for (110) plane, shows two fold symmetry. The pattern for (100) surfaces shows four fold symmetry as in Fig.(5). Such results are compared to those considered in the crystal growth laboratories [7].

Accordingly, the etching rate in the (111) plane was faster than those of (110) and (100) planes when using the same etching solution. This is attributed to the fact that dissolution rates of crystalline silicon surfaces decrease {(111)>(100)>(110)}.

Hence, stigmas appear faster on the surfaces of lower dissolution rates [4] as shown in Table (1).

Conclusion

Regarding to the obtained results from this work, one can conclude that the light patterns of the reflected He-Ne laser beam from a monocrystalline silicon surfaces can be employed to introduce the crystalline orientation. The light patterns of (111), (110) and (100) orientations on the etched silicon surfaces are consisting of 3-folded, 2-folded and 4-folded symmetries, respectively.

References

[1] Nosov Xu G., English Translation of the Bulletin of the Academy of Sciences of the USSR, Physical Series, Vol.40 (1970).
[2] Hayakaw Y. J.” Crystal Growth “Vol.-10,(1996) ,p.(220-225)
[3] Keller W., "Floating- Zone Silicon", Marcel Dekker, INC. (New York) and Basel (1981).
[4] Kane R.F., “Characterization of Semiconductor Materials", McGraw Hill Book Company (1970).
[5] Ueda R., "Crystal Growth and Characterization", Blackwell Scientific (1963).
[6] Schwattke G.H., Sylvania Technol., Vol.11, (1958), p.2.
[7] DIN 50433,pt.2(German slandered for optical orientation),Berlin,(1976).
[8] Annual Book of ASTM standards Section 10, Vol.105, Electronics (11), (1988).

Table (1) The chemical solutions and conditions of etching in this work

Etching solution	Etching time	The required orientation
50% weight NaOH	(5) min at 65°C	For (111) etching
50% weight NaOH	(7) min at 65°C	For (110) etching
50% weight NaOH	(10) min at 65°C	For (100) etching

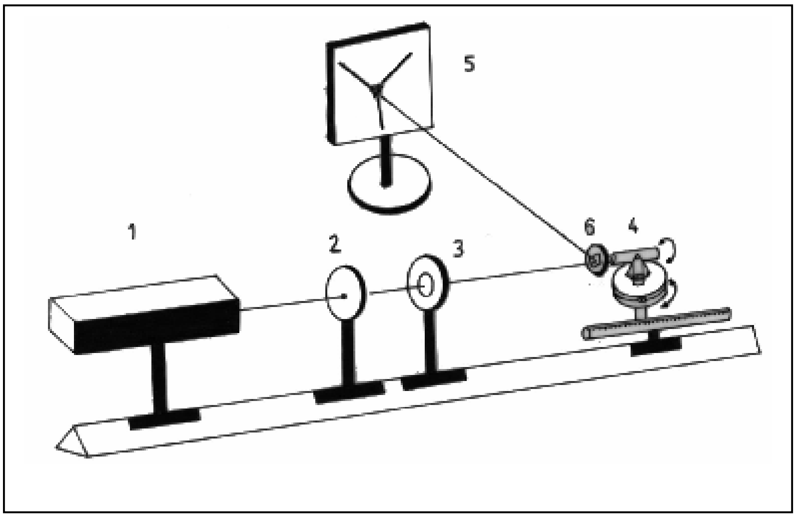

Fig. (1)Experimental Setup

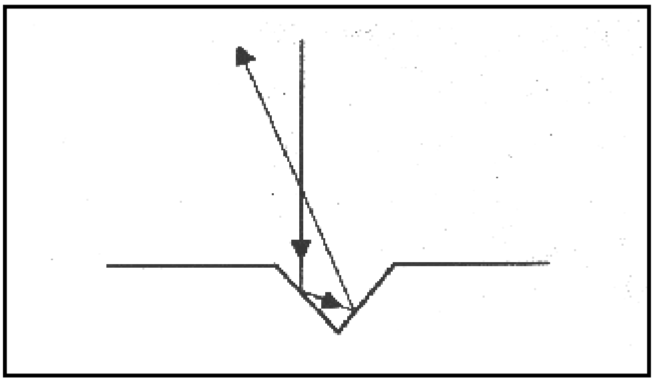

Fig.(2) Shown the shape of expected reflections from geometrical considerations.

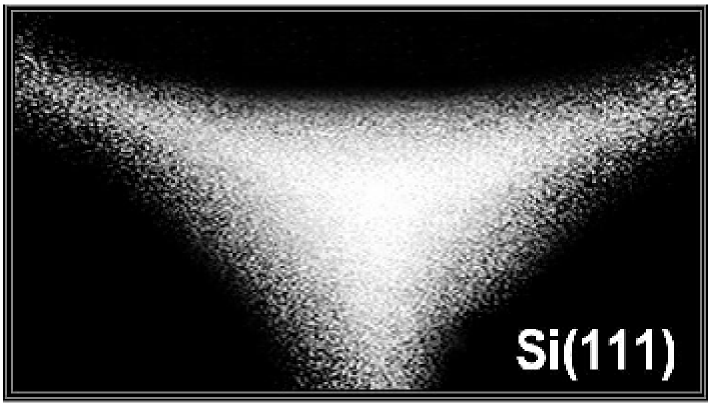

Fig. (3) Light patterns of the laser beam reflected
from the (111) monocrystalline silicon surface

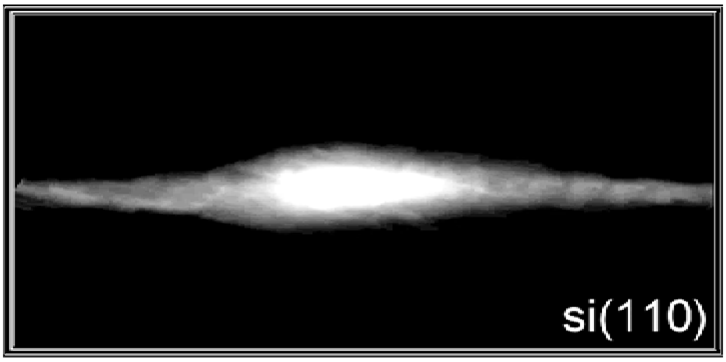

Fig. (4) Light patterns of the laser beam reflected
from the (110) monocrystalline silicon surface

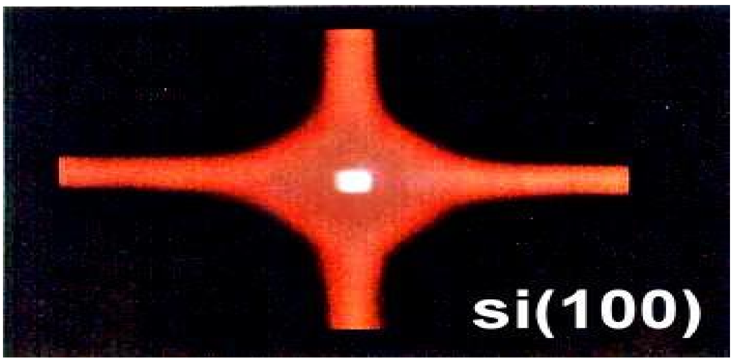

Fig. (5) Light patterns of the laser beam reflected
from the (100) monocrystalline silicon surface