

# Experimental Investigation & Finite Element Analysis of NanoNotches Provided on Chip Surface

Miss Mitali Gore<sup>1</sup>, Mr. Sachin Kulkarni<sup>2</sup>, Mr. Prashant Karajagi<sup>3</sup>

<sup>1</sup> PG Student, Siddhant College of Engineering, Pune, India

<sup>2</sup> Assistant Professor, Siddhant College of Engineering, Pune, India

<sup>3</sup> Head of Department, Siddhant College of Engineering, Pune, India

<sup>1</sup> mitaligore19@gmail.com, <sup>2</sup> Kulkarnisachinsir@rediffmail.com, <sup>3</sup> pgkarajagi@gmail.com

**ABSTRACT** - The Thinning of the chips of the different materials has become necessary such as silicon chips in the solar cells. Surface defects are easily induced on chip during the thinning and machining processes. The stress concentration resulted from defects would be the source of crack and failure of silicon chips. In this paper, the finite element analysis & experimental investigation will be done to study the effect of nano notches on stress concentration caused by surface defect with different parameters for silicon chip. Since we will focus on the stress distribution near the defect and stress concentration factor. nano notches will introduced in the nearby area of defect in the finite element analysis & experimental investigation.

The chips will be under Tensile Testing and the stress distribution at crack tip on simple chip and chip with nano notches will be studied. Hence in this work we are going to analyze the Stress concentration factor due to the crack produced during the thinning operation of the chips will be minimize by the adding the nano notches and hence the life of the thin component or chips can be increase.

**Keywords:-** Chip surface, crack, notches, stress concentration factor.

## Nomenclature

- l Length of chip
- b crack depth
- r radius of curvature at crack tip
- N load in Newton
- $\sigma$  stress at crack tip

## INTRODUCTION :-

As use of solar energy becomes more mature and increasing day by day, it is important to pay more attention on energy conversion efficiency and reliability of solar cell. It is known that nano notches on solar cell surface can increase the anti-reflection and absorption efficiency of solar cell. however, less study was found for the relation between nano notches and mechanical strength of solar cell. In the process of thinning of solar cell would result in some small crack in the chip. these crack would easily be the origin of chip failure when under the external loads.

The cracks and the notches are the important reasons for the failure of the any component because at the tip of the cracks

and the notches the stress generated is higher than the nominal stress. This phenomenon introduces the term stress concentration factor. To avoid the failures of the specimens the study of the stress concentration factor gets vital importance. In 1952, Williams [5] use the Eigen solution expansion method to analyze sophisticated stress singularity of materials with single wedge. Sih [6] summarized many kinds of crack problems with different boundary conditions. [7] It was proved that stress concentration of v-shaped notch relaxed by nano notches. [8] Adis concluded that when building periodical structure on surface, stress concentration on notch would change according to the geometric shape of structure. Chen [9] found that the strength of chips with surface nano notches were 2.5 times better than that of polished chips under bending test furthermore the chips with nano notches broke into several small pieces, in the contrary to the case for polishes chips, breaking into few big pieces. In this paper, the improvement of chip's mechanical strength and stress concentration reduction at crack tip by adding nano notches on chip surface is discussed.

## Methodology

To study the effect of nano notches Experimental Investigation of chip with a single crack and Nano-Notches Provided on Chip Surface has done.

**Experimentation:** For experimental study we select material as EN 24 plate with thickness of 1mm. selection of EN24 plate which is alloy of steel instead of silicon because silicon is very hard to machined by mechanical procedures. EN 24 steel is a high tensile alloy steel having high wear resistance. It is used in components subjected to high stresses. EN 24 plates having dimensions as follows:

length of chip : 100 mm  
width of chip : 10 mm  
thickness of chip: 1 mm

Total 12 plates of EN 24 material are manufactured. In this process raw EN24 material is undergone through processes as follows:

**Milling** operation: milling operation has done to provide proper square shape of required size of raw EN24 material

**Hardening** : material is heated uniformly to 823 to 850° C until heated through. Quench in a oil.

After hardening operation the plates are subjected to grinding followed by surface grinding to make a surface smooth and to reduce its thickness. At last again milling operation has done to reduce thickness of plate to 1 mm.

**MPI Testing** : this is magnetic partial inspection testing done to detect the crack which can be produced during machining process. All the 12 plates are tested for MPI, out of which 2 plates having crack on it are selected for experimentation.

**Wire cut method**: one of the plate having crack on it is subjected to wire cut method to produce nanonotches on it. for this method smallest wire diameter size available is 0.25 mm. we select this size to provide nano notch on chip surface.

width of crack : 1 mm

length of crack: 5mm

second chip is now provided with a nanonotches along with the centrally provided crack of width 0.25 mm. dimensions of nanonotches provided on both sides of central crack as follows: width of notch : 0.25mm

depth of notch: 1 mm

Gap between crack and nanonotches is keep as 5mm. thus total no of notches & cracks are 19 on second plate. After all the processing and testing chips will look like as follows:

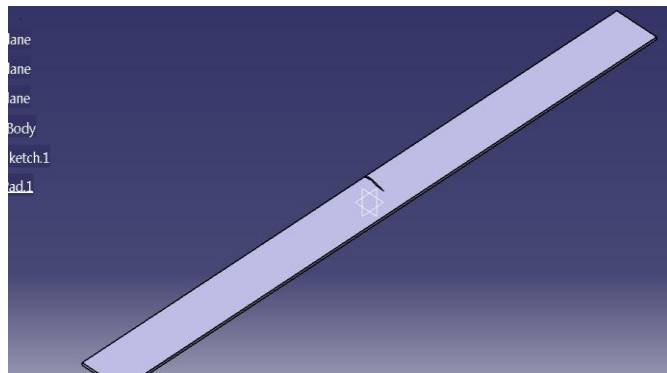


Fig. 1 Chip with crack

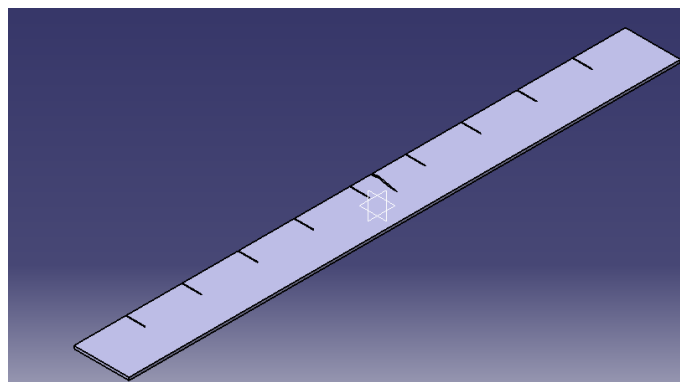


Fig.2 . Chip with crack and notches

We consider tensile testing for checking performance of both the plates. For this plates are subjected to tensile loading conditions. While applying tensile load one face of the chip

parallel to the crack and notches will be kept fixed and tensile load is applied on another side of chip. tensile test is carried on both the plates with Universal Testing Machine. cross head speed for this testing was 5 mm per minute. various loads from 0 N to 800 N will be applied on both the plates to observe stress near crack tip. stress value at which breaking of plates occurs is noted. with this reading other reading such as strain ,displacement, percent elongation were recorded.

### Stress Concentration Factors:-

Theoretically stress distribution along a surface should be uniform but if abrupt changes in geometry occurs stress concentration factor will increase. It occurs for all kinds of stress, axial, bending or shear in presence of notches, holes & fillets. The maximum value of the stress at such condition is given by the elementary equation by stress concentration factor  $K_t$

$$K_t = \frac{\text{actual stress}}{\text{nominal stress}}$$

Stress concentration factor calculated by this formula is called as theoretical stress concentration factor.

### FEA Analysis :-

For FEA analysis model is selected with same dimensions as experimental model. FEA analysis is carried out using ANSYS 16.0 .we consider symmetric model; crack and notches are given from middle of the plate. Meshing element size in ansys is 1mm. tensile load of 800 N is applied same as that of experimental conditions. Material properties selected for analysis are as follows

EN 24

Density :- 7.8611e-06 kg/mm<sup>3</sup>

Young's modulus :- 0.21

Poisson's Ratio : 0.3

Results are noted mainly for von mises stress acting on both the plates represented as follows

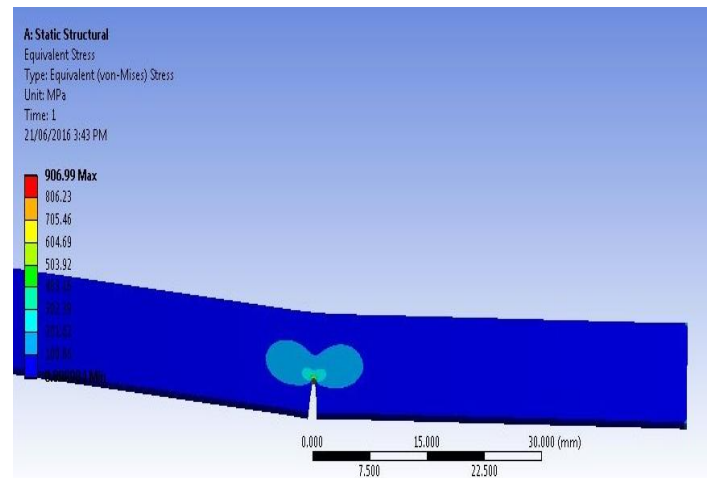


Fig no.3 structural analysis for plate no.1

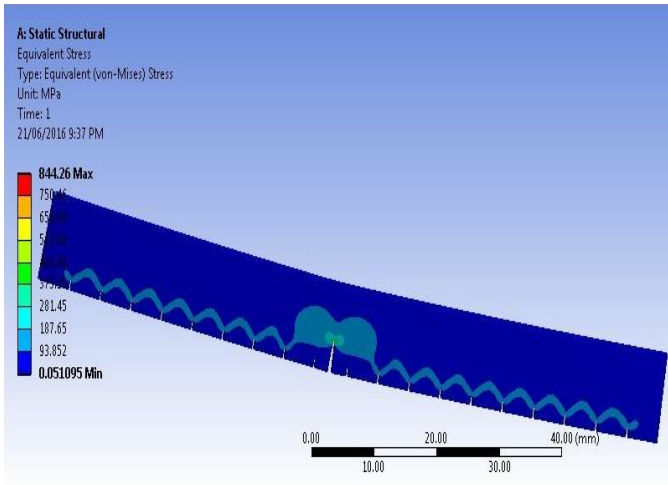


Fig no.4 structural analysis for plate no.2

## Numerical Analysis:

$$I. \text{ Nominal stress} = \frac{\text{Force}}{\text{Area}}$$

Here we consider the area near the tip surface where maximum stress are observed. This area will remain same for both plates.

$$\text{Area} = 5\text{mm} \times 1\text{mm} = 5\text{mm}^2$$

$$I. \text{ Nominal stress} = \frac{800}{5} = 160 \text{ N/mm}^2$$

$$\text{Stress concentration factor} = \frac{\text{actual stress}}{\text{nominal stress}}$$

Value of actual stress is taken from ansys results.

$$I. \text{ For Plate with a crack : } K_t = \frac{906.99}{160} = 5.65$$

II. plate with a crack & notches:

$$K_t = \frac{844.26}{160} = 5.27$$

## RESULT & DISCUSSION :-

Results are recorded for stress concentration factors for tensile loading condition both plates are as follows

	Maximum stress by FEA (MPa)	Nominal Stress from (P/A) (MPa)	Stress concentration Factor
Chip Without nano notches	906.99	160	5.66
Chip With nano notches	844.26	160	5.27

Table 1: Result table

## CONCLUSION:-

It is observed that value for stress concentration factor gets reduced by small amount when plate is provided with notches along the surface. by choosing proper dimensions of notches mechanical strength of plates can be improved. Provision of notches on surface of thin plate helps to reduce the stress concentration at tip of crack. Stress gets distributed across the tip of notches; which helps to increase life of thin plate.

## ACKNOWLEDGEMENT

I am thankful to my guide Prof. S. R. Kulkarni & HOD Prof. P. G. Karajagi for guidance and assistance. I am also grateful to other researchers and authors whose work provided a platform for this paper

## REFERENCES

- [1] P. Vukusic, J. Sambles, Photonic structures in biology, Nature 424 (2003) 852-855.
- [2] F. Song, K.L. Lee, A.K. Soh, F. Zhu, Y.L. Bai, Experimental studies of the Journal of Experimental Biology 207 (2004) 3035-3042.
- [3] Y.R. Jheng, Analysis on the Stress Concentration Effects of Two-dimensional Periodic Surface Feature, Master Thesis, National Cheng Kung University, 2009.
- [4] C.T. Huang, J. Yeh, Stress Relaxation of V-shaped Notch on Single Crystal Silicon Using Nanoholes, Master Thesis, National Tsing Hua University, 2009
- [5] M.L. Williams, Stress singularities resulting from various boundary conditions in angular corners of plates in extension, Journal of Applied Mechanics 19 (1952) 526-528.
- [6] G.C. Sih, Stress analysis of notch problems, Mechanics and Physics 44 (1966) 356-366.
- [7] Meng-Kao Yeha. Stress Concentration Reduction at Crack Tip by Adding Nano notches on Chip Surface.(37 th NCTAM 2013)
- [8] Adis J. Muminovic\*. Numerical Analysis of Stress Concentration Factors 25th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM 2014