Theoretical Modeling of Full-Size Silicon Wafers with micro cracks for the purpose of defect diagnostics.

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Abstract:
A finite element analysis method using ANSYS software is used to model longitudinal resonance vibrations in full size single-crystal and multicrystalline silicon wafers with micro cracks of different sizes and locations on the wafer. Calculations are made for 5*5inch wafer on three resonance ultrasonic vibrations modes that are the most visible modes experimentally. The micro cracks are taken at different locations of the wafer and the frequency shift of the resonance mode is calculated. Some preliminary experimental results were obtained to confirm the theoretical results.

1. Resonance modes in the wafer without cracks.

The wafers we worked with were 5*5 inch octagonal wafers shown in figure 1.

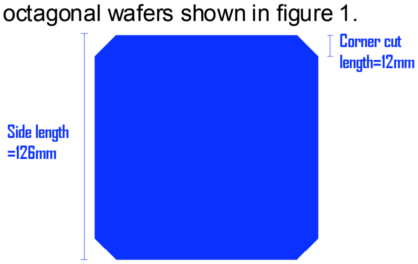

Figure 1 5*5 inch octagonal wafer

These wafers have many resonance vibration modes, however we mainly focused on the three modes that are visible in most experiments. In a wafer without defects these modes are at 39769, 51908 and 57708 Hz. The mode shape of these 3 resonance modes are given below:

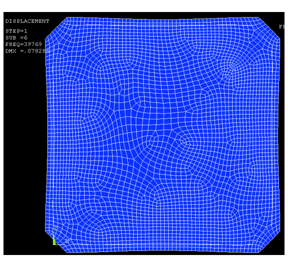

Figure 2 1st resonance mode at 39769

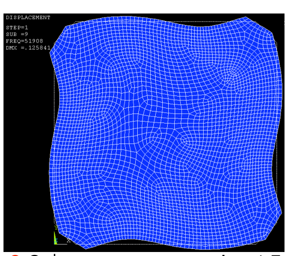

Figure 3 2nd resonance mode at 51908

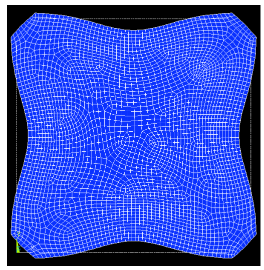

Figure 4 3rd resonance mode at 57708

2. The location of the micro cracks.

We decided to work with 10mm cracks that are located on the side of the wafer at an angle of 45% to the side. The width of the crack was modeled at 0.1mm, however previous models with width of 0.01mm and 0.001 mm suggest that frequency shift does not depend on width in this range. The angle and the length of the cracks are roughly those one would see in practice. The cracks were made in the corner of the wafer, its middle, and two more between, at 1/3 and 1/6 wafer length.

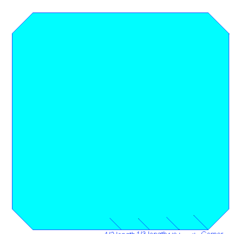

Figure 5 location of the micro cracks

After the cracks have been modeled, we proceeded to find the new resonance frequency modes in these new models. As can be seen from figure 6, resonance modes in the wafers with a 10mm crack are similar to those without a crack.

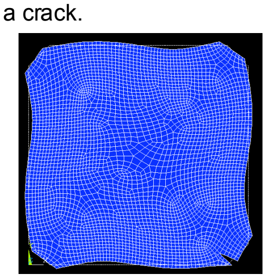

Figure 6 2nd mode in a wafer with a 10mm corner crack.

3. The frequency shift as result of the cracks.

As result of these models it was found that cracks cause a frequency shift in the resonance vibration modes. Other than a few exceptions, we witnessed a low frequency shift in both theoretical models and experimental results. The shift increases with the size of the crack, but the exact relation between the crack size and frequency shift is not yet clear.

The dependence of frequency shift on the position of the crack on the wafer is given in a table below.

Crack location	1 mode frequency	1 mode frequency shift	2 mode frequency	2 mode frequency shift	3 mode frequency	3 mode frequency shift
No crack	39769	0	51908	0	57708	0
Corner	39720	-49	51763	-145	56920	-788
1/6 of length	39604	-165	50448	-1550	57834	+126
1/3 of length	39604	-165	51451	-457	57336	-372
½ of length	39600	-169	51682	-326	57425	-283

Table 1 Frequency shift dependence on the location of micro cracks

It is evident from the table that the frequency shift in those 3 resonance modes shows a different dependence from the crack location. The maximum frequency shift in the first mode occurs in the middle, in the second mode it is in the corner, and in the third mode it is roughly at 1/ 6 of the wafer length

CONCLUSIONS The Finite Element Method was used to calculate the frequency shift of different resonance vibration modes in the wafers for solar cells when these wafers were modeled with micro cracks at different locations. Preliminary results indicate that the existence and location of the micro crack can be estimated by looking at the frequency shift of the resonance modes of the wafer.

Acknowledgements.
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References

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