Application of multi-wavelength light source to micro welding inspection

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Abstract. We have developed a multi-wavelength light source and apply it to micro welding inspection. We project light rays from multiple white light super bright LEDs on a reflection grating. These LEDs are mounted on the specific position to give the diffracted ray with the wavelength range from 480 to 680 nm. The diffracted ray is pass to an optical fibre. The orientation of fibre tube is fixed so diffracted light from each LED will give a specific wavelength. The bandwidths of lights from all LEDs are quite narrow (< 50 nm), which is possible to be used as a light source for multi-wavelength imaging. The diffracted light is transported via optical fibre to a microscope used to inspect the micro welding points on a microelectronics circuit. Due to its very small size, the welding defects are hard to detected, even with high intensity white light. We find that, for typical welding points, the light with wavelength 500 to 600 nm can significantly enhance the contrast of welding image. This agree well with our preliminary result that, with our RGB light source, the maximum contrast can be obtained with the green - yellow to orange - red light. We expect our results to be useful to the inspection of micro welding, especially when integrated to some automation, e.g. machine vision system.

1. Introduction

A light source with narrow wavelength bandwidth is importance in many applications. This is why laser is very useful in modern optics. One active area that benefit from such a light source is multispectral or multi-wavelength imaging. In this application several images of an object are taken, each with different wavelengths. By proper image processing techniques, more information can be obtained than normal imaging using broadband, e.g. white light, source. There are a lot of applications using this technique, ranging from military application, remote sensing, medical imaging, agricultural, or even in art [1–3].

We can perform multi-wavelength imaging in two difference ways. For the first method we take the image using a broadband or natural light source as usual. Images from different wavelengths are separated via wavelength separator, e.g. prism of diffraction grating. Recently there is the development of special kind of CCD sensor which has a large number of filters on each pixel. The advantage of this method is that the device is compact and easy to use [4]. However, using special kind of CCD making this imaging system quite expensive.

For the second method, which we are interested in this work, we take the image using a special light source which can produce multi-wavelength light with narrow wavelength bandwidth. The advantage of this method is that the image can be captured via conventional CCD camera, or we may use grey
scale sensor if we want to speed up the capture time. However, we need to develop the multi-wavelength light source. We may produce multiple narrow bandwidth lights using a filter wheel or projecting a broadband light into a monochromator and use its output. These two methods have a common disadvantage from their slow response due to their mechanical nature. Recently, there is a collection of LEDs with different wavelengths, each of which has a bandwidth of 20 – 70 nm. However, the available wavelengths are limited. We can work only with some discrete range of wavelengths using these LEDs.

In this work we provide an alternative method using a combination of broadband light sources and a diffraction grating to produce an arbitrary wavelength with narrow bandwidth light, where the wavelength depends on the orientation of starting light sources. Description of our system is given in the next section.

2. Multi-wavelength light source using LEDs and diffraction grating

Configuration of our system is shown in figure 1. Super bright, white light, LEDs are placed in the holder, project light rays with different incident angles on a diffraction grating. The diffracted light rays with specific diffraction angle are collected through two narrow slits. These rays can then be transported via optical fiber to be used as a light source.

![Figure 1. Schematic (a) and actual arrangement (b) of apparatuses used in our system.](image)

According to the grating equation [5], \( d (\sin \alpha + \sin \beta) = m \lambda \), for a specific diffraction angle \( \beta \) the output wavelength can be determined from the incident angle \( \alpha \). This means that each LED will produce different output wavelength depending on its orientation. On-off control of each LED can be perform using a microcontroller board. In our system we control the LEDs through the GPIO ports of a Raspberry PI unit by a python program.

Note that the wavelength of output rays is not directly determine from above grating equation. It depends on the position and width of the slits. It also depends on the angular distribution of the intensity and relative spectrum function of the light from the LED. Detail calculations of the output wavelength can be found in [6]. A linear relation between output wavelength and LED incident angle is shown in figure 2. The calibration line can be described as \( \lambda = (8.08 \pm 0.41) \alpha + (415.2 \pm 9.2) \), where \( \lambda \) is in nanometer and \( \alpha \) is in degree. Root mean square uncertainty of the output wavelength at the maximum intensity is about 6.7 nm and the FWHM of the intensity distribution is less than 50 nm for all LEDs. The system is thus suitable to use as a light source for the multi-wavelength imaging system.
3. Application to micro welding inspection

As an example of the usage of our system, we apply it as a light source for micro welding inspection. Welding defect is an important problem in microelectronic. Due to its very small size, the defects are hard to detected, even with high intensity white light. In our case, we want to inspect the soft welding, or soldering, point in a circuit. Width of the circuit is about 0.5 mm. There are 8 welding points on the circuit (at the bottom of the 8 dark rectangular bars in figure 3), so each welding point width is about 60 µm. The main component used as the solder is tin (Sn), which has maximum reflectance for the light with wavelength of 500 to 600 nm, while the circuit line which made from copper has low reflectance at this range. We expect that, using light source with the wavelength in this range to capture the circuit imaging should gives the highest contrast. In our light source there are 3 LEDs those are arranged to give output light ray with wavelengths of 480, 545 and 680 nm, which corresponding to green, yellow and red light, respectively. We focus the output light rays on the circuit area using a set of lenses to obtain the high intensity incident light. We capture the circuit images using the focused output light rays from these LEDs, which are demonstrated in figure 3.

![Figure 3. Color images of microcircuit captured by the light with wavelength of (a) 480 nm, (b) 545 nm and (c) 680 nm](image)

To compare the contrast, the color images are transformed to grey scale. Thresholding is applied to the images, by turning the pixels that have lower grey level than the threshold value to be dark. While increasing the threshold value, only image with high contrast can survive. Figures 4 – 6 are the grey scale version of figure 3, with the threshold value of 100, 150 and 200, respectively. It is obvious that only circuit image taken by the light with the wavelength of 545 nm survive the thresholding of 200. The wavelength of light source suitable for welding inspection in this circuit is about 550 nm.
4. Conclusion
We have shown an application of our multi-wavelength light source by apply it to the micro welding inspection. By varying the wavelength of the output light ray, we can find the most suitable wavelength that give the highest contrast to the circuit image. We can arbitrarily change the wavelength by changing the orientation of the corresponding LED. This can be done easily by making the holder with proper orientation. No special LED which gives a narrow wavelength is needed. In practice we can make many holders as desire to get the output wavelength in needed. We expect our results to be useful to the inspection of micro welding, especially when integrated to some automation, e.g. machine vision system.

References
[1] Belusic G, Ilic M, Meglic A and Pirih P 2016 Sci. Rep. 6 32012
[2] ElMasry G, Mandour N, Al-Rejaie S, Belin E and Rousseau D 2019 Sensors 19 1090
[3] Pelagotti A, Del Mastio A, De Rosa A and Piva A 2008 IEEE Signal Process. Mag. 25(4) 27
[4] Smith R B 2012 Introduction to Hyperspectral Imaging (Raymond, NE: MicroImages, Inc.)
[5] Palmer C 2014 Diffraction Grating Handbook (New York: Newport Corporation)
[6] Markchum J and Jinuntuya N 2020 Proc. 58th Kasetsart Univ. Annu. Conf. no 2 (Bangkok: Kasetsart University) p 10