nano spectrometer, an example of Convergence Science and Technology

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1. Introduction

Optical spectroscopy has been used in a variety of scientific or professional material analysis applications. It has a simple but very significant advantage over other analytic technologies: it is non-invasive and non-destructive. In response to growing demands for personal everyday applications, many efforts have been reported to miniaturize optical spectrometers, taking various different approaches [1]. Most approaches involve diffractive optics elements (such as gratings etc.) and yet could not make the size compact enough. Also these approaches usually involve complicated manufacturing processes and high manufacturing cost. In this presentation, we demonstrate how we utilize the convergence science and technology to overcome the limit of diffractive optics, making the size and cost of spectrometer, compact and affordable for consumer applications.

2. nano spectrometer and its fabrication

Single layer plasmonic filter array, plus signal processing

To overcome the size issue of the conventional diffraction grating based approach, we adopted the filter array based approach. Most of other filter array based approaches use Fabry-Perot filter technology using the different thicknesses for different wavelength filters, and this different thickness requirement causes huge issues to fabrication process and cost for large scale arrays. We take a disruptively different approach, a single layer filter array structure based on plasmonics [2]. The filters in the filter array all have the same thickness and the same materials stack, but all have different lateral nano-scale sizes and shapes which make enable different transmission characteristics. The individual transmission spectral shapes of these nano-optic filter structures are far from the ideal or desired shapes. We then combine a signal processing approach, spectrum reconstruction method, to calculate the estimated input light spectrum [2][3].

Nanoimprint fabrication process

Fabricating such single layer nano-optic structures at low cost, is also extremely difficult, if not impossible, even with most advanced semiconductor wafer process technology, because all the nano-scale structures, currently as many as one thousand, have all different via hole-like shapes and sizes. We adopted a disruptive wafer scale nanoimprint process technology [4] and achieved our goal to mass produce the nano spectrometer.

3. Conclusions

Thanks to such disruptive convergence approaches, the nano spectrometer size became as small as 5x5x5mm and the cost would become affordable for many IoT applications. The performance of nano spectrometer is already close to the performance of the low end commercial spectrometer. Since the technology platform is very flexible, it can evolve into different wavelength ranges and further higher resolution, enabling even more future applications.

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References

[1] R.F. Wolffenbuttel, “MEMS-based optical mini- and microspectrometers for the visible and infrared spectral range,” J. of Micromechanics and Microengineering, 15 , 2005, pp. 145-152.
[2] B. Choi, “Digital Filter Spectrum Sensor,” US Patent US8284401, 2007
[3] C. Chang, “Filter-based miniature spectrometers: spectrum reconstruction using adaptive regularization,” IEEE Sensors Journal, vol. 11, no. 7, pp. 1556-1563, July, 2011
[4] http://www.scivax.com/cp-bin/en/