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Low optical reflectance of vertically aligned graphene sheets

The optical absorption of single layer graphene is 2.3% and almost flat in wide range of wavelengths, therefore touch screen and light emitting devices using graphene transparent conductive films are demonstrated [1,2]. On the other hand, low reflectance applications used graphene nanostructures, which are made from graphite by plasma etching, are proposed [3]. The reported optical properties of the fabricated graphene nanostructures are almost the same as the data of single wall carbon nanotube (SW-CNT) forest [4]. Thus, it is considered that the graphene is one of the most appropriate wide range of low reflectance materials which can improve sensitivity and resolution of microscopies, spectrometers and telescopes. The reported graphene nanostructures and SW-CNT forests are fabricated at the temperature range over 600ºC. Such a high temperatures to form the structures prevent from forming these carbon structures on various substrates. Therefore, decreasing of temperatures to form carbon nanostructure is one of the issues to be solved toward practical applications.
In our previous study, it was reported that graphene was deposed at low temperature (about 300ºC) on large area using microwave plasma chemical vapor deposition. We report about deposition of vertically aligned graphene sheets on Cu foils by surface wave microwave plasma CVD, and optical properties of these sheets characterized after transferring from a Cu foil to a quartz substrate, which enables us to evaluate reflectance and transmittance of the inherent vertically aligned graphene sheets.

The vertically aligned graphene sheets were deposited by surface wave microwave plasma CVD. From SEM and TEM observations, the samples consist of vertically alined multilayer graphene sheets on few layer graphene which are parallel to the substrate. The heights of the graphene sheets are tuned by the deposition periods.
In order to messure the optical transmittance and reflectance of the vertically aligned graphene sheets without substrate components, the Cu foils were etched in ferric chloride ($FeCl_3$) and then the vertically aligned graphene sheets were transferred onto the quartz substrates.

Reflectance and transmittance spectra as a function of light incident angle were measured by UV-visible-NIR spectrometer. The incident angle was changed from 10 to 40º for reflectance measurement and from 0 to 40º for transmittance measurement. The wavelength was changed from 300 to 800nm. As comparison, a flat-surface multi layer graphene (about 90 layers) on a quartz substrate and the commercially available black alumite were used.
The measured reflectance and transmittance spectra of the vertically aligned graphene sheets on the quartz substrate are shown in Fig. 1 (a) and (b), respectively. Weak anguler dependence of the reflectance spectra is obtained. The reflectance increases with increasing the wavelength for all the incident angles, which is consistent with the previous reports about the carbon nanostructures.
Fig. 2 shows the reflectance spectra of at the incident angle of 10º of the vertically aligned graphene sheets, the black alumite plate and the multi layer graphene film. It is confirmed that the lowest reflectance is obtained from the vertically aligned graphene sheets.

We developed the transfer processs of the vertically aligned graphene sheets from the deposited substrate to the target substrate and evaluate the inherent optical properties of the vertical aligned graphene sheets. From the obtained data, it is expected that the sensitivity and the resolution of spectrometer and microscope can be improved by vertical aligned graphene sheets.

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References

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Figures

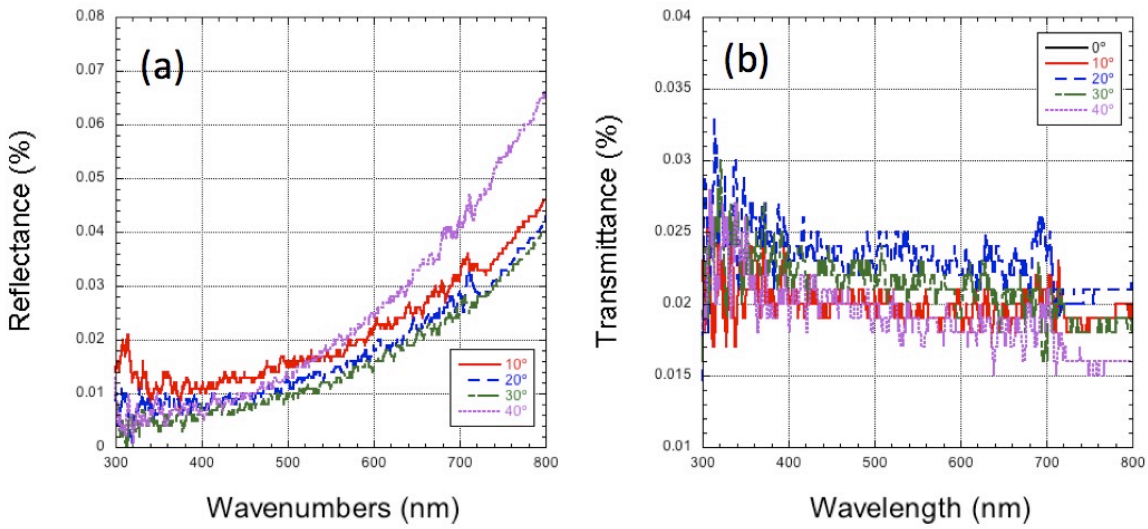

Figure 1: (a) angler-dependent reflectance and (b) transmittance of vertically aligned graphene sheets. For wavelengths between 300 to 800nm.

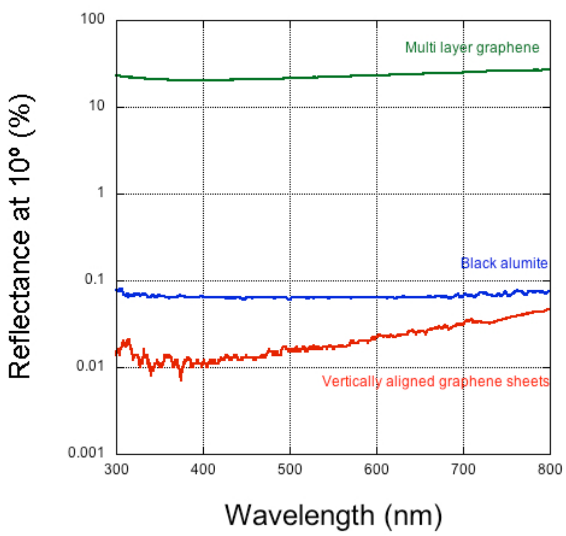

Figure 2: the reflectance at the incident angle of 10º for the vertically aligned graphene sheets, black alumite and multi layer graphene.