Surface Processing for Area Selective Mist Deposition of Nanocrystalline Quantum Dot Films

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Patterned deposition using mechanical masks of nanocrystalline quantum dot (NQD) films by means of mist deposition on various substrates was demonstrated earlier (e.g. [1,2]). The process can be used for the variety of purposes including security labeling, barcode printing as well as in photonic detection/conversion device fabrication.

The goal of this study was to investigate the feasibility of patterned mist deposition of NQD films by pre-deposition surface functionalization instead of the use of mechanical masks during deposition. With this approach desired pattern could be created through the bottom-up process by properly functionalizing SAM material prior to NQD film formation by mist deposition.

In this study NQDs deposited were CdSe/ZnS core/shell NQDs featuring average diameter of 6.5 nm and corresponding red (620 nm) emission wavelength. The method of mist deposition converts colloidal solution, in this case CdSe/ZnS NQDs suspended in toluene, into a fine mist of sub-micrometer sized particles using an atomizer. The mist droplets are carried from the atomizer to the deposition chamber by ultrapure N_2 carrier gas and then coalesce on the substrate in the presence of an electric field. Surfaces of substrates used in this experiment, including Si wafers and laboratory glass were functionalized by immersion in trichloro (1H,1H,2H,2H-perfluorooctyl) silane (FOTS) and let dry in an ambient air. UV exposure was carried out in ambient air and at room temperature using apparatus equipped with low-pressure mercury lamp featuring intense 185 and 254 nm wavelengths. Further modifications of the SAM material were accomplished by means of the lamp-based rapid optical surface treatment (ROST) at the temperatures up to 300 ^oC. Characterization method employed included contact angle measurements as well as optical microscopy and UV fluorescence.

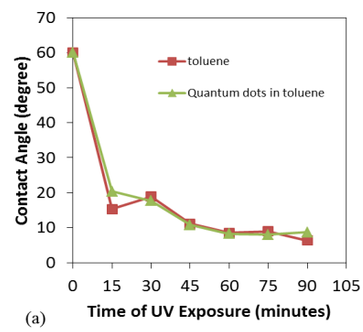
Regardless of the substrate used the surface of the FOTS SAM material did show well defined phobic characteristics (average contact angle of about 100^o in the case of water and about 65^o in the case of toluene). FOTS surface phobicity was not affected even when exposed to strongly oxidizing solutions such as H_2SO_4:H_2O_2. On the other hand, UV exposure of FOTS SAM resulted in conversion of its surface from phobic to philic (Fig. 1a). The process was found to be weakly dependent on the content of oxygen in the ambient, and hence, it was deemed to be controlled primarily by the UV promoted decomposition of FOTS. Rapid thermal treatment at the temperatures of 100^{o}C and above was effective in restoring phobic characteristics of FOTS surface (Fig. 1b)

In terms of selectivity of deposition the results obtained in this study were strongly affected by the modification of wetting properties of the surface by the presence of electric field accelerating process of mist deposition. This effect, known as electrowetting, was influencing FOTS surface wettability and preventing selectivity of the deposition process. The effect can be reversed with the ROST process. The manipulation of the surface wettability of FOTS using UV light, electric field and temperature toward improved selectivity of the deposition process is at the core of this experiment.

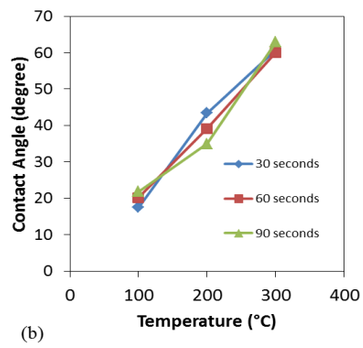
The results obtained demonstrate feasibility of the approach in which UV exposure of FOTS film through mechanical masks allows subsequent selective area mist deposition of NQDs films. In the full account of this work a complete set of experimental results obtained in the course of this investigation is presented and possible application of the process under investigation considered.

References

[1] A. Kshirsagar, et al., *ECS J. S.S.S.T, 2(5),(2013)*
[2] S. Pickering, et al., *Opto-Electro. Rev.20(2), 148 (2012)*

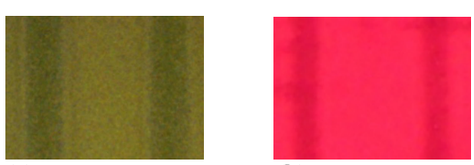


(a)



(b)

Fig. 1 Contact angle of FOTS as a function of (a) time of exposure to UV light and (b) temperature .



(a) (b)

Fig. 2 Images of selectively deposited films (a) optical microscope, (b) UV fluorescence.