Smart Nanostructured Films for Sensitive Chemical Detection and Analysis

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We report on the development of smart, nanostructured films that function as substrates for surface enhanced Raman scattering (SERS) detection of chemicals. The films are made of polyethylene terephthalate (PET) layers partially embedded with multi-walled carbon nanotubes (MWCNTs) and coated with a thin layer of gold (Au). The films are fabricated by a facile method involving spin-coating, acid dip, and magnetron sputtering. The "smart" aspect is from the ability to tune the SERS enhancement factor (up to 10^8) by controlling the MWCNT content in the films, and the thickness of the Au coating. The films are robust in liquid media, have a long shelf life, and are inexpensive compared to SERS substrates made by methods like electron beam lithography.[1] This is the first report on the use of a polymer layer partially embedded with carbon nanotubes to create a nano-scale texture and arbitrary "hot-spots", contributing to the SERS effect.

To prepare the films, a dispersion of 0.5 wt% MWCNTs in a 0.5 wt% aqueous solution of Triton X-100 dispersant in de-ionized water was spin-coated on PET layers (commercially available printer transparency films). This was followed by curing on a hot plate at 75 °C for 30 min. The films are subsequently immersed in nitric acid for 5 min at room temperature to remove the dispersant and partially embed the MWCNTs on the PET surface (Figure 1A, B). The final step involved the magnetron sputtering of gold (Au) layer (~ 20 nm) on the PET-MWCNT films to yield the SERS substrates (Figure 1C). The resulting films (Figure 1D) were successfully used in the SERS detection of different chemicals. An example detection of 100 μM Congo red (CR) dye solution in de-ionized water is shown in Figure 2. Major spectral peaks associated with CR were detected on the Au coated MWCNT-PET films. The CR peaks at 1155 cm^{-1} and 1595 cm^{-1} are due to the N-C stretch and phenyl ring mode, while those at 1375 cm^{-1}, 1400 cm^{-1}, 1452 cm^{-1} correspond to N=N stretching modes.[2] In contrast, no CR related peaks were observed in the case of plain PET substrate. In this case, only the spectral peaks pertaining to PET were visible (Figure 2).

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[1] N.A. Abu Hatab, J.M. Oran, M.J. Sepaniak, ACS Nano, 2, 377 (2008).
[2] H.T. Beier, C.B. Cowan, I-H. Chou, J. Pallikal, J.E. Henry, M.E. Benford, J.B. Jackson, T.A. Good, G.L. Cote, Plasmonics, 2, 55 (2007).

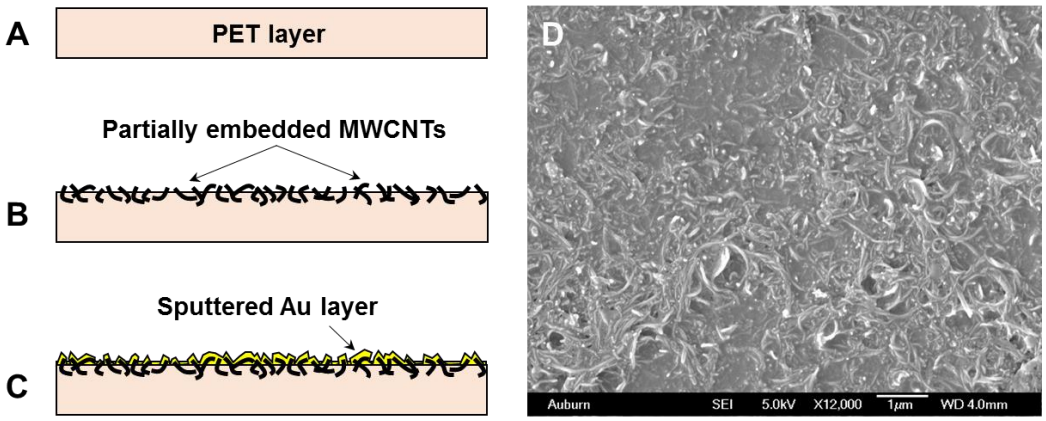

Figure 1: (A) - (C) Schematic diagram of fabrication of the nanostructured films; (D) SEM image of the developed nanostructured film showing MWCNTs partially embedded on the PET surface. The film's surface has a thin Au coating.

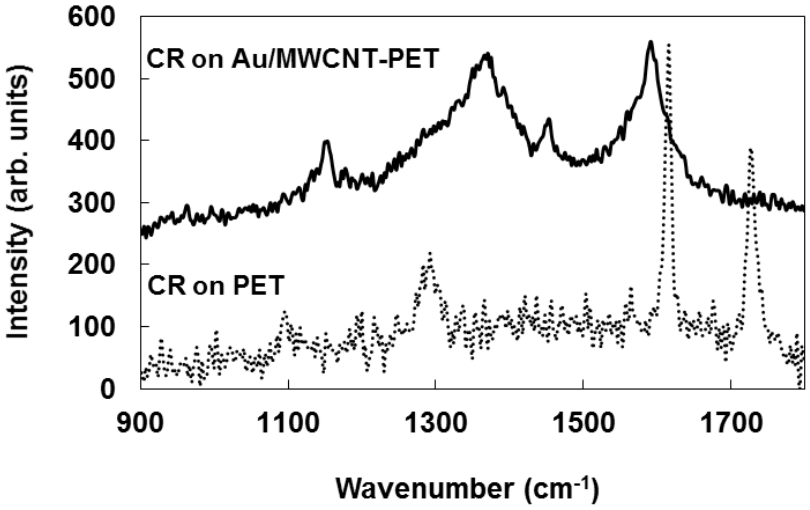

Figure 2: Raman spectra of CR on Au coated MWCNT-PET film shows spectral peaks relating to CR dye. Raman spectra of CR on plain PET shows spectral peaks at 1287 cm^{-1}, 1618 cm^{-1} and 1728 cm^{-1} corresponding to PET, with no visible peaks from CR dye.