Foldable Conductive Cellulose Fiber Networks Modified by Graphene Nanoplatelet-Bio-Based Composites

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Abstract

Truly foldable electronic components require a stretchable/foldable substrate modified with a conducting element that can maintain its electrical properties and mechanical integrity even after severe mechanical manipulations and repeated folding events [1,2]. We design and realize a material with these characteristics, exploiting the combination of biodegradable components (substrate and the polymer matrix) and graphene nanoplatelets [3]. A commercially available thermoplastic starch-polycaprolactone based polymer (Mater-Bi) and graphene nanoplatelets are simultaneously dispersed in an organic solvent obtaining conductive inks [3]. The obtained inks are spray painted on pure cellulose papers and hot-pressed into their fiber network after drying. Transmission electron microscopy shows that during hot-pressing, the conductive ink is physically embedded into the cellulose fibers (see Figures a-b), resulting in high electrical conductivity of the flexible composite. The resultant nanostructure is a flexible composite which exhibits isotropic electrical conductivity, reaching a sheet resistance value in the order of ≈10 Ω/□, depending on the relative concentration of the graphene nanoplatelets and the Mater-bi. Examples of excellent electrical conductivity are reported in Figures c-g. In Figure c, a photograph of a chip carrying 14 LED lights in contact with the conductor is presented. The circuit is powered by a 5V USB cable and the LEDs are lit up as shown in Figure c-d. The paper-like flexible conductors can sustain many harsh folding events (see Figure e-g), maintaining their mechanical and electrical properties and showing only a slight decrease of the electrical conductivity with respect to the unfolded sample. Unlike conductive paper technologies, the proposed paper-like flexible conductors demonstrate both sides electrical conductivity due to pressure-induced impregnation.

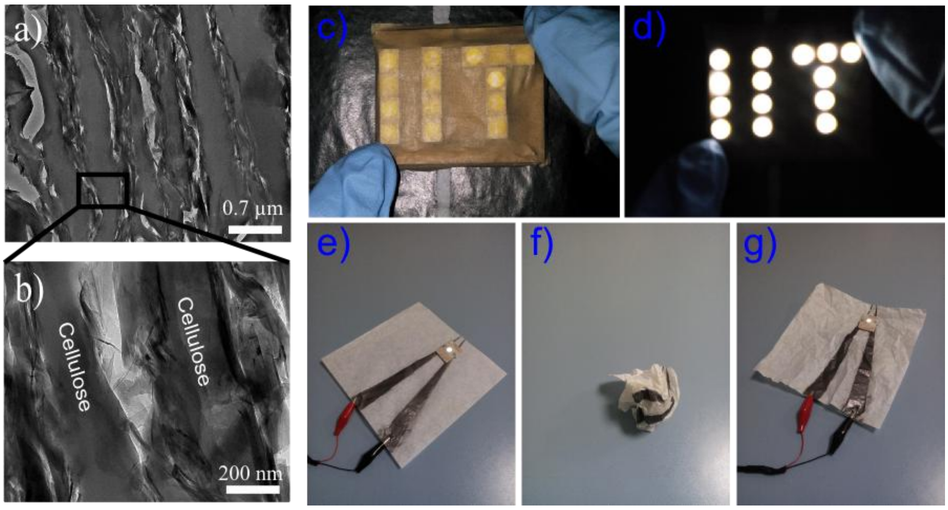

Figure: (a) and (b) show cross-sectional TEM images of the conductive composite. (a) is a lower magnification. In (b) a higher magnification image shows many GnPs flakes embedded into the cellulose fibers. (c) and (d) are photograph of a LED chip placed on the foldable conductor. (c) shows a 14 LED chip lighting up once the foldable paper-like conductor is connected to a 5 V USB port of a computer. In (d) the same photograph of (c) was taken in dark. (e) is a photograph of a similar concept of (c) for a single LED attached to a conducting base with conducting paths embedded into the cellulose sheet. (f) represents the same material squashed and pressed into a wrinkled ball by hands. (g) exhibits a photograph of the paper-like conductor after unflattening the squashed ball of (f). The LED light still works after this severe mechanical treatment.

References

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