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Flexible Electronic Substrate Film Fabricated Using Natural Clay and Wood Components with Cross-Linking Polymer

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Introduction & Background Work

- Construction of highly functional devices like printed and flexible electronics through green processes for environmental sustainability is getting much attention.

- To lower the consumption of chemical reagents and energy during the fabrication process.
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- Target for printed and flexible electronics is to form highly dense and fine electrodes by the hybridization of integrated circuits and/or rigid elements on flexible film substrates.

- Such flexible film substrates must have thermal durability, low thermal expansion comparable to electrode materials, and high gas barrier properties in order to protect the electrode from disconnection and corrosion.

- Therefore, the search for an ideal material as a sustainable flexible substrate with the above-mentioned properties is a continuing issue in the field of materials science.

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Water-Based Isotropically Conductive Adhesives: Towards Green and Low-Cost Flexible Electronics

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This paper reports the first high-performance water-based isotropically conductive adhesives (WBICAs) – a promising material for both electrical interconnects and printed circuits for ultralow-cost flexible/foldable printed electronics. Through combining surface iodination and in situ reduction treatment, the electrically conductivity of the WBICAs are dramatically improved (8 × 10 −5 Ω cm with 80 wt% of silver); moreover, their reliability (stable for at least 1440 h during 85 ° C/85% RH aging) meets the essential requirements for microelectronic applications. Prototyped applications in carrying light emitting diode (LED) arrays and radio frequency identification (RFID) antennas on flexible substrates were demonstrated, which showed satisfactory performances. Moreover, their water-based character may render them more environmentally benign (no volatile organic chemicals involved in the printing and machine maintenance processes), more convenient in processing (reducing the processing steps), and energy economic (thermally sintering the silver fillers and curing the resin is not necessary unlike conventional ICAs). Therefore, they are especially advantageous for mass-fabricating flexible electronic devices when coupled with paper and other low-cost substrate materials such as PET, PI, wood, rubber, and textiles.

Silver nanocolloid, a dense suspension of ligand-encapsulated silver nanoparticles, is an important material for printing-based device production technologies. However, printed conductive patterns of sufficiently high quality and resolution for industrial products have not yet been achieved, as the use of conventional printing techniques is severely limiting. Here we report a printing technique to manufacture ultrafine conductive patterns utilizing the exclusive chemisorption phenomenon of weakly encapsulated silver nanoparticles on a photoactivated surface. The process includes masked irradiation of vacuum ultraviolet light on an amorphous perfluorinated polymer layer to photoactivate the surface with pendant carboxylate groups, and subsequent coating of alkylamine-encapsulated silver nanocolloids, which causes amine–carboxylate conversion to trigger the spontaneous formation of a self-fused solid silver layer. The technique can produce silver patterns of submicron fineness adhered strongly to substrates, thus enabling manufacture of flexible transparent conductive sheets. This printing technique could replace conventional vacuum- and photolithographybased device processing

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Nanoparticle chemisorption printing technique for conductive silver patterning with submicron resolution

Relevant to lab work

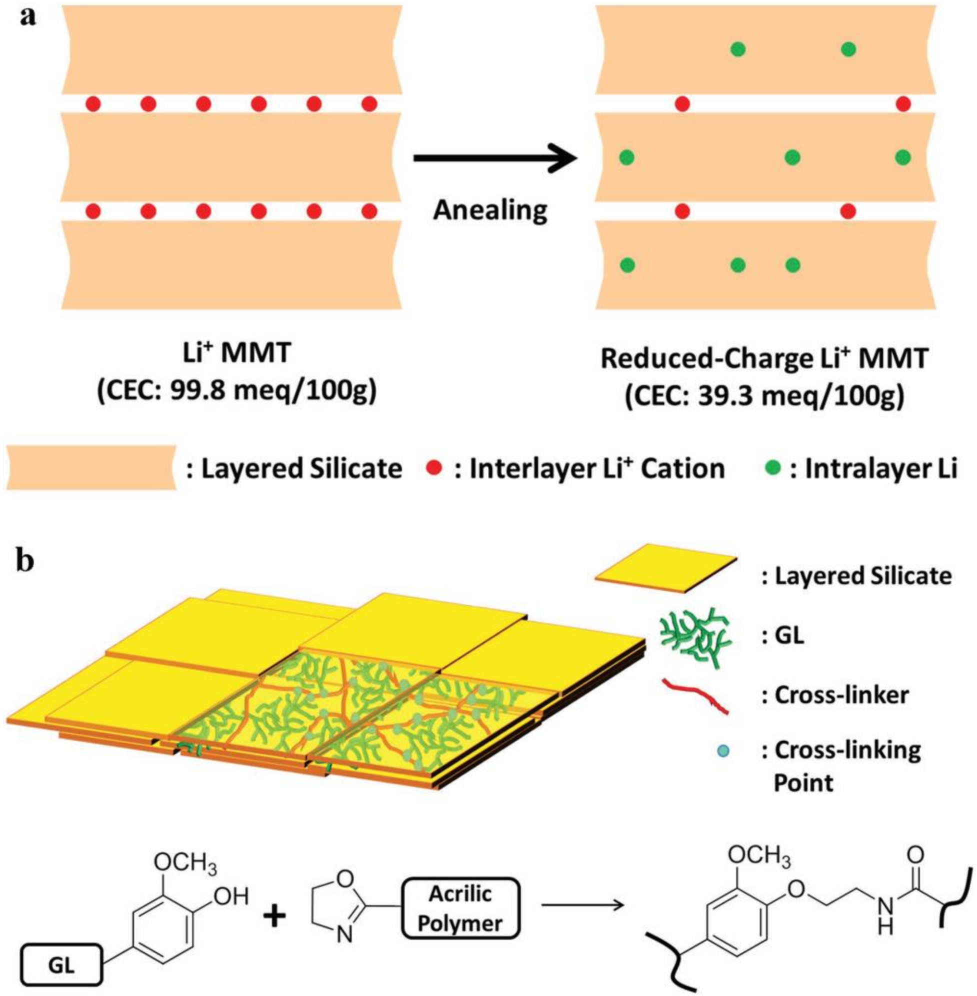
Different types of 2D materials like clays, nacre, superhydrophobic films are also in our lab which have a better tendency to form flexible substrates.

Electrospinning is also able to produce flexible nanofibrous membranes with polymers of different conductivities.

In this paper

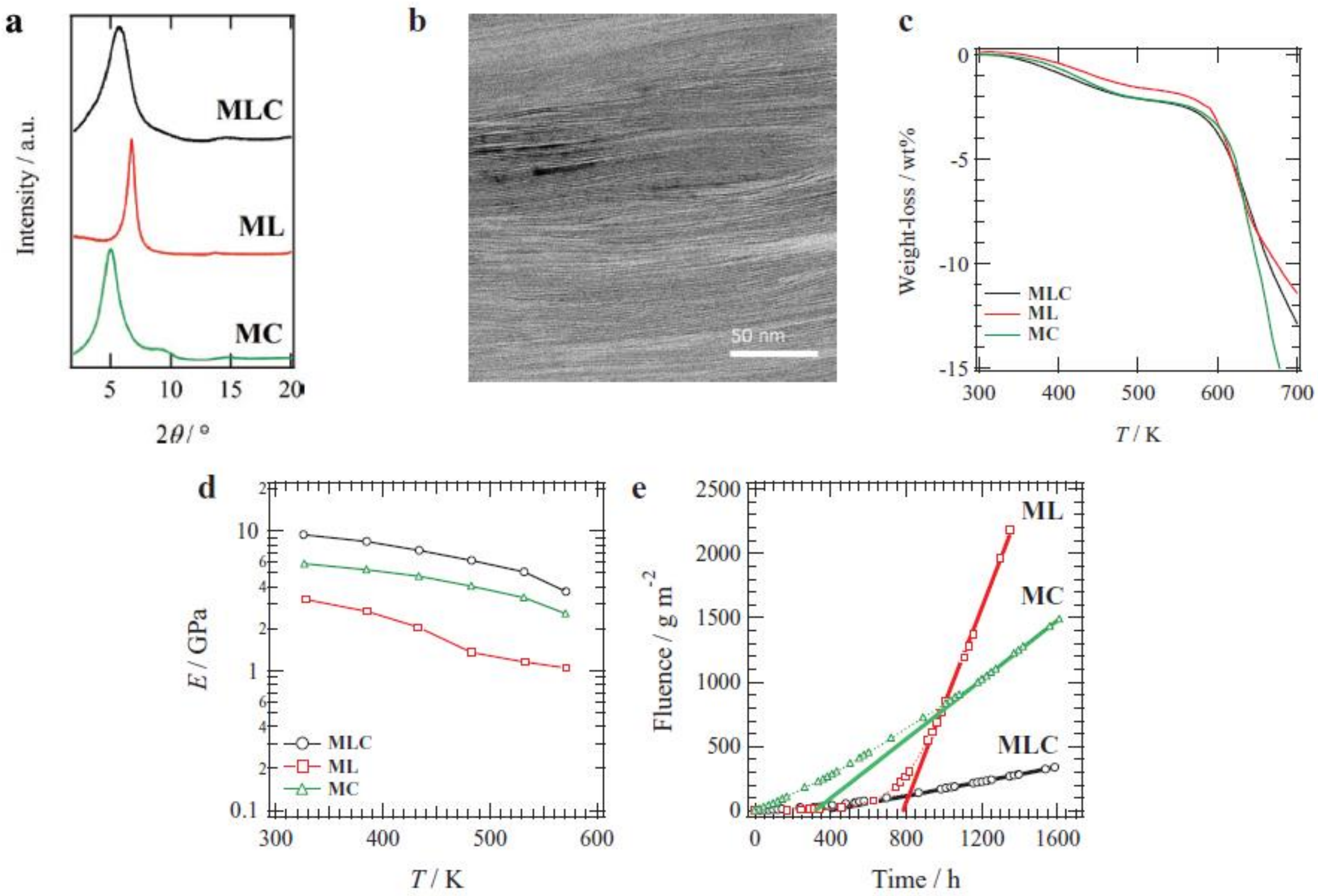
- This is the first report of a film substrate for electronics with natural components.
- This paper has focused on glycol modified biomass lignin and fabrication of a novel nanocomposite film with natural clay (Li^+ montmorillonite clay) along with a cross-linking polymer.
- Multilayer-assembled structure formed due to stacking nature of high aspect montmorillonite, results in thermal durability up to 573 K, low thermal expansion, and oxygen barrier property below measurable limit.
- In order to examine the applicability of the nanocomposite for substrate film, flexible electrodes are finely printed on it and touch sensor device can be constructed with rigid elements on the electrode.

Results and Discussion



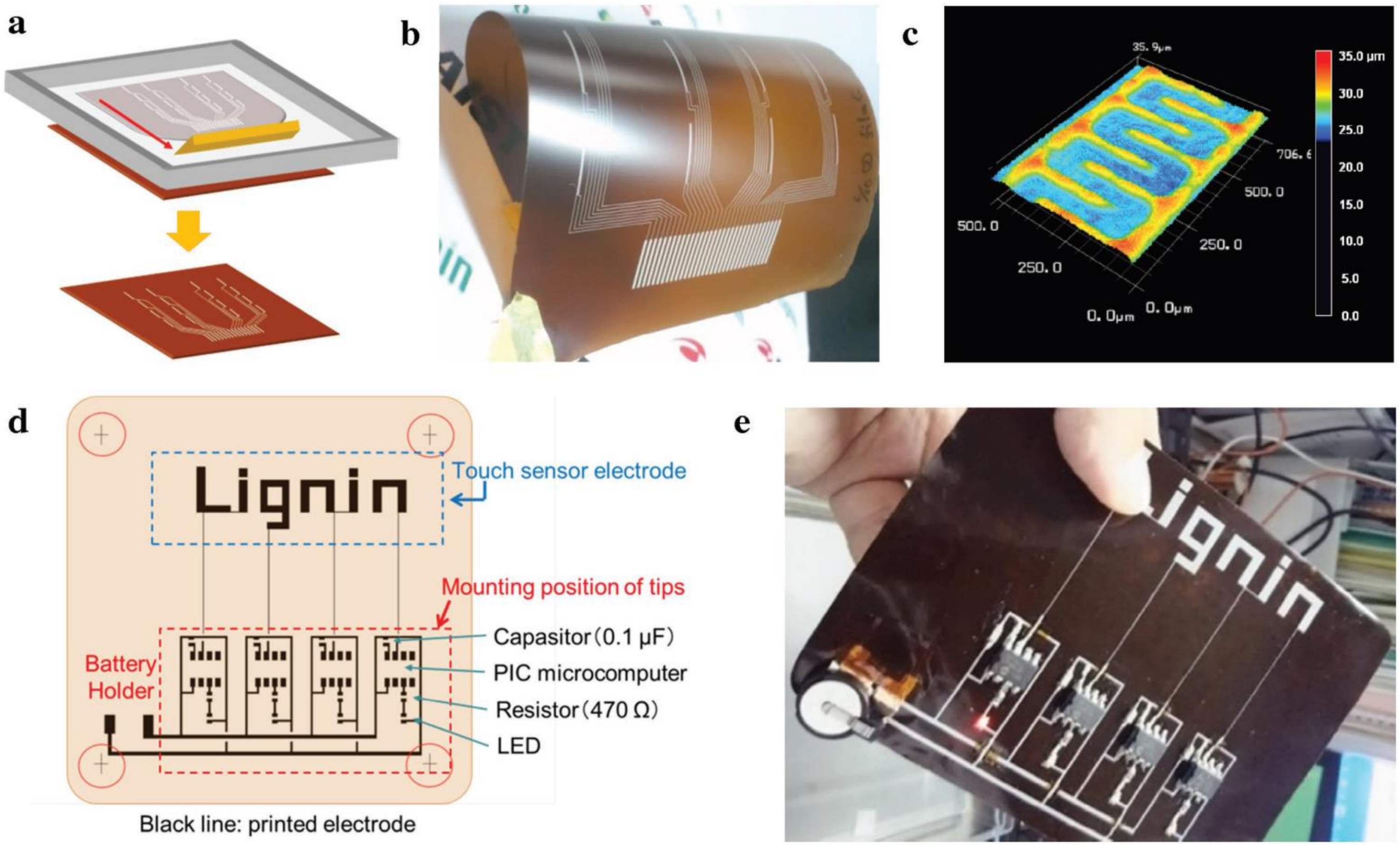
Schematic drawings of material design for high moisture barrier properties and dimensional stability. **a)** Li+ montmorillonite substance was preannealed for partial Li+ migration with dispersivity before nanocomposite fabrication. **b)** In the nanocomposite film, a crosslinking chemical reaction occurred between phenolic-OH (and/or carboxyl groups) of GL and the oxazoline groups in the side chains of the cross-linking polymer.

Results and Discussion



Structural characteristics and thermal, mechanical, and moisture vapor barrier properties for the nanocomposite films. Black, red, and green colored plots and lines correspond to the MLC, ML, and MC films, respectively. **a)** XRD patterns for the films in the 2θ range between 2° and 20°. **b)** Cross-sectional TEM image of the MLC film. **c)** TG profiles of the films. **d)** Temperature-dependent Young's moduli (*E*) of the films. **e)** Time-dependent vapor permeation fluence and linear fittings (bold line) for estimation of gas permeability constants.

Results and Discussion



Schematic drawing of screen-printing method, image of printed electrode, and a touch sensor device with rigid elements on a flexible base film of MLC. **a)** Mesh screen with electrode pattern set on the film surface. Ag paste is dropped onto this screen, and then the squeegee is moved forward to print this pattern. **b)** Photograph of rolled film with printed electrode. **c)** Co-focus 3D laser scanning microscopic image of Ag electrode printed on the film surface in a 500 × 706 μm2 area. **d)** Construction of rigid elements and printed electrode for touch sensor device**. e)** Photograph of the touch sensor device in the emitted state by touching the "L."

Conclusions

- Ecofriendly flexible electronic substrate was successfully fabricated using natural clay and lignin derivative of wood component.
- Li+ MMT, GL, and a cross-linker were mixed and dried at moderate temperature to develop the nanocomposite film.
- The cross-linked polymers were homogeneously dispersed in Li+ MMT, resulting in multilayered stacking. This layered structure provided thermal stability, low linear coefficient of thermal expansion,high moisture vapor barrier property and high oxygen gas barrier properties below the detection limit.
- The developed nanocomposite film provided an excellent substrate for screen printing of well-defined test electrode patterns.
- Integrated circuits and rigid elements have been mounted to construct a touch sensor device.