セルロースナノファイバーコーティングによるイオンマイグレーション抑制挙動の評価

Evaluation of electrochemical migration inhibition by cellulose nanofiber coatings

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Electrochemical migration is an important reliability issue related to corrosion in electronic devices. During electrochemical migration process, two oppositely biased and closely spaced electrodes are connected by water or humid, and dissolved metal ions migrate to form dendrites (Fig 1a). Such dendrite growth may ultimately lead to short circuit failure to devices. For better reliability, various coatings have been adopted for sealing electrodes from exploring to water. However, most coatings can only provide physical barriers for the surface of electronics but no efficient inhibition once water presents inside and metal ions form dendrites. TEMPO-oxidized cellulose nanofiber (TOCN), as a wood-derived nanomaterial, has great potential to interact with metal ions for its rich carboxylate groups at surface. Our group's previous work has coated TOCN-Na (with sodium carboxylate groups) on copper electrodes, and it exhibited a totally new inhibition strategy. Instead of waterproofing, the coated TOCN-Na film formed hydrogel that can trap dissolved copper ions to prevent dendrites growing thus inhibiting electrochemical migration (Fig 1b). The previous work suggested the role of hydrogel on electrochemical migration inhibition, however, a deeper understanding towards the mechanism involved is needed to optimize the effect.

The carboxylate groups on TOCNs can provide places to modify their surface structures by converting the counter-ions of carboxylate groups to other ions. In this work, surface-modified TOCNs with different alkyl ammonium carboxylates were coated on copper electrodes for testing their electrochemical migration inhibition performances (Fig 1c). From *in situ* observation, the inhibition abilities of surface-modified TOCNs were closely related with their hydrogel formation. Since the surface-modified TOCNs were first dispersed into water from the coated dry films and attracted by anodes, the experiments for simulation and investigation of redispersion behaviors were carried and the conductivity of redispersed dispersion were measured. With high redispersion ability, the TOCNs were more easily/quickly dispersed into water; while with high conductivity, the dispersed TOCNs showed more attraction by electric fields and tended to form dense hydrogel at anode for effective inhibition. The morphology and 3D structure of formed hydrogel in relation to the inhibition behavior were also further investigated. These results will help to understand using TOCNs coating for anticorrosion protection of electronics more clearly, which can be expanded to other bio-based hydrophilic polymers for the use of improving electronics' reliability in a sustainable way.

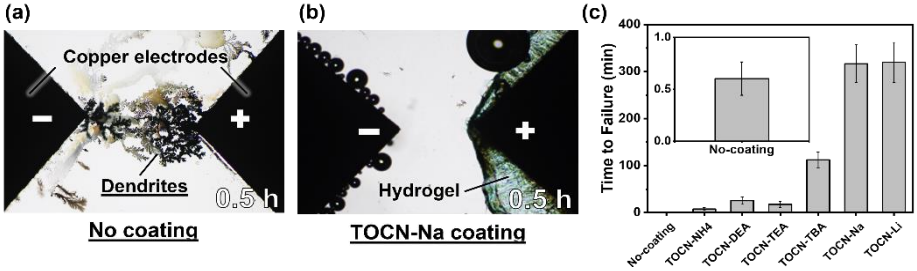

Figure 1: Water submersion test of copper electrodes: (a) without coating, (b) with a TOCN-Na coating; (c) Time to failure of electrochemical migration inhibition by different types of TOCN coatings.