

Electrostatic adhesion in polymer nanocomposites and blends

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Abstract – Miscibility and compatibility limitations to the making of multi-phase polymeric solids are overcome by mixing the components in aqueous dispersion and drying it under controlled conditions, when widely different particles undergo capillary adhesion that is followed by electrostatic adhesion in the dry solid, where different particles are bridged by counter-ions. This procedure is especially effective using very small, wetting particles like polymer latexes and exfoliated clays or nano-sized particles and it allows the formation of thermoplastic, non-vulcanised rubber nanocomposites. Mechanical and other properties are fine-tuned by changing the bridging counter-ions and particle surface properties.

Polymer material designers are often limited by mixing and compatibility issues, while attempting to combine different phases into the desired structures. Success has been achieved by using growingly sophisticated synthetic chemical techniques, self-assembly and even nanofabrication but designing for large-scale production requires the use of raw materials that are not subject to environmental or economic constraints. Recent work from this laboratory is showing that electrostatic adhesion is an effective means to self-assemble highly incompatible polymer and inorganic phases, relying on their surface characteristics only and with little dependence from bulk properties. Electrostatic adhesion between different phases was considered decades ago but it was later neglected and went into discredit. The recent discovery of experimental procedures for making polymer-clay nanocomposites by blending and drying aqueous dispersions [1], without doing any chemical modification of the clay or the polymer and forming nanocomposites with tunable and unprecedented properties led to the re-examination of electrostatic adhesion. Experimental evidence was obtained using clays with different cations [2], showing a strong dependence of the nanocomposites mechanical properties with the counter-ion. Converging results were obtained by examination of dilute dispersions dried on microscope sample holders, showing that particles with completely different bulk properties easily form aggregates, irrespective of the particle electric charge in dispersion. According to model calculations [3] electrostatic adhesion between different phases can indeed account for stabilization energies comparable to covalent bonding.

These findings help us to understand previous results on particle self-assembly forming colloidal crystals and macrocrystals, while revealing a new, broad-scope strategy that can be explored by designers, helping them to overcome well-known mixing limitations while using “green” procedures and relying on the role of water as a cohesion mediating agent.

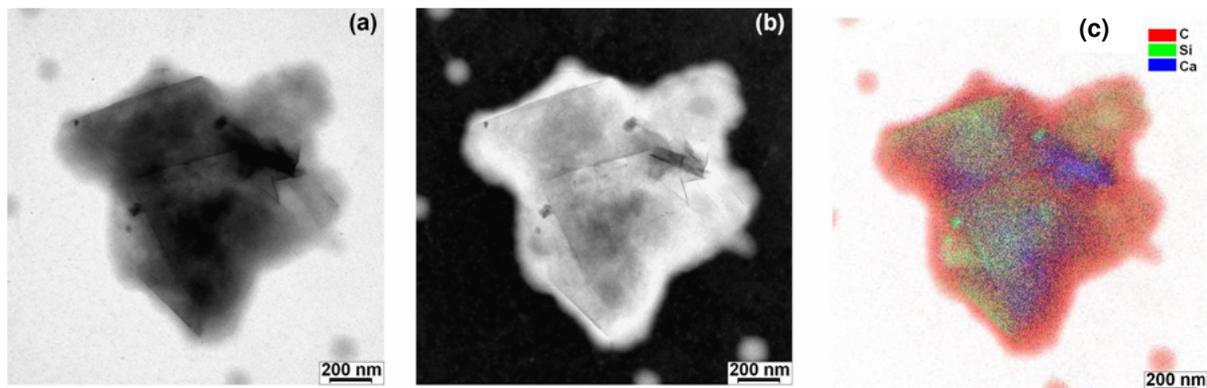


Figure 1: Analytical microscopy evidence for electrostatic adhesion between polymer and clay particles, dried over coated microscope grids from dilute dispersion. Left: bright-field image; center: 25 eV EFTEM micrograph; right: composite C (red), Si (green) and Ca (blue) elemental maps..

References

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