Material Properties of Nanoclay PVC Composites

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SUPPORTING INFORMATION

Below additional information is provided in support of the data and conclusions of the manuscript. Specifically:

In tables A, B, and C, the complete set of tensile data, including the respective uncertainties, is provided for two strain-rates [250 mm/min, tables A and B, a rate which provides representative tensile (Young's) moduli[1], and 50 mm/min, table C, which provides more representative elongation at break and yield points[1]].

In figure S1, color-corrected digital photos of the specimens are provided to demonstrate haze, indicative of dispersion of additives and fillers, and color development upon thermal aging (specimens are shown on a white background bearing black lettering, the specimen thickness is 1.56±0.10 mm). These same specimens were used for the yellowness index measurements discussed in the manuscript.

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[1] ASTM D638

Table A – Effect of dispersant and mixing conditions on the tensile properties of DIDP-plasticized PVC and its (nano)composites. For comparison, the tensile properties of non-plasticizer PVC (nano)composites are also shown. All systems are before thermal aging.

Tensile @ 250 mm/min	Tensile modulus **E** (MPa)	ΔE (%)	Tensile strength σ_{max} (MPa)	Δσ (%)	Elongation at break ε_{max} (%)	Δε (%)
PVC	**2390 ± 189**	0	**49.4 ± 0.9**	0	**32 ± 2**	0
PVC + hectorite	2724 ± 91	14	49.8 ± 1.6	1	33 ± 14	3
PVC + bentonite	2797 ± 136	17	49.0 ± 1.1	-1	24 ± 5	-25
PVC + talc	2273 ± 79	-5	49.4 ± 1.7	0	27 ± 6	-16
PVC + kaolin	2248 ± 159	-6	48.2 ± 0.7	-2	41 ± 6	28
PVC + plasticizer	**2032 ± 124**	0	**43.2 ± 1.2**	0	**43 ± 29**	0
PVC + plasticizer + hectorite (MO1)	1920 ± 159	-6	44.9 ± 1.2	4	44 ± 9	2
PVC + plasticizer + bentonite (MO1)	2230 ± 430	10	45.7 ± 1.3	6	44 ± 11	2
PVC + plasticizer + hectorite (MO2)	2172 ± 177	7	45.0 ± 2.3	4	35 ± 8	-19
PVC + plasticizer + bentonite (MO2)	2037 ± 237	0	45.2 ± 0.9	5	37 ± 9	-14
PVC + plasticizer + dispersant	1930 ± 245	-5	42.4 ± 1.7	-2	67 ± 14	49
PVC + plasticizer + dispersant + hectorite (MO1)	2051 ± 490	1	44.4 ± 1.2	3	40 ± 14	-7
PVC + plasticizer + dispersant + bentonite (MO1)	2243 ± 308	10	45.6 ± 1.5	6	36 ± 8	-16
PVC + plasticizer + dispersant + hectorite (MO2)	2249 ± 178	11	46.3 ± 0.1	7	40 ± 19	-7
PVC + plasticizer + dispersant + bentonite (MO2)	2166 ± 26	7	45.9 ± 2.0	6	33 ± 4	-23

MO1: mixing order 1, one-shot direct compounding;
MO2: mixing order 2, pre-gel of organo-clay in DIDP with subsequent addition to PVC;
plasticizer: di-isodecyl phthalate (DIDP, at 10 wt% loading);
dispersant: propylene carbonate (at 1wt% loading);
hectorite: tallow-triethanol-ammonium modified EA-3300 (at 3 wt% loading);
bentonite: tallow-triethanol-ammonium modified EA-3284 (at 3wt% loading).

Table B – Effect of dispersant and mixing conditions on the tensile properties of DIDP-plasticized PVC and its (nano)composites. For comparison, the tensile properties of non-plasticizer PVC (nano)composites are also shown. All systems are after thermal aging (80 ^{o}C for 7 days).

Tensile @ 250 mm/min	Tensile modulus **E** (MPa)	ΔE (%)	Tensile strength σ_{max} (MPa)	Δσ (%)	Elongation at break ε_{max} (%)	Δε (%)
PVC	**2014 ± 208**	0	**49.6 ± 1.6**	0	**30 ± 2**	0
PVC + hectorite	2184 ± 193	8	49.4 ± 1.7	0	18 ± 4	-40
PVC + bentonite	2200 ± 104	9	47.8 ± 1.7	-4	18 ± 5	-40
PVC + talc	2242 ± 99	11	48.8 ± 1.6	-2	27 ± 7	-10
PVC + kaolin	1936 ± 75	-4	49.3 ± 1.5	-1	27 ± 2	-10
PVC + plasticizer	**1922 ± 147**	0	**41.2 ± 1.9**	0	**51 ± 11**	0
PVC + plasticizer + hectorite (MO1)	1998 ± 500	4	39.7 ± 0.7	-4	42 ± 26	-18
PVC + plasticizer + bentonite (MO1)	2101 ± 238	9	42.3 ± 1.9	3	42 ± 2	-18
PVC + plasticizer + hectorite (MO2)	1922 ± 103	0	39.8 ± 0.6	-3	37 ± 10	-27
PVC + plasticizer + bentonite (MO2)	2232 ± 430	16	38.9 ± 1.5	-6	17 ± 3	-67
PVC + plasticizer + dispersant	2250 ± 169	17	38.7 ± 0.5	-6	61 ± 17	20
PVC + plasticizer + dispersant + hectorite (MO1)	2204 ± 331	15	40.8 ± 0.5	-1	33 ± 12	-35
PVC + plasticizer + dispersant + bentonite (MO1)	2072 ± 143	8	40.2 ± 0.7	-2	41 ± 12	-20
PVC + plasticizer + dispersant + hectorite (MO2)	2501 ± 187	30	40.5 ± 1.1	-2	49 ± 8	-4
PVC + plasticizer + dispersant + bentonite (MO2)	2389 ± 84	24	40.2 ± 0.5	-2	43 ± 4	-16

MO1: mixing order 1, one-shot direct compounding;
MO2: mixing order 2, pre-gel of organo-clay in DIDP with subsequent addition to PVC;
plasticizer: di-isodecyl phthalate (DIDP, at 10 wt% loading);
dispersant: propylene carbonate (at 1wt% loading);
hectorite: tallow-triethanol-ammonium modified EA-3300 (at 3 wt% loading);
bentonite: tallow-triethanol-ammonium modified EA-3284 (at 3wt% loading).

Table C – Effect of dispersant and mixing conditions on the tensile properties of DIDP-plasticized PVC and its (nano)composites. For comparison, the tensile properties of non-plasticizer PVC (nano)composites are also shown. All systems are before thermal aging.

Tensile @ 50 mm/min	Tensile Modulus **E** (MPa)	Yield Point		Elongation at break	Tensile strength	Break Energy
		Stress **σ** (MPa)	Strain **ε** (%)	ε_{max} (MPa)	**σ** (MPa)	(J)
PVC	1518 ± 2	49.3 ± 0.8	4.9 ± 0.2	35.2 ± 9.7	49.3 ± 0.8	2.5
PVC + hectorite	1721 ± 138	48.8 ± 0.2	4.7 ± 0.3	39.9 ± 16.5	48.8 ± 0.2	2.9
PVC + bentonite	1752 ± 40	47.6 ± 0.6	4.4 ± 0.3	16.8 ± 5.7	47.6 ± 0.6	1.2
PVC + talc	1577 ± 21	48.9 ± 0.8	4.9 ± 0.2	29.0 ± 2.6	48.9 ± 0.8	1.9
PVC + kaolin	1567 ± 29	47.4 ± 0.1	5.0 ± 0.1	40.1 ± 12.4	47.4 ± 0.1	2.8
PVC + plasticizer	1606 ± 64	42.9 ± 1.5	3.9 ± 0.1	69.2 ± 11.4	42.9 ± 1.5	4.6
PVC + plasticizer + hectorite (MO1)	1553 ± 25	44.3 ± 0.1	4.4 ± 0.1	30.1 ± 4.1	44.3 ± 0.1	1.7
PVC + plasticizer + bentonite (MO1)	1676 ± 47	45.6 ± 1.8	4.2 ± 0.1	21.7 ± 12.2	45.6 ± 1.8	1.1
PVC + plasticizer + hectorite (MO2)	1565 ± 50	46.2 ± 0.4	4.6 ± 0.2	29.0 ± 6.8	46.2 ± 0.4	1.6
PVC + plasticizer + bentonite (MO2)	1685 ± 6	46.0 ± 0.9	4.3 ± 0.2	26.3 ± 15.6	46.0 ± 0.9	1.5
PVC + plasticizer + dispersant	1435 ± 20	43.4 ± 0.6	4.3 ± 0.2	42.3 ± 7.2	43.4 ± 0.6	2.2
PVC + plasticizer + dispersant + hectorite (MO1)	1581 ± 35	44.2 ± 0.4	4.1 ± 0.2	18.9 ± 3.9	44.2 ± 0.4	1.0
PVC + plasticizer + dispersant + bentonite (MO1)	1587 ± 28	44.0 ± 0.3	4.4 ± 0.2	26.2 ± 4.9	44.0 ± 0.3	1.4
PVC + plasticizer + dispersant + hectorite (MO2)	1507 ± 55	44.9 ± 1.4	4.6 ± 0.2	17.1 ± 2.6	44.9 ± 1.4	0.9
PVC + plasticizer + dispersant + bentonite (MO2)	1602 ± 34	44.5 ± 0.7	4.4 ± 0.3	22.4 ± 12.4	44.5 ± 0.7	1.2

MO1: mixing order 1, one-shot direct compounding;
MO2: mixing order 2, pre-gel of organo-clay in DIDP with subsequent addition to PVC;
plasticizer: di-isodecyl phthalate (DIDP, at 10 wt% loading);
dispersant: propylene carbonate (at 1wt% loading);
hectorite: tallow-triethanol-ammonium modified EA-3300 (at 3 wt% loading);
bentonite: tallow-triethanol-ammonium modified EA-3284 (at 3wt% loading).

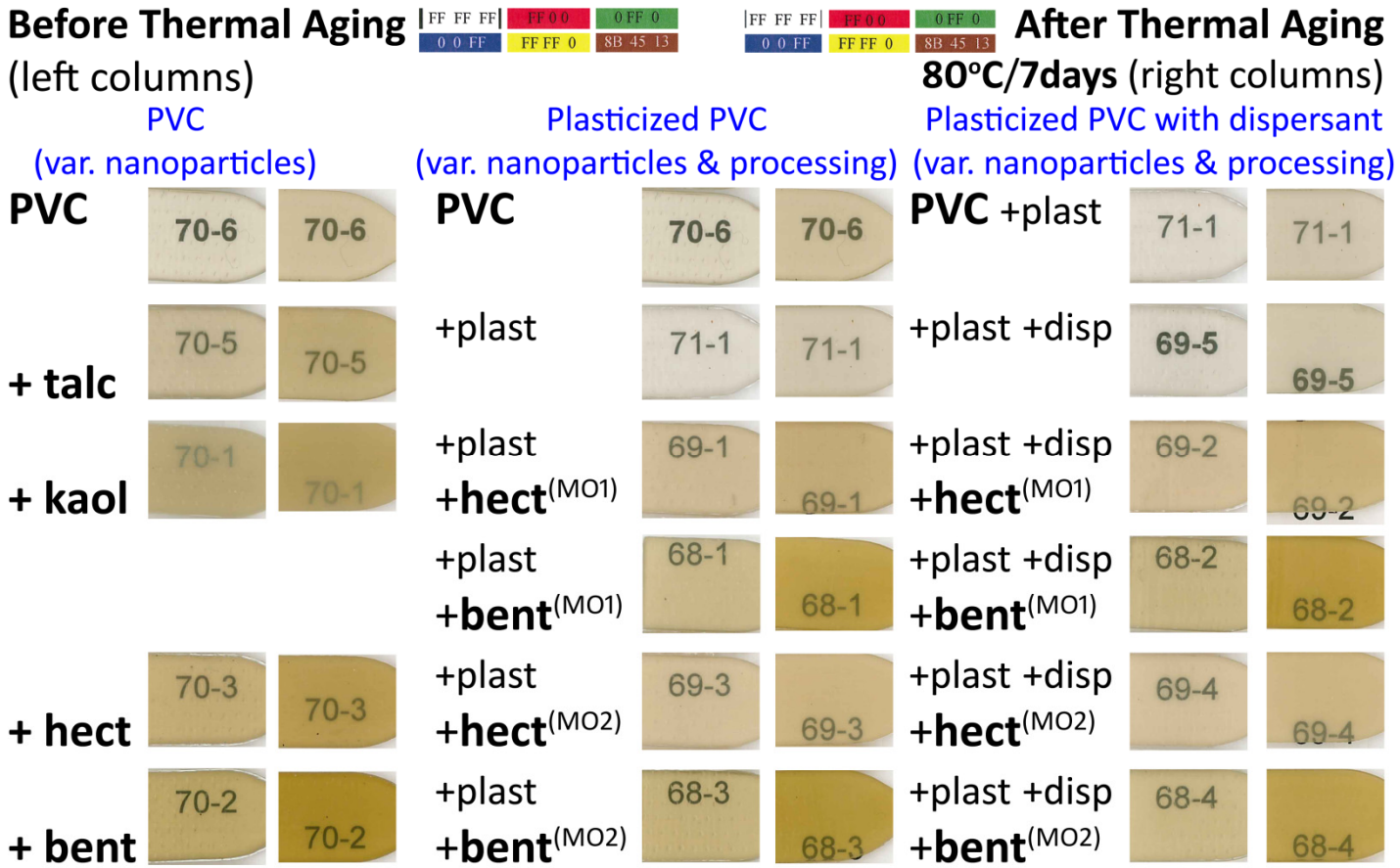

Figure S1 – Color development and haze: Effects of additives: DIDP-plasticizer, dispersant, and fillers, as well as additional effect of thermal aging (80 °C for 7 days, **right columns**) compared to before thermal aging (**left columns**). [**hect**: organically modified hectorite; **bent**: organically modified bentonite; **kaol**: kaoline; **MO1** and **MO2**: processing methods, as described on tables A-C above; **plast**: DIDP-plasticizer; **disp**: propylene carbonate dispersant]. Sample numbering is as follows:

PVC + DIDP	71-1	PVC + DIDP + dispersant	69-5	PVC	70-6
PVC + DIDP + Bentonite (MO1)	68-1	PVC + DIDP + Bentonite + disp (MO1)	68-2	PVC + Kaolin	70-1
PVC + DIDP + Bentonite (MO2)	68-3	PVC + DIDP + Bentonite + disp (MO2)	68-4	PVC + Bentonite	70-2
PVC + DIDP + Hectorite (MO1)	69-1	PVC + DIDP + Hectorite + disp (MO1)	69-2	PVC + Hectorite	70-3
PVC + DIDP + Hectorite (MO2)	69-3	PVC + DIDP + Hectorite + disp (MO2)	69-4	PVC + Talc	70-5
PVC + TETQ (quat amine surfactant)	70-4	PVC + DIDP + Hectorite	71-2		
		PVC + DIDP + Bentonite	71-3		