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posite material with the shear thickening formulation in the matrix. In one embodiment, the fiber includes carbon fiber, glass fiber, or polyamide fiber.

Below, exemplary embodiments will be described in detail so as to be easily realized by a person having ordinary knowledge in the art. The inventive concept may be embodied in various forms without being limited to the exemplary embodiments set forth herein. Descriptions of well-known parts are omitted for clarity, and like reference numerals refer to like elements throughout.

EXAMPLES

Shear Thickening Formulation

Example 1

76 g of silicon oxide with an average diameter of about 500 nm (SO-E2 silica, commercially available from Denka Co.), 24 g of polyethylene glycol (PEG, Mw=200, commercially available from Aldrich), and 75 g of ethanol solvent (commercially available from Cheng Chun Plastics Co.) were put into a one-necked glass reactor (500 mL) and then stirred at room temperature for 2 hours to 24 hours. Thereafter, the solvent was removed by vacuum evaporator and the reaction result was concentrated to a shear thickening formulation with physical properties as tabulated in Table 1.

Example 2

Similar to Example 1, and the differences in Example 2 were the silicon oxide amount being changed to 78 g and the PEG amount being changed to 22 g. Physical properties of the shear thickening formulation are tabulated in Table 1.

Comparative Examples 1-2

Similar to Example 1, the differences in Comparative Examples 1-2 were the silicon oxide amount and the PEG amount (being changed as shown in Table 1). Physical properties of the shear thickening formulations are tabulated in Table 1.

TABLE 1

	Silicon oxide (g)	PEG-Mw and amount	Testing temperature (° C.)	Initial viscosity (cps)	Maximum viscosity (cps)	Shear rate (s^{-1})	Silica/PEG ratio
Comparative Example 1	60	PEG-200 40 g	25	158	1164	180	1.50
Comparative Example 2	70	PEG-200 30 g	25	439	1230	58	2.33
Example 1	76	PEG-200 24 g	25	37802	290078	8	3.17
Example 2	78	PEG-200 22 g	25	29040	294803	9	3.54

*Viscometer: Brookfield HBOV - III

As shown in Table 1, the shear thickening formulations in Examples 1 and 2 with silicon oxide and the PEG having a weight ratio of 3 to 4 might achieve the maximum viscosity at a shear rate of 8 s^{-1} to 9 s^{-1}. Compared to Comparative Examples 1 and 2, Examples 1 and 2 may largely enhance the fast thickening effect.

Example 3

The physical properties of the shear thickening formulation in Example 1 were tested at 50° C., as shown in Table 2.

Examples 4 and 5

Similar to Example 1, and the differences in Examples 4-5 were the silicon oxide amount, the PEG Mw, and PEG amount (being changed as shown in Table 2). Physical properties of the shear thickening formulations are tabulated in Table 2.

TABLE 2

	Silicon oxide (g)	PEG-Mw and amount	Testing temperature (° C.)	Initial viscosity (cps)	Maximum viscosity (cps)	Shear rate (s^{-1})
Example 1	76	PEG-200 24 g	25	37802	290078	8
Example 3	76	PEG-200 24 g	50	24171	24171	—
Example 4	76	PEG-200 12 g PEG-1000 12 g	25	42977	320528	7
Example 5	76	PEG-200 12 g PEG-1000 12 g	50	37801	215760	8

As shown in Table 2, the mixtures of two PEGs with two Mw values in Examples 4 and 5 made the shear thickening formulations still have fast thickening effect at high temperature.

Examples 6 and 7

Similar to Example 4, and the differences in Examples 6 and 7 were a different amount of nanoclay (Laponite RDS clay, diameter of 25 nm, thickness of 0.92 nm, commercially available from Rockwood Co.) being added into the shear thickening formulations. The nanoclay amount and the physical properties of the shear thickening formulations are tabulated in Table 3.

TABLE 6

	Silicon oxide (g)	PEG-Mw and amount	Clay or nanocellulose content	Testing temperature (° C.)	Flexible testing results
Example 1	76	PEG-200 24 g	0	25	Acceptable
Example 2	78	PEG-200 22 g	0	25	Acceptable
Example 3	76	PEG-200 24 g	0	50	Acceptable
Example 4	76	PEG-200 12 g PEG-1000 12 g	0	25	Acceptable
Example 5	76	PEG-200 12 g PEG-1000 12 g	0	50	Acceptable
Example 6	76	PEG-200 12 g PEG-1000 12 g	Clay 1 g	25	Acceptable
Example 7	76	PEG-200 12 g PEG-1000 12 g	Clay 2 g	25	Acceptable
Example 8	76	PEG-200 12 g PEG-1000 12 g	0	75	Acceptable
Example 9	76	PEG-200 12 g PEG-1000 12 g	Clay 1 g	75	Acceptable
Example 10	76	PEG-200 12 g PEG-1000 12 g	Clay 2 g	75	Acceptable
Example 11	76	PEG-200 12 g PEG-1000 12 g	Nanocellulose 4 g	25	Acceptable

Composite Film Materials 2

Example 12

Carbon fibers (Tairyfil Carbon Fiber TC35-12K, commercially available from Formosa Plastics Corporation) were impregnated in the shear thickening formulation in Example 7. 8 sets of the impregnated carbon fiber layers were alternately stacked (0°/90°/0°/90° . . .). The stack was heated to 80° C. to 90° C. and pressed at 80° C. to 90° C. for 0.5 to 4.5 hours, thereby obtaining a composite film material.

Example 13

Glass fibers (Direct Roving 346, 2300±230 tex, commercially available from Taiwan glass Industry Corporation) were impregnated in the shear thickening formulation in Example 7. 4 sets of the impregnated glass fiber layers were alternately stacked) (0°/90°/0°/90°. The stack was heated to 80° C. to 90° C. and pressed at 80° C. to 90° C. for 0.5 to 4.5 hours, thereby obtaining a composite film material.

Example 14

Polyamide fibers (Twaron 2000, 1680 dtex, commercially available from Teijin Aramid Co., Ltd.) were impregnated in the shear thickening formulation in Example 7. 8 sets of the impregnated polyamide fiber layers were alternately stacked (0°/90°/0°/90° . . .). The stack was heated to 80° C. to 90° C. and pressed at 80° C. to 90° C. for 0.5 to 4.5 hours, thereby obtaining a composite film material.

Comparative Examples 3 and 4

Similar to Example 12, and the differences in Comparative Examples 3 and 4 were the carbon fibers being changed to steel plate (Thickness of 1.0 mm, commercially available from SHIN SHING CHIKUNG CO., LTD.) and six carbon fiber cross woven fabrics (G13-DB0301B, 3K carbon yarn, commercially available from HOMYTECH CO., LTD), respectively.

Comparative Example 5

No composite film material was used, which served as a control group of the impact test.

[Impact Test]

Subsequently, Comparative Example 5 and the composite film materials in Examples 12 to 14 and Comparative Examples 3 to 4 were checked by impact test. First, one face of the composite film material was adhered to clay with a thickness of 30 mm, and a steel round head (110.4 g and 14.29 cm^2) was disposed at another face of the composite film material, wherein the composite film material was disposed between the clay and the steel round head. The steel round head was impacted by a golf ball with a diameter of 42.67 mm and a velocity of 48 m/s, such that the composite film material was impacted by the steel round head with a velocity of 25 m/s, wherein the contact area of the steel round head and the composite film material was 0.1 to 3 cm^2. The sinking degrees and sinking volume of the composite film materials and the clay were then measured, as shown in Table 7.

TABLE 7

	Composite film material thickness (mm)	Sinking depth of the composite film material (mm)	Sinking depth of the clay (mm)	Sinking volume of the clay (c.c.)
Example 12	2.38	<0.20	0.30	1.00
Example 13	2.02	<0.30	0.35	1.50
Example 14	1.28	<0.30	0.30	1.50
Comparative Example 3	1.03	5.09	5.11	4.00
Comparative Example 4	1.74	0.50	4.36	3.00
Comparative Example 5	—	—	14.26	15.00

It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed methods and materials. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims and their equivalents.