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(54) DISCRIMINATING BETWEEN MATERIALS USING AN ELECTROADHESIVE GRIPPER

(57) A method of discriminating between different materials, the method comprising presenting a sample (4a, 4b, 4c) formed of a material to an electroadhesive gripper (1), and discriminating the material of the sample (4a, 4b ,4c) dependent upon whether the electroadhesive gripper (1) grips the sample. Typically, the method comprises driving the electroadhesive gripper (1) at a voltage, a frequency and duration and varying at least one parameter selected from the group comprising the voltage, the frequency and the duration with which the electroadhesive gripper (1) is driven, and then discriminating between the material of the samples (4a, 4b ,4c) dependent on whether it is gripped by the electroadhesive gripper (1) as each parameter is varied.

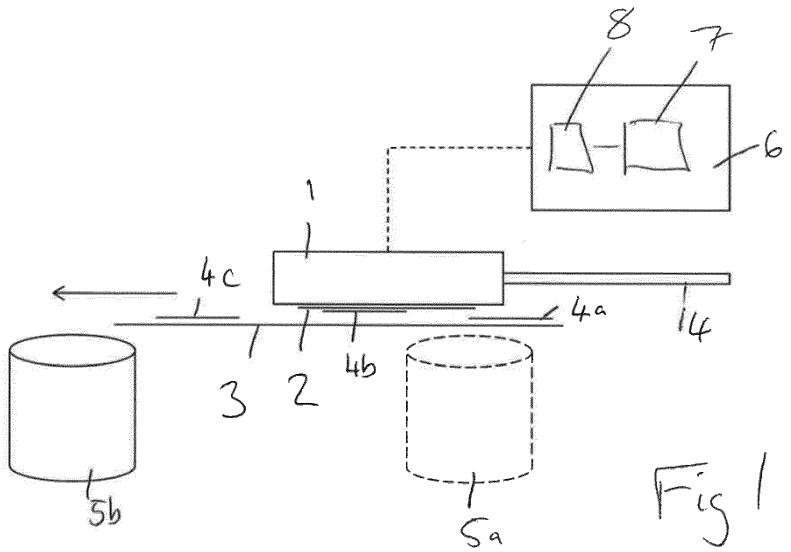

Fig 1

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Description

[0001] This invention relates to a method of and an apparatus for discriminating between materials using an electroadhesive gripper.

[0002] Electroadhesive grippers are known in the art. They comprise a pair of electrodes across which is applied either an alternating current (AC) or direct current (DC) drive signal. They generate an electric field. This generates an electrostatic charge in any material that may be nearby, especially where that material is non-conducting. The electrostatic charge generated is then attracted to the electrodes. Thus, the electroadhesive effect can be used to provide an astrictive, non-permeating gripper.

[0003] As such, the gripper avoids the problems of various other gripping techniques, such as impactive grippers (such as jaws or clamps) which may interfere with the structure of a delicate product, ingressive grippers which can puncture the structure of a product and contiguitive grippers which make use of chemical or thermal bonds and so may damage the product or leave residues thereon. Furthermore, unlike another common astrictive gripper, the electromagnet, it does not require that the material gripped to be magnetic.

[0004] Electroadhesive grippers have been used in wall-climbing robots such as shown in US Patent no 8 125 758. Sheet and hand-shaped electroadhesive grippers have been disclosed in the International (PCT) patent application published as WO2011/100028.

[0005] According to a first aspect of the invention, there is provided a method of discriminating between different materials, the method comprising presenting a sample formed of a material to an electroadhesive gripper, and discriminating the material of the sample dependent upon whether the electroadhesive gripper grips the sample.

[0006] As such, we present a novel use of an electroadhesive gripper, where the gripper can be used to discriminate between different materials. The uses of this method that present themselves are numerous, and include sorting recyclable materials, quality control to check the correct materials have been used and so on. Furthermore, this method uses an astrictive technique that has a low risk of damaging or contaminating the sample; this can be important when handling delicate goods, or goods that will be used in healthcare or other applications where infection and contaminant control is important.

[0007] The method may comprise conveying the sample to the gripper, typically on a conveyor. The method may comprise selectively moving the sample away from the gripper, such that samples of material that have been differently discriminated are deposited in different locations. For example, samples comprising a first material may remain on the conveyor (because they are not gripped by the gripper), whereas samples of a second material may be moved to a further location, such as another conveyor or a receptacle. As such, the gripper may be moveable, so that it can move samples off the conveyor to at least one further location.

[0008] Typically, the method comprises driving the electroadhesive gripper at a voltage and frequency, and for a duration. The method may further comprise varying at least one parameter selected from the group comprising the voltage, the frequency and duration with which the electroadhesive gripper is driven, and then discriminating between the material of the samples dependent on whether it is gripped by the electroadhesive gripper as each parameter is varied. As such, the method may allow selection between materials dependent on whether they are gripped at different voltages and frequencies.

[0009] The samples may typically, but not necessarily be of sheet material, typically a thin sheet or comprising a wall having thickness, which may be less than 2 mm thick. Examples of materials that can be distinguished are carbon fibre, glass, polyethylene, nitrile and latex rubber. The samples will typically be formed of a non-conducting, non-magnetic material.

[0010] According to a second aspect of the invention, there is provided an apparatus for discriminating between different materials, the apparatus comprising an electroadhesive gripper and being arranged to as to discriminate between samples of materials presented to the electroadhesive gripper dependent on whether the samples are gripped by the electroadhesive gripper.

[0011] The apparatus may comprise a drive circuit for the electroadhesive gripper, which is coupled to the electroadhesive gripper and is arranged to drive the electroadhesive gripper with a drive signal having a voltage, frequency and duration. The frequency will typically be greater than zero.

[0012] The apparatus may further comprise a conveying means for conveying the sample to the gripper; typically, the conveying means may comprise a conveyor.

[0013] The apparatus may further comprise a control circuit (such as a microprocessor) which is arranged to control the operation of the apparatus. As such, the control circuit may be arranged to make a determination of whether a sample has been gripped by the electroadhesive gripper and to control the operation of the apparatus dependent on the determination.

[0014] The apparatus may comprise movement means which can selectively, possibly using computer vision system, moving the sample, such that samples of material that have been differently discriminated are deposited in different locations. For example, the movement means may comprise an arm, such as a robotic arm, on which the electroadhesive

gripper is mounted. A secondary gripper of conventional construction may also be used to aid the picking process. The control circuit may be arranged to control the movement of the movement means; typically, the control circuit can be arranged so as to control the movement means to move the electroadhesive gripper dependent upon the determination of whether the sample has been gripped.

[0015] In one embodiment, if the determination is that sample has been gripped, the control circuit may control the movement means to move the electroadhesive gripper over a location away from the conveying means (for example a receptacle) and then control the drive circuit to cease driving the electroadhesive gripper so that the sample is no longer gripped and drops onto the location. A secondary means of cleaning or release such as an air blast may also be incorporated. Samples which are not gripped may remain on the conveying means.

[0016] Typically, the control circuit may be arranged so control the drive circuit so as to vary at least one parameter selected from the group comprising the voltage, the frequency and duration (time) with which the electroadhesive gripper is driven, and to make the discrimination dependent on whether the sample is gripped by the electroadhesive gripper as each parameter is varied. As such, the apparatus may allow selection between materials dependent on whether they are gripped at different voltages, frequencies and time.

[0017] The samples may typically but not necessarily be of a sheet material, typically a thin sheet or comprising a wall having a thickness which may be less than 2mm thick. Examples of materials that can be distinguished are nitrile and latex rubber. The samples will typically be formed of a non-conducting, non-magnetic material.

[0018] The electroadhesive gripper may comprise a pair of electrodes mounted on a substrate. The pair of electrodes will typically be coplanar on the substrate, and may be interdigitated, for increased performance. Typically, each electrode will be coupled to the drive circuit. The drive circuit may be arranged so that the drive signal is applied across the electrodes, so that a potential difference is set up between the electrodes, generating an electric field that acts to attract the samples.

[0019] The control circuit may be arranged such that the apparatus carries out the method of the first aspect of the invention. The method of the first aspect of the invention may use the apparatus of the second aspect of the invention.

[0020] There now follows, by way of example only, description of an embodiment of the invention, described with reference to the accompanying drawings, in which:

Figure 1 shows a schematic view of an apparatus for use in discriminating between samples of different materials; and

Figure 2 shows an underside plan view from underneath of the electrodes of the apparatus of Figure 1.

[0021] The accompanying drawings show an apparatus for use in discriminating between samples of different materials, making use of an electroadhesive gripper. The apparatus comprises an electroadhesive gripper 1 positioned over a conveyor 3. Samples 4a, 4b, 4c are passed along the conveyor 3 and a discrimination is made between the samples 4a, 4b, 4c dependent upon the material from which they are formed.

[0022] The electroadhesive gripper 1 has a set of electrodes 2 formed on its lower face, facing the conveyor 3. These electrodes can be seen in more detail in Figure 2 of the accompanying drawings, where it can be seen that there are a pair of electrodes 10, which are mutually interdigitated, in that each electrode 10 is formed as a number of parallel fingers 12 separated by gaps 13, the fingers 12 of one electrode 10 extending into the gaps 13 of the other electrode 10. This has been found to provide an electroadhesive gripper with a good performance. The electrodes 10 are typically but not exclusively formed of copper or silver, on a substrate (potentially polymer) 9.

[0023] Electrical connections 11 are provided to each electrode. These are coupled to a control module 6, which houses a drive circuit 8 and a control circuit 7 (which may be implemented as a microprocessor running computer program instructions). The drive circuit is coupled to the electrical connections 11, so as to provide a current signal across the electrodes 10. Typically but not exclusively voltages are in the region of 1-100 kilovolts (1-100kV), at X frequency. The control circuit 7 controls the drive circuit and the other functions of the apparatus.

[0024] The electroadhesive gripper 1 is provided on a moveable arm 14, which is driven by actuators (not shown) under the control of the control circuit 14. This can move the electroadhesive gripper from a position over the conveyor to a position to one side. A receptacle 5a is provided under the side position of the electroadhesive gripper 1 and another receptacle 5b is provided at the end of the conveyor 3.

[0025] As such, the drive circuit 8 drives the electrodes 2 with the drive signal, so that an electric field is created. Samples 4a, 4b, 4c are passed down the conveyor 3, so that they pass the electrodes 2. The inventors have appreciated that the propensity to be gripped by the electroadhesive gripper 1 depends on the material of the sample 4a, 4b, 4c and that this differential propensity can be used to discriminate or sort the samples.

[0026] Depending on the material of the sample 4a, 4b, 4c, the sample may be either gripped or not gripped. In the situation shown in Figure 1 of the accompanying drawings, the sample 4c has passed along the conveyor 3 past the electroadhesive gripper 1 and as such has not been gripped. It will fall off the end of the conveyor into receptacle 5b. Sample 4b has been gripped. The control circuit 7 will detect this (for example, by a change in the capacitance of the

electrodes 2 or by a change in weight or pressure on the conveyor 3 or the electroadhesive gripper 1) and will control the arm 14 to move the electroadhesive gripper 1 to the aside position over receptacle 5a. The drive circuit 8 is then controlled to cease driving the electrodes 2, so that the electroadhesive effect ceases and the sample 4b will drop into receptacle 5a.

[0027] Sample 4a has yet to reach the electroadhesive gripper 4b.

[0028] The inventors have found that such a system can distinguish between nitrile (rubber) and latex, in that it will grip up a nitrile (latex) glove but not a latex rubber balloon of similar thickness material and of similar weight. The possibilities that this could be used for include but are not limited to, different types of waste recycling or sorting, manufacturing industry, nuclear and toxic site decommissioning.

Example 1

[0029] In one example using the embodiment described above, the substrate 9 comprises a dielectric layer of polyimide (on which the electrodes are mounted) on a polystyrene base. At 24.7 degrees centigrade and 48.3% relative humidity, it was found that this embodiment could separate carbon fibre composite from high density polyethylene (HDPA) by varying the electrode voltage:

	Release times (s)	
Electrode Voltage (kV)	Carbon fibre composite	HDPE
1.00	No pickup	No pickup
1.50	No pickup	No pickup
2.00	No pickup	No pickup
2.50	0.65	No pickup
3.00	0.7	0.46

Example 2

[0030] Similarly, with the same setup, it was possible to discriminate between the two materials mentioned above and glass composite:

	Release times (s)		
Electrode Voltage (kV)	Glass composite	Carbon fibre composite	HDPE
1.00	No pickup	No pickup	No pickup
1.50	No pickup	No pickup	No pickup
2.00	1.32	No pickup	No pickup
2.50	10 mins +	0.65	No pickup
3.00	10 mins +	0.7	0.46

Example 3

[0031] With the same setup, it is also possible to discriminate between glass, carbon fibre composite and HDPE:

	Release times (s)		
Electrode Voltage (kV)	Glass	Carbon fibre composite	HDPE
1.00	No pickup	No pickup	No pickup
1.50	No pickup	No pickup	No pickup
2.00	0.38	No pickup	No pickup
2.50	0.38	0.65	No pickup

(continued)

	Release times (s)		
Electrode Voltage (kV)	Glass	Carbon fibre composite	HDPE
3.00	0.8	0.7	0.46

Example 4

[0032] In a slightly modified embodiment, with the dielectric layer being polyurethane on a nylon base (and with temperature being 25.3°C and 40.4% relative humidity), it was possible to distinguish between glass, glass composite and HDPE:

	Release times (s)		
Electrode Voltage (kV)	Glass	Glass composite	HDPE
1.00	0.66	No pickup	No pickup
1.50	0.77	No pickup	No pickup
2.00	0.84	No pickup	No pickup
2.50	0.89	No pickup	No pickup
3.00	0.5	No pickup	0.88

Example 5

[0033] With the same setup as Examples 1 to 3, it was possible to distinguish between a nitrile glove, glass or glass composite, HDPE and carbon fibre composite, although in this case glass and glass composite was pickup up at the same voltage, 2 kV:

	Release times (s)				
Electrode Voltage (kV)	Nitrile	Glass	Glass composite	Carbon fibre composite	HDPE
1.00	No pickup	No pickup	No pickup	No pickup	No pickup
1.50	0.91	No pickup	No pickup	No pickup	No pickup
2.00	3.29	0.38	1.32	No pickup	No pickup
2.50	9.8	0.38	10 mins +	0.65	No pickup
3.00	26.8	0.8	10 mins +	0.7	0.46

[0034] In an extension to this embodiment, the control circuit 7 can be programmed so as to cause the drive circuit 8 to vary the voltage and/or frequency for differing durations of the drive signal. In such a case, determination between various different materials can be achieved, as the determination can be based upon not only if the sample is grabbed, but when, bearing in mind the varying parameters. Various other sorting arrangements are also possible.

Claims

1. A method of discriminating between different materials, the method comprising presenting a sample formed of a material to an electroadhesive gripper, and discriminating the material of the sample dependent upon whether the electroadhesive gripper grips the sample.

2. The method of claim 1, comprising conveying the sample to the gripper, typically on a conveyor and/or selectively moving the sample away from the gripper, such that samples of material that have been differently discriminated are deposited in different locations.

3. The method of any preceding claim, in which the method comprises driving the electroadhesive gripper at a voltage, a frequency and duration and varying at least one parameter selected from the group comprising the voltage, the frequency and the duration with which the electroadhesive gripper is driven, and then discriminating between the material of the samples dependent on whether it is gripped by the electroadhesive gripper as each parameter is varied.

4. The method of any preceding claim in which the sample is of a sheet material or having thin wall construction and/or is formed of a non-conducting, non-magnetic material.

5. An apparatus for discriminating between different materials, the apparatus comprising an electroadhesive gripper and being arranged to as to discriminate between samples of materials presented to the electroadhesive gripper dependent on whether the samples are gripped by the electroadhesive gripper.

6. The apparatus of claim 5 comprising a conveying means for conveying the sample to the electroadhesive gripper.

7. The apparatus of claim 5 or claim 6, comprising a control circuit which is arranged to control the operation of the apparatus and which is arranged to make a determination of whether a sample has been gripped by the electroadhesive gripper and to control the operation of the apparatus dependent on the determination.

8. The apparatus of claim 7, comprising movement means which can selectively move the sample, such that samples of material that have been differently discriminated are deposited in different locations.

9. The apparatus of claim 8, in which the movement means comprises an arm, such as a robotic arm, on which the electroadhesive gripper is mounted, the control circuit being arranged to control the movement of the movement means dependent upon the determination of whether the sample has been gripped.

10. The apparatus of any of claims 5 to 9, comprising a drive circuit for the electroadhesive gripper, which is coupled to the electroadhesive gripper and is arranged to drive the electroadhesive gripper with a drive signal having a voltage, frequency and duration.

11. The apparatus of claim 10 as it depends from claim 7, in which the control circuit is arranged so control the drive circuit so as to vary at least one parameter selected from the group comprising the voltage, the frequency and duration with which the electroadhesive gripper is driven, and to make the discrimination dependent on whether the sample is gripped by the electroadhesive gripper as each parameter is varied.

12. The apparatus of any of claims 5 to 11, in which the electroadhesive gripper comprises a pair of electrodes mounted on a substrate.

13. The apparatus of claim 12 as dependent from claim 10, in which each electrode is coupled to the drive circuit, the drive circuit being arranged so that the drive signal is applied across the electrodes, so that a potential difference is set up between the electrodes, generating an electric field that acts to attract the samples.

14. The apparatus of claim 7, or any claim dependent thereon, in which the control circuit is arranged such that the apparatus carries out the method of any of claims 1 to 4.

15. The method of any of claims 1 to 4, comprising use of the apparatus of any of claims 5 to 13.

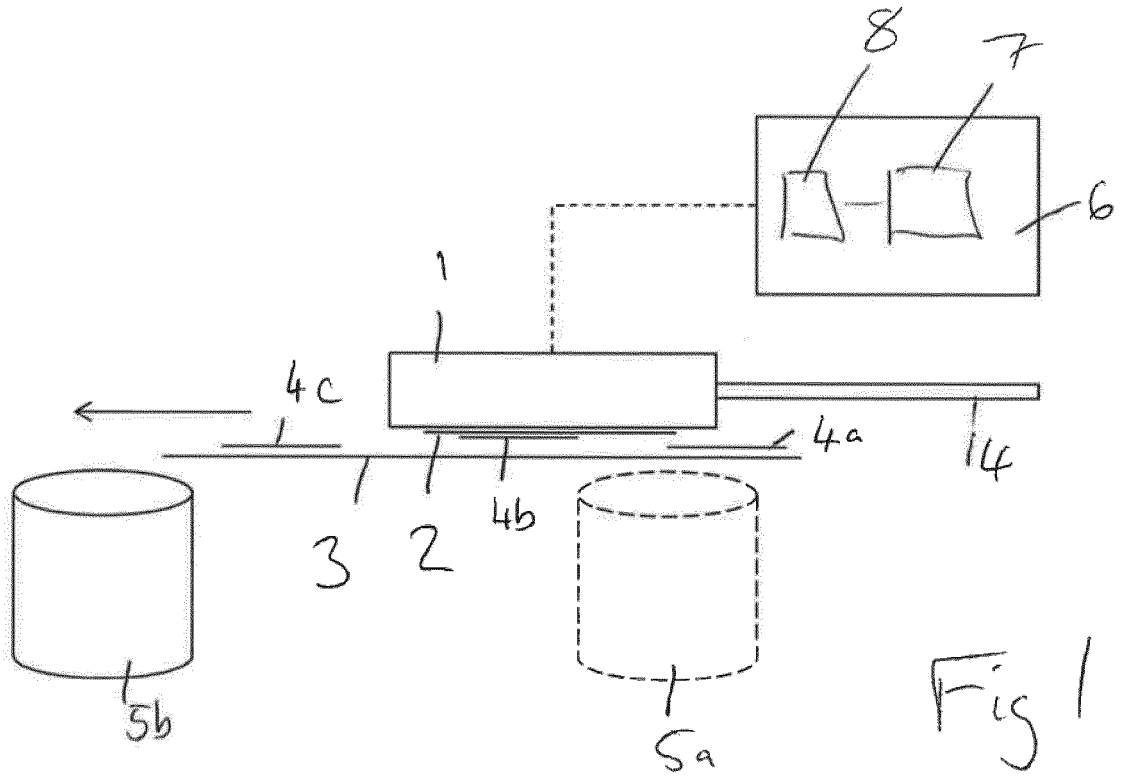

Fig 1

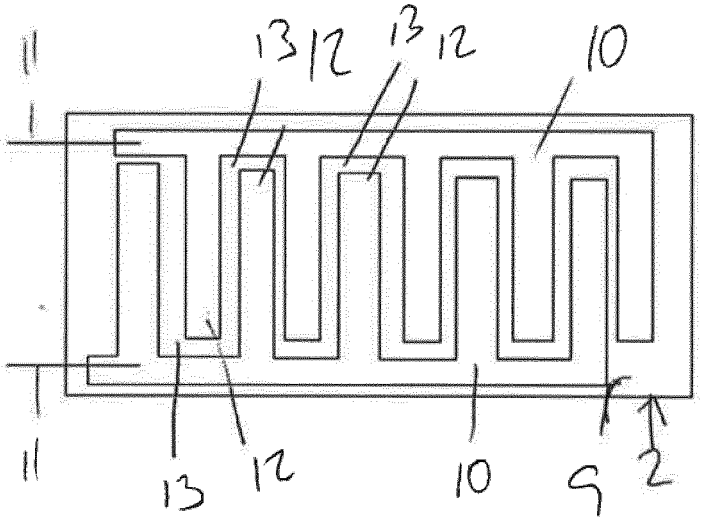

Fig 2

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EUROPEAN SEARCH REPORT

Application Number
EP 15 19 6484

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TECHNICAL FIELDS SEARCHED (IPC)

B07C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 April 2016	Wich, Roland

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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