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(54) Title: SAMPLE WELL PLATE

(57) Abstract: A sample well plate (10), having an array of sample wells (12) formed therein, has its underside surfaces coated with a highly reflective coating (16), including the outer surfaces of the sample wells (12). The coating is preferably formed from metal, for example silver or nickel. The sample well plate (10) is formed of a light transmissive material to ensure the full benefit of the reflectivity of the coating (16). The coating provides substantial increases in reflectivity compared with prior art sample well plates.

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SAMPLE WELL PLATE

The present invention relates to a sample well plate or sample well, particularly for use in chemical and biochemical analysis.

It is well known, particularly in the field of analysis, to provide a plate having numerous sample wells for allowing a plurality samples to be treated and analysed simultaneously. In some cases, the analysis of samples within sample wells involves measuring the light properties of the sample. For example, a polymerase chain reaction may be tested by measuring the amount of fluorescence produced by a fluorescent tag applied to the sample on test.

Typically, the sample well plate is made of a plastics material, for the sake of cost and weight. It may, however, be made of any suitable material.

In practice, the sample well plate is placed within the test apparatus which controls the reaction environment to which the samples are subjected. The environment may, for example, be a particular test temperature or cycle of changing temperatures. In order to measure the amount of fluorescence, suitable sensors are provided in the test equipment at locations which align with the tops of the sample wells.

Although existing systems can provide a measure of fluorescence, they are not as efficient or as reliable as is desired. For example, the amount of fluorescence which can be measured is at least in part dependent upon the structure of the sample wells and the manner in which the fluorescent light is transmitted to the top surface of the sample well. For instance, this light can be reflected within the sample well until it reaches the associated sensor at the top of the sample well. However, this reflection is on the whole dependent upon uncertain factors such as the quality fit of the sample well plate within the test apparatus, especially within a temperature regulated block, and of the characteristics and condition of the temperature regulated block.

A possible improvement to such an arrangement is to provide a sample well plate made of a metal or metal alloy. The material of the sample well plate can thus provide direct reflection within the sample wells. However, such a sample well plate is not practicable for single-use applications. Moreover, it is difficult in a manufacturing process to control the polishing within the sample wells to an accurate enough degree to produce reliable reflective properties within all the sample wells. Furthermore, this type of plate suffers problems of discoloration by tarnishing, oxidisation and the like, which causes difficulties in maintaining reliable reflectivity in the sample wells.

The present invention seeks to provide an improved sample well and sample well plate.

According to an aspect of the present invention, there is provided a sample well or sample well plate formed of a light transmitting material and a coating of highly reflective material on a surface of the sample well or sample well plate for providing reflectivity
5 within the sample wells or sample well plate.

The coating can provide much more reliable reflectivity than can be provided with prior art arrangements. Furthermore, the side of the coating which provides the reflectivity, that is the side bonded to the or each sample well, is protected by the material
10 of the sample well or sample well plate. Therefore, there is at least a substantially reduced risk of discoloration of the operative side of the coating.

Preferably, the coating is heat conductive.

Advantageously, the coating is on an exterior surface of the sample well or wells or sample well plate.

15 In the preferred embodiment, the light transmissive material of the sample well plate is substantially transparent. In another embodiment, the material may be translucent and/or coloured.

The coating may be of any material although in the preferred embodiment it includes silver, advantageously pure silver. An alternative material is nickel or an alloy
20 containing nickel.

Preferably, the translucent material of the sample well or sample well plate is formed of a plastics material. This enables the sample well or sample well plate to be used a single time and then disposed.

The coating can be provided by any suitable technique although in the preferred
25 embodiment this is by vacuum metallisation, typically by electro-plating in a vacuum chamber. Other examples include painting by spraying or coating and so on.

A protective layer may be provided over the surface of coating opposite that in contact with the light transmissive portion.

According to another aspect of the present invention, there is provided test
30 apparatus including support means designed to accommodate a sample well or sample well plate as specified herein and heating means operable to heat the coating of a sample well or sample well plate by electrical heating.

The heating means may include one or more sets of electrical terminals which can be coupled to the coating, which sets of electrical terminals can be arranged across and/or along the sample well plate.

In the preferred embodiment the test apparatus includes control means operable to control the current supplied to the or each set of electrical terminals to produce different currents in the sample plate so as to produce different heating effects.

According to another aspect of the present invention, there is provided test apparatus including support means designed to accommodate a sample well or sample well plate as specified herein and heating means operable to heat the coating of a sample well or sample well plate by inductance.

The heating means may include one or more inductors arranged across and/or along the sample well plate.

In the preferred embodiment the test apparatus includes control means operable to control the inductors to induce different currents in the sample plate so as to produce different heating effects.

According to another aspect of the present invention, there is provided test apparatus including support means designed to accommodate a sample well or sample well plate as specified herein and heating means operable to heat the coating of a sample well or sample well plate by heated air.

The heating means may include an infrared heating source such as a halogen lamp or a resistive heater.

In the preferred embodiments the test apparatus includes one or more fans operable to blow air from the heating means to the sample well or sample well plate.

An embodiment of the present invention is described below, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a portion of an embodiment of sample well plate;

Figure 2 is a schematic diagram of an embodiment of test apparatus using a resistive heater;

Figure 3 is a schematic diagram of an embodiment of test apparatus using inductive heating;

Figure 4 is a schematic diagram of an embodiment of test apparatus using infrared heating; and

Figures 5 to 8 are tables showing the improved signal and uniformity thereof for coated sample plates.

The preferred embodiment is described in the context of a sample well plate. However, it will be appreciated that it could be applied to any similar well structure, such as individual wells and any other reaction vessels which would benefit from this invention.

Referring to Figure 1, the embodiment of sample well plate 10 is typically of rectangular shape and has an array of sample wells 12 formed therein. There may be, for example, an array totalling ninety-six wells 12.

The wells are conical in form, tapering from the top of the sample well plate 10. This form, which is not essential for the purposes of this invention, can maximise the light emitted through the opening of each well.

The sample well plate 10 can be described as being hollow in that the sample wells 12 depend from the top surface of the sample well plate 10 so as to have exterior surfaces for the purposes of temperature control, as described below.

Also depending from the top surface of the sample well plate 10 are four side walls 14, provided for the purposes of strength and rigidity of the plate 10 and also for assisting in placing and fixing the sample well plate 10 in test apparatus.

The entirety of the underside surfaces of the sample well plate 10 are coated with a highly reflective coating 16, including the outer surfaces of the sample wells 12. The coating may be of any suitable material but preferably includes silver, most preferably being substantially pure silver. In an alternative embodiment, the coating may include or be nickel. Any other suitable or highly reflective material can be used, although in tests silver produced the best reflectivity.

The coating can be applied by any suitable process but in the preferred embodiment is applied by vacuum metallisation, typically by electro-plating in a vacuum chamber.

A protective layer may be provided over the exposed side of the coating 16 if desired.

The sample well plate 10 is formed of a light transmissive material, preferably being substantially completely transparent. This ensures the full benefit of the reflectivity of the coating 16. Typically, the sample well plate 10 is of a type which is used only once. For this purpose, it is preferably made of a plastics material, although for the purposes of this invention, it could be made of any material.

This example of sample well plate 10 may be placed on a temperature regulated block (not shown) which is provided with an array of recesses into which the sample wells 12 fit. The temperature regulated block typically fits within the side walls 14 and there is also provided a mechanism for securing the plate 10 in this position during processing.

5 In use, the temperature regulated block provides a controlled temperature during reaction of the samples within the sample wells. The shape of the wells 12 of this example can also maximise the surface area of the wells in contact with the temperature regulated block to assist in heat conduction to the samples within the sample wells.

Another embodiment of sample well plate consists of a substantially flat plate, that
10 is having a substantially flat bottom surface, and an array of sample wells located therein. The lower surface of the plate is provided with the coating. An example of sample well plate can be found in the applicant's co-pending British patent application number 2,370,112.

Another feature of this reflective layer, particularly when made of metal or a metal
15 alloy, is that it has much improved heat conductive properties. This can be used to create a new type of test apparatus.

One embodiment of such apparatus, shown in Figure 2, provides a support 22 for supporting a sample well plate 10 and a resistive heating arrangement which includes a plurality of sets of electrical terminals 20. Each electrical terminal 20 is electrically
20 coupled to the conductive layer 16 by any suitable means. One example is to have each terminal 20 within a clamping arrangement (which can of course be incorporated into the plate 10 support system).

There may only be provided a single set of electrical terminals 20, through which a current is made to pass. By having a coating 16 with some electrical resistance, any
25 current passing through the coating will produce heat which will heat the sample wells 12.

Alternatively, the resistivity of the coating 16 can be varied across the sample well plate 10 to produce different heating effects within the sample wells. This can be achieved by having a coating with different thicknesses and/or of different composition. For example, an area of coating twice the thickness of another area will have half the resistance
30 and therefore will heat to a lesser extent. This arrangement can provide temperature gradients across the sample well plate 10.

In addition or in the alternative, there could be provided a plurality of sets of electrical terminals 20. For example, there could be provided along the longitudinal axis of the sample well plate 10 a plurality of sets of electrical terminals each traversing the sample well plate 10. By passing different electrical currents across the various sets of terminals 20 different heating effects can be produced. Another example includes electrical terminals along the transverse axis of the sample well plate and yet another example has sets of electrical terminals both along and across the sample well plate to allow the production of complex temperature gradient patterns.

Temperature gradients by this method can be provided in coatings 16 which are uniform. They can equally be provided with coatings which are not uniform in their characteristics, such as having the characteristics mentioned above. Furthermore, the coating could be broken (discontinuous) to separate each set of electrical terminals and associated coating portion, if it is desired to have completely separate temperature effects produced in different sets of sample wells 12.

The test apparatus may also be provided with a cooling mechanism to assist in cooling the sample well plate after heating. The cooling mechanism may include, for example, a fan.

Another embodiment of apparatus, shown in Figure 3, provides a support 30 for supporting a sample well plate 10 and an inductive heat source 32. The heat source 32 may include one or more inductors which produce a current in the coating 16 to produce a heating effect. Preferably, in the case of a plurality of inductors 32, these are arranged either in a linear row along or across the sample well plate or in an array both along and across the sample well plate.

Where a plurality of inductors 32 are provided, these can be operated differently, that is at different currents, to produce different currents in the coating of the sample well plate 10 and hence different heating effects. By this method, temperature gradients can be produced. Such a gradient could be produced using simply relying upon heat conductivity within the coating 16 and could be assisted by suitable modification of the coating. More specifically, in some embodiments the coating of the sample well plate 10 may not be uniform across the plate. For example it may have a different thickness or composition or be discontinuous, to provide different inductive/heat conductive effects.

The test apparatus may also be provided with a cooling mechanism to assist in cooling the sample well plate after heating. The cooling mechanism may include, for example, a fan.

In another embodiment of apparatus, shown in Figure 4, there is provided a support 40 for supporting a sample well plate 10 and a heat source 42. The heat source 42 may be of any type which heats the surrounding air and may for example be an infrared heating source such as a halogen lamp, for example a 500w quartz halogen lamp, a resistive heating source or a Peltier effect source which can also provide cooling. In the case of an infrared heating source, this can typically be located between 1 to 5 centimetres from the sample well plate 10.

In the preferred embodiment, there are provided one or more fans 44 which are operated to blow air heated by the heat source 42 towards the sample well plate 10. The fan or fans 44 can control the rate of heating and cooling of the sample well plate 10.

It has been found in tests that this structure of sample well plate is substantially more efficient than prior art sample well plates in measuring the light properties of samples in the sample well. For example, in fluorescence measurements, this sample well structure has given an improvement in fluorescent signals over a standard black anodised block of over 300%. Substantial improvements in such signals have been measured in a plurality of different measurement devices.

Figures 5 to 8 show experimental results for various sample well plates which demonstrate the improved signals and signal uniformity obtainable with coated sample plates. The numbers denote reflection readings obtained for various sample well plates and include mean values and standard deviation values for a well plate having 96 wells. The improved results with the prototype coated plates are clearly noticeable.

The combination of the coating on the light transmitted plate provides significant practical advantages. In particular, the side of the coating bonded to the light transmissive material is protected by that material from discoloration by tarnishing, oxidation and the like. Therefore, even if some discoloration of the metal of the coating occurs, this does not normally affect the side of the coating bonded to the light transmissive material. This provides significant handling and testing environment advantages. Indeed, substantial improvements in the level of intensity of fluorescence signals have been noted even in comparison to polished metal blocks.

This coating also provides other significant advantages with respect to metal sample well plates in that it can give a better thermal conductivity and therefore better temperature uniformity across the sample well plate and better performance during desired changes in temperature in the sample well plate or across the sample well plate. Moreover, because of the structure of well plates, it provides lower sample evaporation.

The coating can also provide improved uniformity of heating of the plate 10.

Of course, this invention is not limited to the particular light property measured for samples under test. It can be used in the measurement of fluorescence, luminescence and any other type of light property.

CLAIMS

1. A sample well or sample well plate formed of a light transmitting material and a coating of highly reflective material on a surface of the sample well or sample well plate
5 for providing reflectivity within the sample wells or sample well plate.
2. A sample well or sample well plate according to claim 1, wherein the coating is heat conductive.
- 10 3. A sample well or sample well plate according to claim 1 or 2, wherein the coating is on an exterior surface of the sample well or wells or sample well plate.
4. A sample well or sample well plate according to any preceding claim, wherein the light transmissive material is substantially transparent.
15
5. A sample well or sample well plate according to any one of claims 1 to 3, wherein the light transmissive material is translucent.
6. A sample well or sample well plate according to any preceding claim, wherein the
20 light transmissive material is coloured.
7. A sample well or sample well plate according to any preceding claim, wherein the coating is formed from a metal or metal alloy.
- 25 8. A sample well or sample well plate according to claim 7, wherein the coating includes silver or is substantially pure silver.
9. A sample well or sample well plate according to claim 7, wherein the coating includes nickel.
30

10. A sample well or sample well plate according to any preceding claim, wherein the translucent material of the sample well or sample well plate is formed of a plastics material.
- 5 11. A sample well or sample well plate substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.
12. Test apparatus including support means designed to accommodate a sample well or sample well plate according to any preceding claim and heating means operable to heat the
10 coating of a sample well or sample well plate by electrical heating.
13. Test apparatus according to claim 12, wherein the heating means includes one or more sets of electrical terminals which can be coupled to the coating.
- 15 14. Test apparatus according to claim 13, wherein in the case of a plurality of sets of electrical terminals, the sets are arranged across and/or along the sample well plate.
15. Test apparatus according to claim 12, 13 or 14, including control means operable to control the current supplied to the or each set of electrical terminals to produce different
20 currents in the sample plate so as to produce different heating effects.
16. Test apparatus including support means designed to accommodate a sample well or sample well plate according to any one of claims 1 to 11 and heating means operable to heat the coating of a sample well or sample well plate by inductance.
25
17. Test apparatus according to claim 16, wherein the heating means includes one or more inductors arranged to lie across and/or along the sample well plate.
18. Test apparatus according to claim 16 or 17, including control means operable to
30 control the inductors to induce different currents in the sample plate so as to produce different heating effects.

19. Test apparatus including support means designed to accommodate a sample well or sample well plate according to any one of claims 1 to 11 and heating means operable to heat the coating of a sample well or sample well plate by heated air.

5 20. Test apparatus according to claim 19, wherein the heating means includes an infrared or resistive heater.

21. Test apparatus according to claim 19, wherein the heating means includes a halogen lamp.

10

22. Test apparatus according to any one of claims 12 to 21, including one or more fans operable to blow air from the heating means to the sample well or sample well plate.

15

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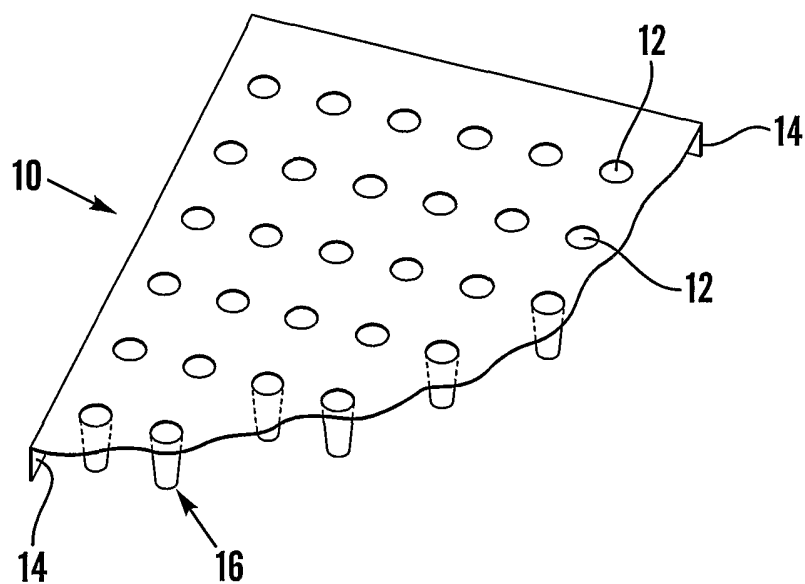


Fig. 1

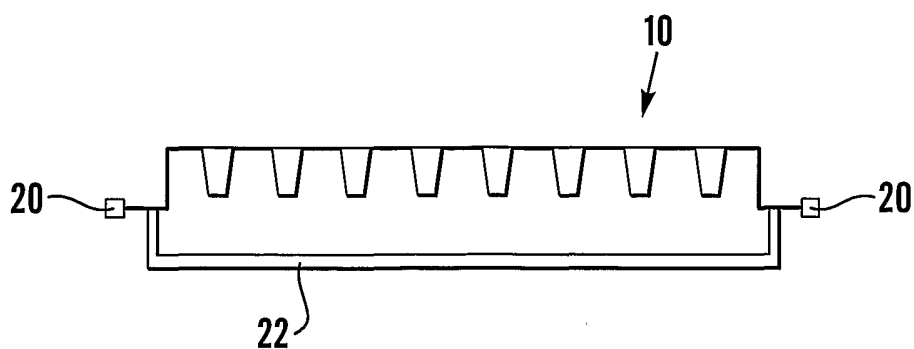


Fig. 2

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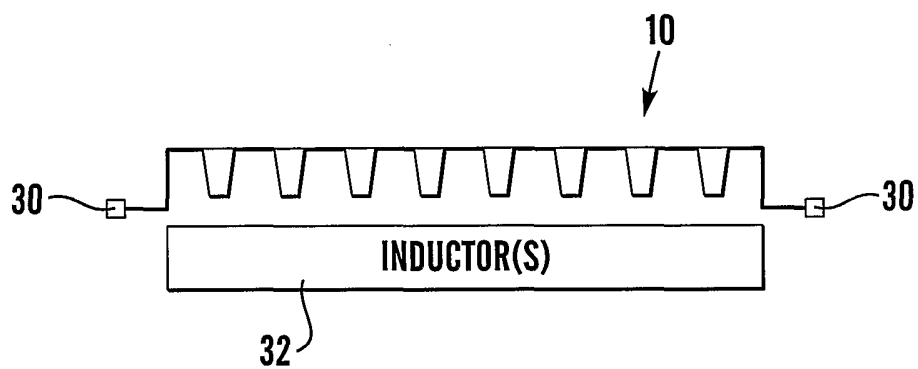


Fig.3

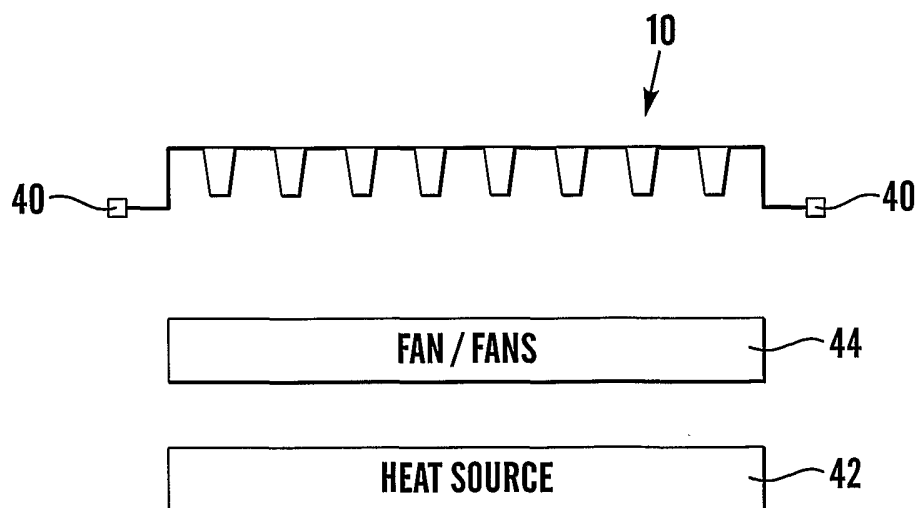


Fig.4

Silver and non silver coated Plates
genomic DNA with Sybr Green

Non coated (with tape)

0.0282	0.0291	0.0216	0.0186	0.0222	0.0154	0.0201	0.0207	0.0188	0.0294	0.0313	0.0429
0.0288	0.0323	0.0181	0.0213	0.0185	0.0154	0.0181	0.0154	0.0334	0.0295	0.0269	0.0394
0.0282	0.0255	0.0232	0.0196	0.0205	0.0173	0.0182	0.0131	0.0181	0.0353	0.0481	0.0666
0.0295	0.0382	0.0292	0.0196	0.0215	0.0383	0.0308	0.0148	0.0229	0.053	0.0344	0.0443
0.0263	0.029	0.0232	0.0227	0.0243	0.0662	0.037	0.0219	0.0388	0.0344	0.0493	0.0374
0.0369	0.0311	0.0338	0.0305	0.0299	0.0426	0.0305	0.0245	0.0253	0.0458	0.0429	0.0853
0.0254	0.0661	0.034	0.0368	0.0379	0.057	0.046	0.0489	0.0414	0.0322	0.0537	0.0549
0.0216	0.0368	0.0408	0.0446	0.0338	0.0388	0.0334	0.0367	0.0339	0.036	0.039	0.0557

sum = 3.1606
mean = 0.0329229
standard dev = 0.013201
CV = 0.401 (40.1%)

SUBSTITUTE SHEET (RULE 26)

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0.0266	0.0272	0.02	0.0174	0.021	0.0153	0.0206	0.0204	0.0186	0.0291	0.0316	0.0415
0.0271	0.03	0.0171	0.0199	0.0178	0.0148	0.0183	0.0161	0.0321	0.0297	0.0266	0.0382
0.0265	0.0241	0.0218	0.0183	0.0191	0.0161	0.0184	0.0137	0.0178	0.0345	0.0466	0.0647
0.0282	0.0356	0.0279	0.0184	0.0205	0.0365	0.0306	0.0158	0.0232	0.052	0.0339	0.0435
0.0247	0.0273	0.022	0.0212	0.024	0.0633	0.037	0.023	0.0377	0.0344	0.0486	0.0367
0.0345	0.0284	0.0323	0.0297	0.0284	0.0417	0.0307	0.0246	0.0262	0.0455	0.0421	0.0829
0.0235	0.0624	0.0322	0.0353	0.0361	0.0538	0.0447	0.0478	0.0407	0.0318	0.0526	0.0536
0.0202	0.0343	0.0384	0.0432	0.0332	0.0373	0.0327	0.0347	0.0337	0.0365	0.0384	0.0544

sum = 3.0631
mean = 0.0319073
stddev = 0.012772
CV = 0.4 (40%)

0.0256	0.0255	0.0176	0.0158	0.0198	0.0143	0.0195	0.0189	0.0177	0.0276	0.0296	0.0405
0.0255	0.0281	0.0155	0.0183	0.0163	0.0136	0.0162	0.0136	0.0301	0.0275	0.0252	0.0366
0.0263	0.0226	0.0205	0.0167	0.0187	0.0148	0.0166	0.0127	0.0163	0.0334	0.0451	0.0629
0.0277	0.034	0.0265	0.0174	0.0191	0.0355	0.0288	0.0144	0.0215	0.05	0.0324	0.0424
0.0243	0.0254	0.0204	0.0194	0.0229	0.0611	0.0357	0.0211	0.0355	0.0322	0.0468	0.036
0.0342	0.027	0.0304	0.0271	0.0262	0.0399	0.0293	0.0229	0.0243	0.0432	0.0403	0.0812
0.0233	0.0608	0.0305	0.0334	0.0344	0.0513	0.0434	0.0459	0.0393	0.03	0.0509	0.052
0.0203	0.0331	0.0364	0.0409	0.0312	0.0355	0.0314	0.0336	0.0323	0.0345	0.0366	0.052

sum = 2.915
mean = 0.0303646
stddev = 0.012628
CV = 0.416 (41.6%)

Fig.5

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Silver coated (with tape)																	
0.042	0.0413	0.0524	0.1038	0.0529	0.0469	0.0451	0.0796	0.0459	0.0568	0.0554	0.0491						
0.0544	0.0506	0.0502	0.064	0.0544	0.0538	0.0481	0.0536	0.05	0.0848	0.0725	0.0797						
0.0623	0.0709	0.0587	0.0603	0.0654	NR	0.0644	0.0697	0.0682	0.0687	0.0652	0.0598						
0.0695	0.0603	0.0578	0.0631	0.0689	0.0765	0.0746	0.0626	0.0668	0.0584	0.0616	0.049						
0.0699	0.0898	0.0679	0.0727	0.0772	0.0891	0.0985	0.0751	0.0738	0.0711	0.0717	0.0641	sum = 7.0942					
0.0916	0.0749	0.0788	0.0896	0.0863	0.0808	0.0767	0.0825	0.078	0.0938	0.0887	0.0687	mean = 0.0746758					
0.0917	0.0833	0.0925	0.0926	0.0911	0.085	0.0868	0.0867	0.0974	0.0929	0.0968	0.0937	stdev = 0.019086					
0.0854	0.1032	0.0977	0.096	0.084	0.0852	0.1225	0.0906	0.1446	0.1126	0.1157	0.0849	CV = 0.25 (25.56%)					
0.043	0.0427	0.0532	0.103	0.0535	0.0479	0.0456	0.0819	0.0456	0.0582	0.0571	0.0496						
0.0554	0.052	0.051	0.0649	0.0557	0.0544	0.0482	0.0547	0.0507	0.0866	0.075	0.0825						
0.0646	0.0715	0.0599	0.0618	0.0656	NR	0.0651	0.0705	0.0688	0.0712	0.067	0.0602						
0.0705	0.0616	0.0588	0.0642	0.0693	0.0787	0.0765	0.0638	0.0681	0.0596	0.0624	0.0502						
0.0716	0.0916	0.069	0.0742	0.0781	0.0905	0.1007	0.0764	0.0754	0.072	0.0732	0.0654	sum = 7.2171					
0.093	0.0768	0.0801	0.0908	0.0869	0.0816	0.0781	0.0844	0.0788	0.0957	0.0896	0.0704	mean = 0.0759695					
0.0926	0.0851	0.0939	0.0935	0.0929	0.0861	0.0876	0.0895	0.0998	0.0941	0.0989	0.0953	stdev = 0.019335					
0.0871	0.1047	0.0997	0.0977	0.0852	0.0865	0.1238	0.0917	0.1471	0.115	0.1168	0.0859	CV = 0.25 (25.45%)					
0.0427	0.0418	0.0526	0.0995	0.0525	0.0464	0.0447	0.0801	0.0443	0.0571	0.0559	0.0496						
0.0542	0.0509	0.05	0.0628	0.054	0.0531	0.0468	0.0531	0.0506	0.0849	0.0733	0.0814						
0.0634	0.069	0.0585	0.06	0.0649	NR	0.0638	0.0694	0.0679	0.0702	0.0665	0.059						
0.0692	0.0604	0.058	0.0627	0.0681	0.0767	0.0743	0.0625	0.0672	0.0589	0.0613	0.0496						
0.07	0.0901	0.0667	0.0726	0.0773	0.0894	0.0988	0.0755	0.0741	0.0714	0.0709	0.0646	sum = 7.0804					
0.0906	0.0749	0.0791	0.0898	0.0855	0.0799	0.0767	0.0837	0.0782	0.0929	0.0878	0.0697	mean = 0.0745305					
0.0904	0.0837	0.0917	0.0922	0.0914	0.0848	0.0866	0.0868	0.097	0.0926	0.0975	0.0916	stdev = 0.018966					
0.0853	0.104	0.0978	0.0954	0.0839	0.0854	0.121	0.0901	0.1441	0.1135	0.1154	0.0842	CV = 0.25 (25.45%)					
												sum = 7.0942					
												mean = 0.0746758					
												stdev = 0.019086					
												CV = 0.25 (25.56%)					
												sum = 7.2171					
												mean = 0.0759695					
												stdev = 0.019335					
												CV = 0.25 (25.45%)					
												sum = 7.0804					
												mean = 0.0745305					
												stdev = 0.018966					
												CV = 0.25 (25.45%)					

Fig.6

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no tape silver coated (no tape)															
0.0561	0.054	0.0705	0.1171	0.0679	0.0597	0.0592	0.1129	0.0584	0.0797	0.0793	0.064	sum = 9.6702 mean = 0.1017916 stdev = 0.02608 CV = 0.26 (25.62%)			
0.0733	0.0686	0.0674	0.0875	0.0736	0.0727	0.0637	0.074	0.0664	0.1289	0.1073	0.1197				
0.0851	0.0939	0.0817	0.0842	0.0889	NR	0.0886	0.0987	0.094	0.1002	0.0954	0.0841				
0.0907	0.082	0.0785	0.0849	0.0947	0.1053	0.1011	0.0879	0.0944	0.0853	0.0856	0.0672				
0.0919	0.1219	0.0921	0.0983	0.1048	0.1361	0.1304	0.1057	0.1018	0.0963	0.102	0.09				
0.124	0.1004	0.1074	0.1228	0.1161	0.1063	0.1029	0.1132	0.1072	0.1318	0.1196	0.0973				
0.1236	0.1115	0.1237	0.1255	0.1241	0.1169	0.1165	0.117	0.1329	0.1242	0.1359	0.1191	sum = 8.9339 mean = 0.094041 stdev = 0.025277 CV = 0.27 (26.88%)			
0.1157	0.1388	0.1303	0.1276	0.1111	0.1133	0.1625	0.12	0.2006	0.1589	0.1567	0.1092				
0.0486	0.048	0.0626	0.1003	0.0599	0.0533	0.0536	0.1046	0.0538	0.0728	0.0715	0.0568				
0.0641	0.0606	0.0594	0.0775	0.0674	0.0665	0.0595	0.0692	0.0627	0.118	0.0976	0.1067				
0.0748	0.0826	0.0732	0.0757	0.081	NR	0.0815	0.0926	0.088	0.0935	0.0863	0.076				
0.0821	0.0743	0.0706	0.0774	0.0878	0.0992	0.0942	0.0827	0.0884	0.08	0.0789	0.0615				
0.0827	0.1102	0.0835	0.0913	0.097	0.1277	0.1229	0.0993	0.0953	0.0906	0.0939	0.0833	sum = 8.6448 mean = 0.0909979 stdev = 0.025103 CV = 0.28 (27.59%)			
0.1126	0.0927	0.0993	0.1155	0.1087	0.1	0.097	0.1074	0.1008	0.1228	0.1125	0.0902				
0.1141	0.1035	0.1153	0.1173	0.116	0.1097	0.1106	0.1103	0.1252	0.1173	0.1279	0.1117				
0.1069	0.129	0.1212	0.119	0.1041	0.1068	0.1535	0.1125	0.1893	0.1495	0.1465	0.1022				
0.0465	0.0449	0.0582	0.0948	0.0571	0.0506	0.0511	0.1	0.0508	0.07	0.0683	0.0549				
0.0606	0.0579	0.0567	0.074	0.0647	0.0637	0.0564	0.067	0.0599	0.1143	0.0938	0.1028				
0.0713	0.0805	0.0696	0.0726	0.0783	NR	0.078	0.0898	0.0855	0.0904	0.0825	0.0725	sum = 8.6448 mean = 0.0909979 stdev = 0.025103 CV = 0.28 (27.59%)			
0.0779	0.0707	0.0684	0.0759	0.0855	0.0967	0.0922	0.0794	0.0865	0.0772	0.0761	0.0584				
0.0788	0.1066	0.081	0.0883	0.0951	0.1248	0.121	0.0957	0.0924	0.0873	0.0913	0.0803				
0.1083	0.089	0.0969	0.1131	0.1063	0.0969	0.0947	0.1039	0.098	0.1194	0.1097	0.0879				
0.1104	0.1004	0.1117	0.1135	0.114	0.1076	0.108	0.1074	0.1219	0.1145	0.124	0.1083				
0.103	0.125	0.1183	0.1163	0.1017	0.1047	0.1506	0.1102	0.1849	0.1455	0.1425	0.0988				

Fig.7

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non coated (no tape)											
0.0313	0.031	0.0216	0.0185	0.024	0.0186	0.0232	0.0226	0.037	0.038	0.0515	sum = 3.6963 mean = 0.0385031 stdev = 0.018455 CV = 0.48 (47.9%)
0.0296	0.0341	0.0164	0.022	0.0185	0.0166	0.0196	0.0181	0.0394	0.0339	0.0495	
0.0285	0.0276	0.0239	0.0199	0.0211	0.0181	0.0204	0.0163	0.0482	0.0627	0.085	
0.0302	0.0408	0.0304	0.0193	0.0214	0.0473	0.0365	0.0184	0.0724	0.0429	0.0561	
0.025	0.0299	0.0227	0.0219	0.0253	0.0805	0.0459	0.0265	0.044	0.057	0.0492	
0.0377	0.032	0.0364	0.0329	0.0319	0.0533	0.0344	0.0274	0.0611	0.0553	0.1218	sum = 3.5166 mean = 0.036631 stdev = 0.017563 CV = 0.48 (47.9%)
0.0241	0.0781	0.0358	0.0412	0.0409	0.0687	0.0559	0.0582	0.0396	0.0687	0.0718	
0.0181	0.0383	0.0436	0.0494	0.0375	0.0434	0.0385	0.0423	0.0453	0.0488	0.0688	
0.029	0.0296	0.0205	0.0171	0.0228	0.0176	0.022	0.0221	0.0357	0.0357	0.0483	
0.0269	0.0317	0.0161	0.0209	0.0181	0.0161	0.0191	0.0162	0.0381	0.031	0.0463	
0.0267	0.0263	0.0229	0.0189	0.0199	0.0177	0.0194	0.015	0.0457	0.0581	0.0809	sum = 3.4617 mean = 0.0360594 stdev = 0.017649 CV = 0.9 (48.9%)
0.0283	0.038	0.0291	0.018	0.0206	0.0462	0.0349	0.0184	0.0692	0.0396	0.0529	
0.0238	0.0277	0.0222	0.0209	0.0241	0.0775	0.0439	0.026	0.0431	0.0534	0.0462	
0.0352	0.0295	0.0349	0.0313	0.0306	0.051	0.0327	0.0258	0.0593	0.0519	0.1151	
0.0227	0.074	0.0344	0.0386	0.0391	0.0661	0.054	0.056	0.0384	0.0656	0.0678	
0.0164	0.0368	0.0422	0.0466	0.0361	0.0419	0.0367	0.0402	0.0439	0.0459	0.0658	sum = 3.4617 mean = 0.0360594 stdev = 0.017649 CV = 0.9 (48.9%)
0.0285	0.027	0.0181	0.0165	0.0214	0.0172	0.0215	0.0218	0.0353	0.0365	0.0483	
0.0263	0.0296	0.0147	0.019	0.017	0.0152	0.0189	0.017	0.0384	0.0323	0.0464	
0.0259	0.0245	0.0213	0.0172	0.0188	0.0171	0.0197	0.0154	0.0451	0.0578	0.0799	
0.0272	0.0371	0.0279	0.0164	0.0197	0.0458	0.0349	0.0181	0.0682	0.0409	0.0525	
0.0234	0.0278	0.0202	0.0192	0.0247	0.0763	0.0438	0.025	0.0433	0.053	0.047	sum = 3.4617 mean = 0.0360594 stdev = 0.017649 CV = 0.9 (48.9%)
0.0346	0.0299	0.0333	0.0296	0.0305	0.0509	0.0331	0.0253	0.0584	0.0531	0.1145	
0.0223	0.0719	0.0332	0.0371	0.0392	0.0644	0.0536	0.0562	0.0384	0.0652	0.0682	
0.0161	0.0365	0.0404	0.0452	0.0358	0.0415	0.0367	0.0393	0.0433	0.046	0.0656	

Fig.8