

621.382; 621.37

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000

⁴ Institute of Technology, University of Rzeszow, 35-959 Rzeszow, Poland.

Article is devoted to complex issue of development history, physical principles and materials for ink-jet technology of functional units and devices formation for electronics. We focus on the synthesis of operational inks and aspects of application of ink-jet printing to patterning of metal nanoparticles, metal-organic complexes, organic compounds for fabrication of thin-film transistors, light-emitting diodes, solar cells, as well as use of carbon nanotubes for energy storage devices and sensors.

Keywords: ink-jet print, stream technology, nanoparticles, conductivity, touch-controls, carbon nanotubes.

1.



Inktronic KSR (keyboard send-receive) set



1. :) Teletype Inktronic System
 , 1963 .. [4];) Dimatix Materials Prin-
 ter DMP-3000 (),
 [5];) Autodrop Gantry System Microdrop AG () [6]

20 \$300
 “2D”
 2 [7].
 , Dry-Ink ; Hot-melt-
 [8].

” (continuous ink-jet)

[13].

“2D” 20 \$300 . [14].

. 3, 4

10^6

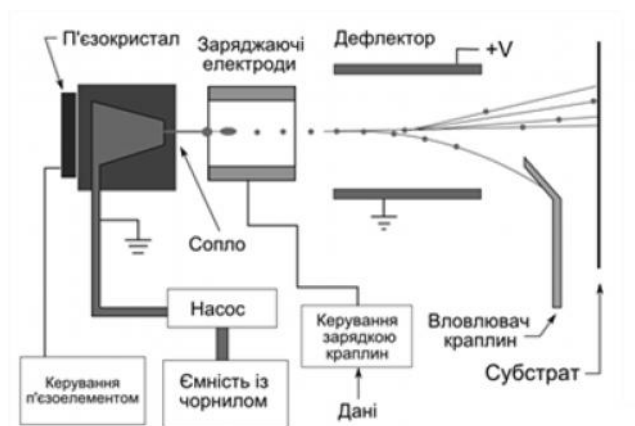
$V = 40$ / .

[15].

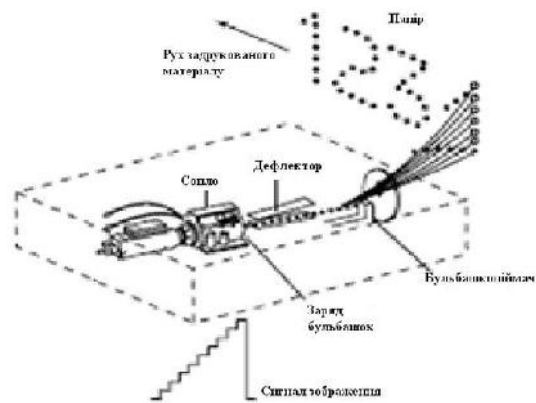
[16]:

$$Q_r = fT \frac{fR^2 r_0^2 K}{8 \sim L} \left[1 - \frac{1}{2} \left(\frac{r_0}{R} \right)^2 \right] (p_r - p_m)$$

, Q_r – , p_r – , p_m – , T –
 , R – , L – , r_0 – , μ – , f –



. 3.

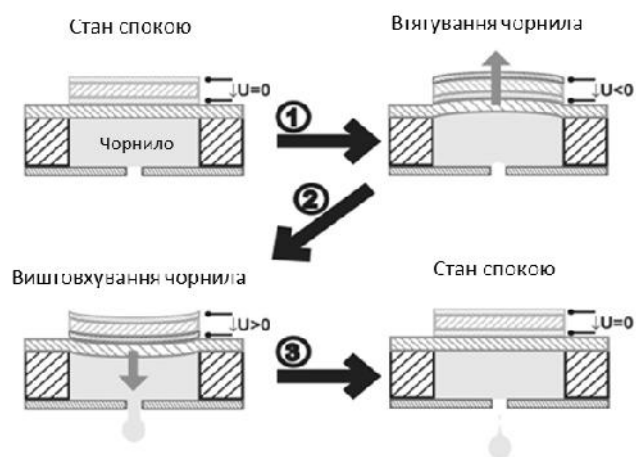


. 4.

«
- „binary deflecting“
».
(. 3) „multi deflecting“
(. 4).

„multi deflecting“

„Edgeshooter“ 90°).



.5.

Sideshooter ()

200 400 [17].

(Bubble Jet, «

»),

[13].

(. 6)

3

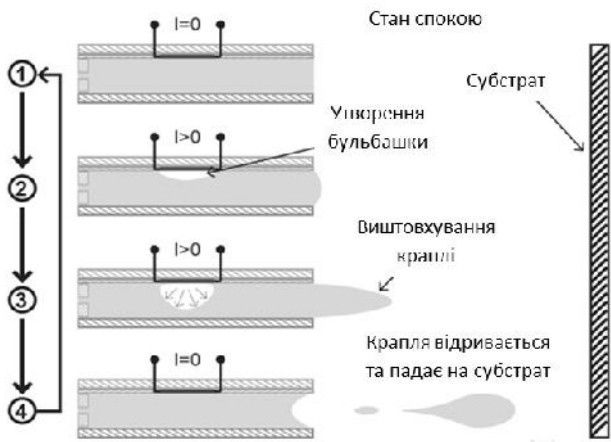
300° C.

3÷10

$V = 10 /$

$= 10$

10-20 80 [18].



6. ()

[19].

±5

2

Microdrop,

2.		DoD ()					
Xaar	Trident	Konica Minolta	FujiFilm Dimatix	FujiFilm Dimatix	MicroFab Technologies Inc.	PIXDRO	
1001 1000	256Jet 256	KM512XN 512	SE3 128	NovaJA256 256	Jetlab II 4	LP50 inkjet 128	
7-50	6-14	—	10-14	8-20	3-10	10-15	
(- 70,5)	397	70,5	508	279	-	-	
360 dpi	64 dpi	360 dpi	50 dpi	90 dpi (450 dpi)	300 dpi	200 dpi	
2	1	2	1	1	1	1	
70,5	102,4	35,5	64,5	71,5	300	210	

A horizontal line with several punctuation marks above it: a colon, a comma, a dash, a comma, and a comma.

20 / (1 / = 0,001 /).

(' 1 . , ,),

6 (400 /),

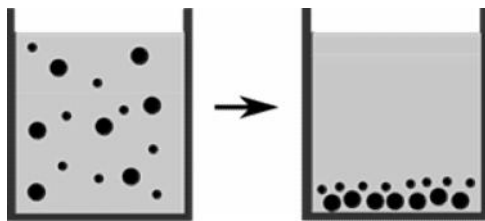
[20]. >40 “ ” —

() [18].

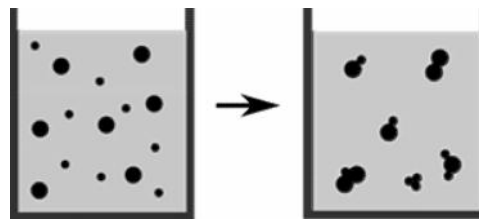
5%

[21].

(. 7).

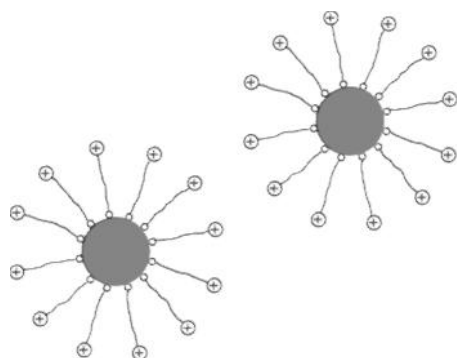
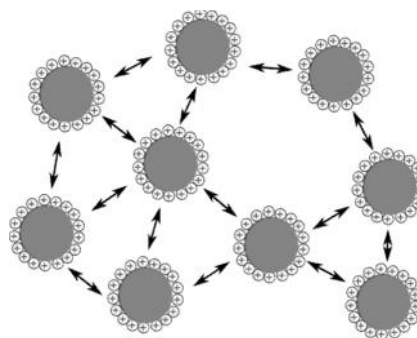
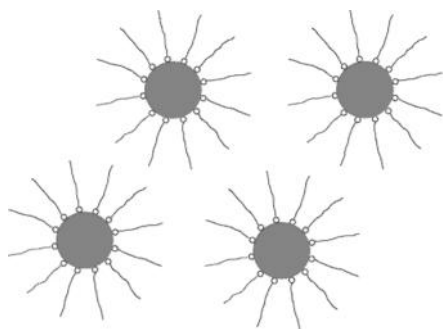


.7.



.8.

, , ,
 , , () ,
 , , -
 , -
 (.8), , -
 [22]; [23]. , (.9) , -
 , -
 , -
 (.9) , -
 , -
 (.9) , -
 , -
 [24]; [25].



.9.

() : - -
 (), -
 ;
 ,
 ; -
 .

(. . « »)

[26].

(50-80%) [27-29].

3.

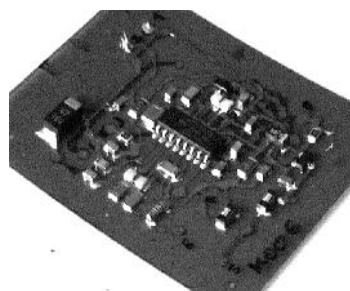
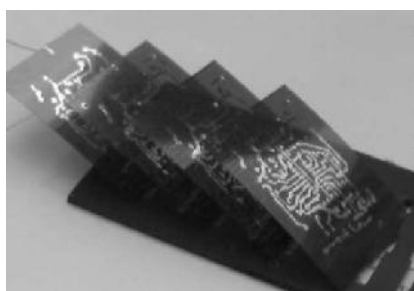
(800).

(. 10).

29 \$/)

(0,24 \$/

[30].



. 10:)

(40×50)

250 60 . (
 ~2×10⁷ / .

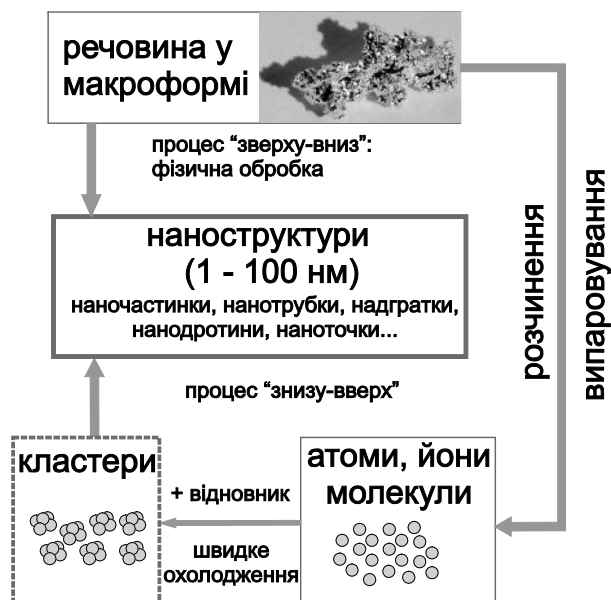
36,6%).

[31]

down, » , – « - » (bottom-up, -) [32] (. 11).

- -) « - » (top- « -

10-100 .



. 11.

([33]).

(~10%)

al.

[34].

[35].

[36].

[37],

, , – .

[38], [39]. -

[39] (d =

7,1 , = 0,9)

, , -

[36].

, , -

[36].

[40]

5-7 (10%),

- , *Redinger et al.* [41; 42], *Kamushny et al.* [43], ,

: - [43] « »

40-60 (-). -

(8% wt). ,

[44;

45]. *Kim et al.* [46; 47] -

, .

, , ,

, *Kim et al.*

, .

(2,5 / = 100)

17±2 ().

- [41] 2- NaBH₄,

-2 .

- 2) [46] ,

, 120 (30).

, ,

: 21±3 47±15 .

3%- ;

- *Lee et al.* NaOH.

, 50 .

[48].

, - ,

, (,) , -

Lee et al. [48].

(1,59 × 1,7 × (4,5) (, PEDOT). [49].

1999-2000 [50], 2000- -

Park et al. [47] 45±8 , 17 × .

(30%) - 30-65 Lee et al. [51] 200 3,6 × .

(NaH₂PO₂·H₂O), (CuSO₄·5H₂O), -

($\text{Cu}^{2+} + \text{H}_2\text{PO}_2^- + \text{H}_2\text{O} \rightarrow \text{Cu}^0 + \text{H}_2\text{PO}_3^- + 2\text{H}^+$);

(3) (0,2 , 5).

Volkman et al. [41]. : CuCl₂·H₂O (0,1) 2- (85) 2 , (0,22), 2- (85).

[30], [52] (Samsung Electro-Mechanic,) : - 5 , 2- , 40%. [30] 5 × , [52] - 3,67

200 Saito et al. [53], Harima Inc., -

<10 5 × 15- . 300 [54], - () -

(YAG:Nd, ~37%), (30), , (40%)

(20). (~30 , 1).

- 9,2 $\times 10^{230}$ [55].
- Novacentrix (),
- Metalon[®] ICI-003 [56].
- (~1-10)
- <20 / , [57]
- 003 50 \times (30 ,).
- (-)
- :
1. Elmqvist, R., Measuring Instrument of the Recording Type: US Patent 2 566 443 1951 1951, Google Patents.
 2. Drucker.de., M.d.G. []. – : <http://www.drucker.de/news-7/tintenstrahldrucker-und-tintenpatronen-geschichte-und-info-139.html>.
 3. Zournatzidis, A., Tintendrucker - Tintendrucker.net. [Online] 09. 03 2011. []. – : <http://www.tintendrucker.net/tintendrucker.html>.
 4. Teletype Inktronic Page Printer []. – : <http://www.baudot.net/teletype/Inktronic.htm>.
 5. []. – : <https://www.fujifilmusa.com/products/>.
 6. Microdrop AG, B. []. – : <http://www.microdrop.de/newsevents.html>.
 7. Waßmer, M., Inkjet-Druck passiver elektronischer Dickschichtbauelemente, 2011, Universitätsbibliothek.
 8. Schwarz, W. M., et al., Hot melt ink compositions, 1991, Google Patents.
 9. Basaran, O. A., Small-scale free surface flows with breakup: Drop formation and emerging applications. AICHE Journal, 2002. 48: p. 1842-1848.
 10. de Gans, B. J., P. C. Duineveld, and U. S. Schubert, Inkjet printing of polymers: state of the art and future developments. Advanced materials, 2004. 16 (3): p. 203-213.
 11. Logothetidis, S., Flexible organic electronic devices: Materials, process and applications. Materials Science and Engineering: B, 2008. 152 (1): p. 96-104.
 12. Yin, Z., et al., Inkjet printing for flexible electronics: Materials, processes and equipments. Chinese Science Bulletin, 2010. 55 (30): p. 3383-3407.
 13. Allen, M. L., Nanoparticle sintering methods and applications for printed electronics. 2011.
 14. Singh, M., et al., Inkjet printing—process and its applications. Advanced materials, 2010. 22(6): p. 673-685.
 15. Kipphan, H. and H. Druckmaschinen-Akti, Handbuch der Printmedien2000: Springer Berlin, Heidelberg.
 16. Teng, K. and R. Vest, Mathematical models of ink jet printing in thick-film hybrid microelectronics. Applied mathematical modelling, 1988. 12(2): p. 182-188.
 17. Elsner, P., 3D-Drucktechnologie—Grundlagen zur Herstellung polymerer Bauteile mit gradierten Werkstoffeigenschaften, 2009, Universitätsbibliothek.
 18. Kipphan, H., Handbuch der Printmedien: Technologien und Produktionsverfahren2000: Springer DE.
 19. Kamysny, A., J. Steinke, and S. Magdassi, Metal-based inkjet inks for printed electronics. Open Applied Physics Journal, 2011. 4: p. 19-36.
 20. Pique, A. and D.B. Chrisey, Direct-write technologies for rapid prototyping applications: sensors, electronics, and integrated power sources2001: Academic Press.
 21. Magdassi, S., The Chemistry of Inkjet Inks. 2010: p. 101-110.
 22. Israelachvili, J. N. and H. Wennerstroem, Entropic forces between amphiphilic surfaces in liquids. The Journal of Physical Chemistry, 1992. 96 (2): p. 520-531.
 23. Elimelech, M., et al., Particle deposition & aggregation: measurement, modelling and simulation1998: Butterworth-Heinemann.
 24. Comba, S. and R. Sethi, Stabilization of highly concentrated suspensions of iron nanoparticles using shear-thinning gels of xanthan gum. Water research, 2009. 43 (15): p. 3717-3726.

53. Saito, H. and Matsuba. Y. Liquid wiring technology by ink-jet printing using NanoPaste. in 35th International Symposium on Microelectronics IMAPS, San Diego. 2006.
54. Yung, K. and T. Plura, Selective laser processing of ink-jet printed nano-scaled tin-clad copper particles. *Applied Physics A*, 2010. 101 (2): p. 393-397.
55. Khan, A., et al. Direct printing of copper conductive micro-tracks by multi-nozzle electrohydrodynamic inkjet printing process. *Journal of Materials Processing Technology*, 2012. 212 (3): p. 700-706.
56. []. – : <http://www.novacentrix.com/products/metalon-inks/copper>.
57. Marjanovic, N., et al. Inkjet printing and low temperature sintering of CuO and CdS as functional electronic layers and Schottky diodes. *Journal of Materials Chemistry*, 2011. 21 (35): p. 13634-13639.
58. Wuelfing, W. P., et al. Nanometer gold clusters protected by surface-bound monolayers of thiolated poly (ethylene glycol) polymer electrolyte. *Journal of the American Chemical Society*, 1998. 120 (48): p. 12696-12697.
59. Hostetler, M.J.G., S. J.; Stokes, J. J; Murray, R. W., Monolayers in three dimensions: synthesis and electrochemistry of omega-functionalized alkanethiolate-stabilized gold cluster compounds. *J. Am. Chem. Soc.*, 1996. 118: p. 4212-4213.
60. Badia, A., et al. Structure and chain dynamics of alkanethiol-capped gold colloids. *Langmuir*, 1996. 12 (5): p. 1262-1269.
61. Hostetler, M. J., et al. Alkanethiolate gold cluster molecules with core diameters from 1.5 to 5.2 nm: core and monolayer properties as a function of core size. *Langmuir*, 1998. 14 (1): p. 17-30.
62. Leff, D. V., et al. Thermodynamic control of gold nanocrystal size: experiment and theory. *The Journal of Physical Chemistry*, 1995. 99 (18): p. 7036-7041.
63. Bieri, N., et al. Microstructuring by printing and laser curing of nanoparticle solutions. *Applied Physics Letters*, 2003. 82 (20): p. 3529-3531.
64. Chung, J., et al. Conductor microstructures by laser curing of printed gold nanoparticle ink. *Applied Physics Letters*, 2004. 84 (5): p. 801-803.
65. Chung, J., et al. In-tandem deposition and sintering of printed gold nanoparticle inks induced by continuous Gaussian laser irradiation. *Applied Physics A*, 2004. 79 (4-6): p. 1259-1261.
66. Choi, T. Y., D. Poulidakos, and C. P. Grigoropoulos, Fountain-pen-based laser microstructuring with gold nanoparticle inks. *Applied Physics Letters*, 2004. 85 (1): p. 13-15.
67. Chung, J., et al. Damage-free low temperature pulsed laser printing of gold nanoinks on polymers. *Journal of heat transfer*, 2005. 127 (7): p. 724-732.
68. Ko, S., et al. Fabrication of inkjet printed flexible electronics by low temperature subtractive laser processing. *Proceedings of the IMECE, Orlando, FL, USA Nov, 2005*: p. 5-10.

18.05.2013 .

”
E-mail: kravchuk.oleksandr@ukr.net

E-mail: rostyslav.lesyuk@ndsu.edu
rolebox@ukr.net

().
E-mail: bobitski@lp.edu.ua

E-mail: kotlyar_stcu@mail.lviv.ua