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Switching discharge phenomena when use composite materials Cu—Cr under low voltage dc inductive load of a small power

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Paper presents and discusses investigated results of composite materials Cu—Cr used in electric contacts operating under DC low voltage loads of a small power. Formulates conclusions of possibility of the use of just such material to control the arc to glow transformation for practical use in electric auxiliary switching devices.

Keywords: *composite material Cu—Cr, switching phenomenon, inductive load, low voltage, small power.*

Introduction

To increase reliability and life time of auxiliary switches operating under heavy DC conditions the possibility of arc to glow discharge seems to be a key factor. It depends on many technical factors among which selection of proper contact material is of a great importance [1, 2]. To reduce contacts price by replacing noble metals (like silver) and/or sophisticated and money consuming technologies (like powder metallurgy) seeking another alternative manufacturing is both economically and technically justified [3—5]. One of these can be use of electron beam high-rate evaporation method with following condensation in vacuum [6]. Therefore, possibility of application of multilayer material Cu—Cr was investigated for operation under open air conditions. Chromium content was varied from zero up to about 100%. The investigations were carried out for DC inductive load (110 V, 0,5 A, ~30 ms) in air under normal pressure. The arc to glow transition was analyzed by means of emission spectroscopy consideration as well. On the basis of investigated results the conclusions about possibility of use of multilayer composite materials Cu—Cr to control the arc to glow transformation for practical use in low voltage, low power electrical auxiliary switching devices are formulated.

Contact sample selection

Composite material for the study was prepared in the form of sheets of varied content of Cr and Cu. The contact samples were made of a material part selected for the various content of component materials as illustrated in fig. 1. The chromium content according to the examinations was ranged from 0,6 to about 80% (fig. 2). Surface structure of new contact samples Cu—Cr of the minimum (~0,6%) and maximum (~76%) chromium content is shown for

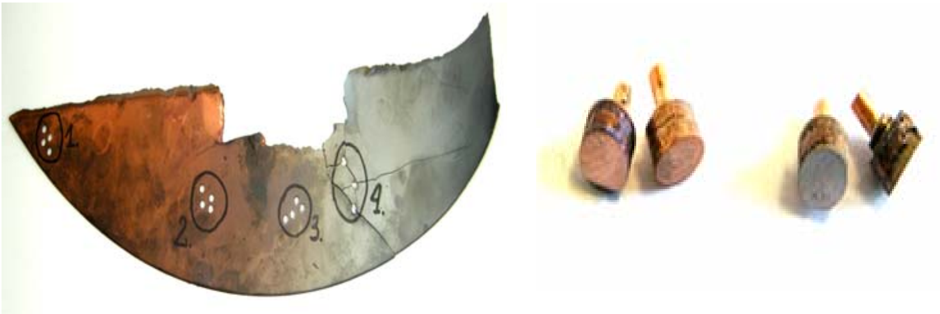

Fig. 1. The composition Cu—Cr for preparation contact samples
(1—4 — number of samples).

example in figs. 3, 4. The test contacts were made as flat of 5 mm in diameter and thickness of about 2,5 mm.

a

Spectrum	In stats.	C	Si	Cr	Cu	Total
Spectrum 1	Yes	11.86	1.91	0.65	85.58	100.00
Spectrum 2	Yes	10.12	1.78	0.61	87.49	100.00
Spectrum 3	Yes	10.57	2.39	0.65	86.39	100.00
Mean		10.85	2.03	0.64	86.49	100.00
Std. deviation		0.90	0.32	0.02	0.96	
Max.		11.86	2.39	0.65	87.49	
Min.		10.12	1.78	0.61	85.58	

All results in weight%

b

Spectrum	In stats.	C	Si	Cr	Cu	Total
Spectrum 1	Yes	9.35	0.69	7.80	82.15	100.00
Spectrum 2	Yes	7.71	1.35	7.51	83.42	100.00
Spectrum 3	Yes	12.45	0.60	7.16	79.80	100.00
Mean		9.84	0.88	7.49	81.79	100.00
Std. deviation		2.40	0.41	0.32	1.84	
Max.		12.45	1.35	7.80	83.42	
Min.		7.71	0.60	7.16	79.80	

All results in weight%

c

Spectrum	In stats.	C	Si	Cr	Cu	Total
Spectrum 1	Yes	6.06	0.26	32.68	60.99	100.00
Spectrum 2	Yes	6.92	0.26	32.63	60.19	100.00
Spectrum 3	Yes	7.10	0.34	31.55	61.00	100.00
Mean		6.70	0.29	32.29	60.73	100.00
Std. deviation		0.56	0.05	0.64	0.46	
Max.		7.10	0.34	32.68	61.00	
Min.		6.06	0.26	31.55	60.19	

All results in weight%

d

Spectrum	In stats.	C	Si	Cr	Cu	Total
Spectrum 1	Yes	7.63	0.24	71.06	21.08	100.00
Spectrum 2	Yes	8.47	0.53	76.86	14.14	100.00
Spectrum 3	Yes	6.90	0.44	81.25	11.41	100.00
Mean		7.67	0.40	76.39	15.54	100.00
Std. deviation		0.79	0.15	5.11	4.98	
Max.		8.47	0.53	81.25	21.08	
Min.		6.90	0.24	71.06	11.41	

All results in weight%

Fig. 2. Composition of material Cu—Cr for selected contact samples:
a — No. 1; *b* — No. 2; *b* — No. 3; *c* — No. 4.

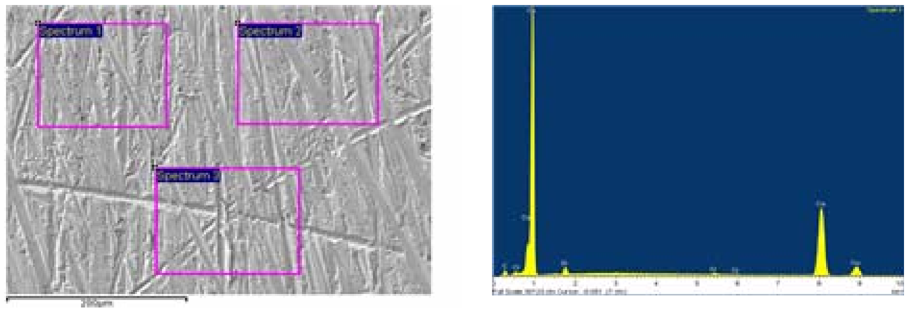

Fig. 3. Surface structure of new contact Cu—Cr sample (No. 1) with low content of chromium (~0,6%).

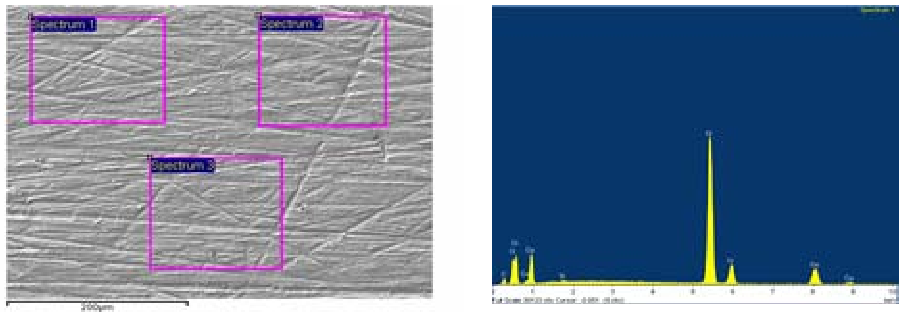

Fig. 4. Surface structure of new contact Cu—Cr sample (No. 4) with highest content of chromium (~76%).

Switching test and discussion of results

The tests were performed in air at room temperature and normal pressure for DC load 110 V, 30 ms time constant and current to about 1,0 A. The average value of the contact force, the speed of opening and length of the contact gap at open state were 0,58 N, 0,2 m/s and 2,4 mm respectively. In order to reduce the impact of electromagnetic field disturbances on the measurements of voltage — current characteristic and emission spectrum variation under electric switching discharges the special high — stop filters were used. Contact resistance during operation was controlled for the test load current. All tests were performed in a special lab stand with removable contact chamber [2]. Earlier studies conducted by the authors have shown that transient of switching arcing into glowing under interrupting DC inductive current is possible to achieve when use selected contact materials such as pure nickel or molybdenum (fig. 5 and 6).

The study shows that regardless of the content of chromium in the contact material the opening tends to initiate a glow discharge soon as you start to open contact. It is manifested by sudden increase in the voltage value between contacts (fig. 7, 8). It is related to the conditions prevailing in the real contact area at the moment of interruption of current which is also reflected in the contact resistance value. The contact resistance is typically highest for the first switching and increases with increasing chromium content (from 0,3 to about 1,0 Ω).

Duration of the arc is the longest for the lowest chromium content. For the highest however, chromium content is achieved not only the shortest arc time but increases significantly probability of glow discharge existence even immediately at the time of the contact opening (fig. 8). It should be noted that in the case of glow discharge existence, duration of the switching (breaking)

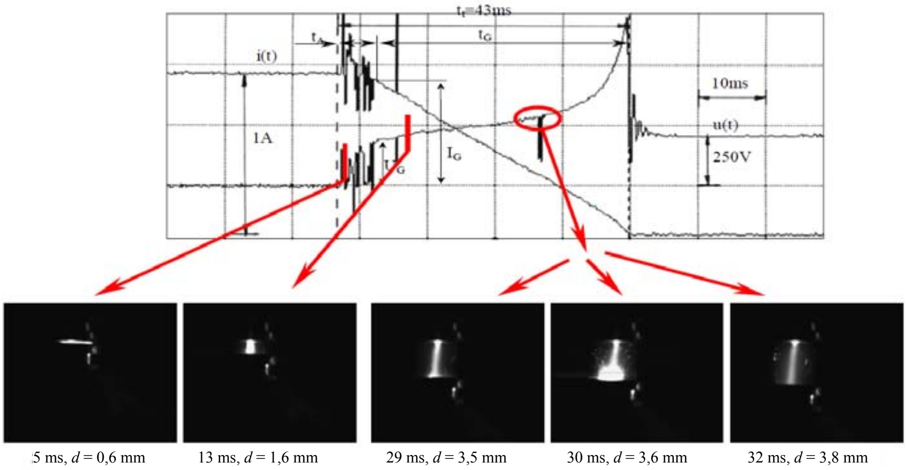

Fig. 5. The unstable arc to glow transition when use the nickel contacts (250 V, 1 A, 40 ms, air ~ 100 kPa): (t_t. t_{arc}, t_G — total, arcing and glow discharge time respectively; U_G — glow voltage; I_G — arc to glow transformation current value; d — contact gap.

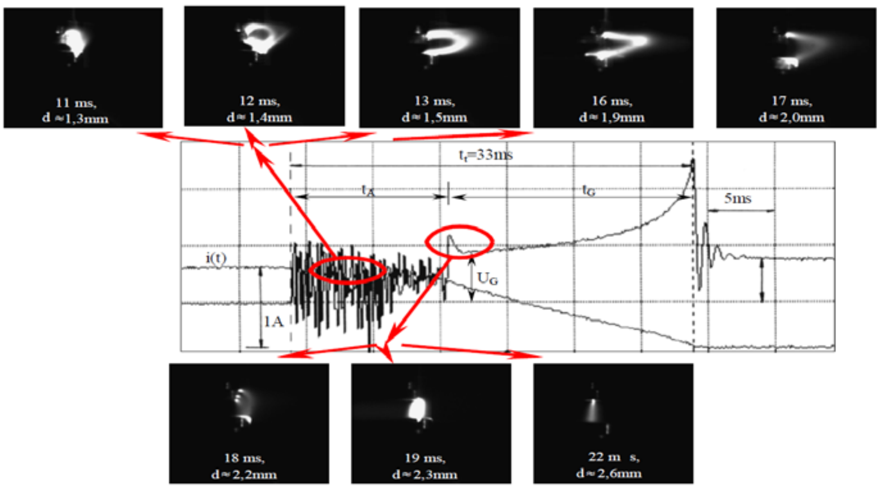

Fig. 6. Development of the electrical discharge when use contacts made of fine molybdenum (250 V, 0,5 A, 40 ms, in air under 100 kPa).

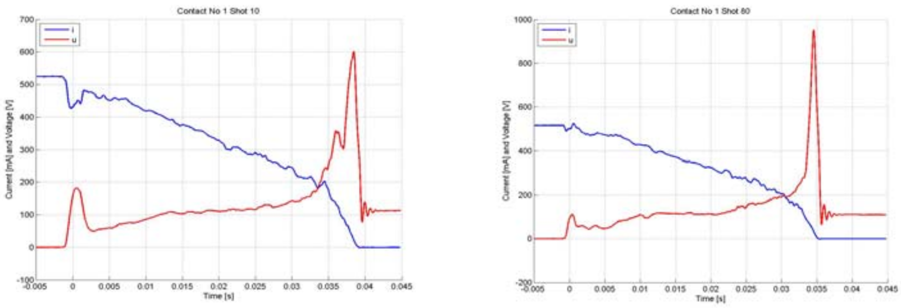

Fig. 7. Voltage — current characteristics at contact opening (110 V, 0,5 A, 31 ms, in air under normal pressure) for samples of small amount of chromium (<1%) at 10th and 80th switching cycle respectively.

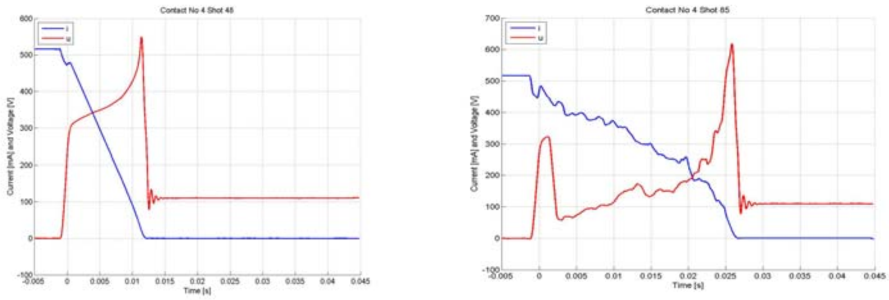

Fig. 8. Voltage — current characteristics at contact opening (110 V, 0,5 A, 31 ms, in air under normal pressure) for samples of highest amount of chromium (<76%) at 48th and 85th switching cycle.

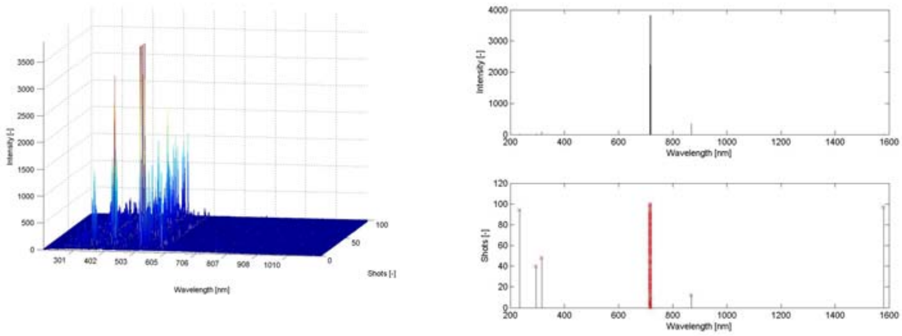

Fig. 9. Emission spectrum variation under switching.

process is much shorter what significantly reduces contact erosion thus increasing its life time. Emission spectrum variation under switching for contacts made of about 80% of chromium can be compared for example from fig. 9.

Conclusions

The multilayer composite materials Cu—Cr made by means of electron beam high-rate evaporation method with following condensation in vacuum seems to be suitable as contact material for low voltage, low power auxiliary switches operating at DC inductive load in open-air conditions under normal pressure.

The best results if about electrical arc to glow transition were obtained for higher amount of chromium (around 80%).

Under further investigations copper should be modified by doping with such elements like W, Mo or/and Ni to increase and/or control melting point value of the composition. Increased stability of material processing to decrease high non-uniformity of applied metallic elements inside whole contact sample volume is of great importance as well.

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Явления в электрической дуге при использовании композиционных материалов Cu—Cr при коммутации в цепях с низковольтной DC нагрузкой малой мощности

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Предложены результаты исследований композиционных материалов Cu—Cr, используемых в качестве электрических контактов при коммутации в цепях постоянного тока низкого напряжения малой мощности. Сделан вывод о возможности использования именно этого материала для контроля изменения свечения дуги при практическом использовании в электрических вспомогательных коммутационных устройствах.

***Ключевые слова**: композиционный материал Cu—Cr, электрическая дуга, индуктивная нагрузка, низкое напряжение, малая мощность.*

Явища в електричній дузі при використанні композиційних матеріалів Cu—Cr при комутації в ланцюгах з низьковольтної DC навантаженням малої потужності

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Представлено результати досліджень композиційних матеріалів Cu—Cr, що використовують в якосты електричних контактів при комутації в ланцюгах постійного струму низької напруги малої потужності. Зроблено висновок про можливість використання саме цього матеріалу для контролю зміни світіння дуги при практичному використанні в електричних допоміжних комутаційних пристроях.

***Ключові слова:** композиційний матеріал Cu—Cr, електрична дуга, індуктивне навантаження, низька напруга, мала потужність.*