On Physical and Chemical Interaction of IAG/Nd-laser Radiation with Printing Plate Material

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Abstract: In continuation of previous works concerning direct methods of plate-making (c-to-p-technology) the interaction of IAG/Nd laser radiation with printing plate materials had been investigated.

These new results are partly correlated with those received earlier with CO_2-laser but in the case of IAG/Nd laser the absorptivity of polymeric layers does not depend on metallic background preparation.

That is why, evidently, it becomes possible to rise the energetic sensitivity of the plate material by introducing of the laser radiation additional absorbents into polymeric layers composition. The higher sensitivity of the coating results in its higher absorptivity and in the higher speed of the thermal destruction, i.e. in the faster plate-making process.

The higher resolution of IAG/Nd-laser devices in comparison to CO_2-laser devices gives a possibility to rise the printing quality.

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Widespread use of direct (filmless) methods of plate-making with laser recording in graphic arts industry had been predicted for the end of the 80-s taking into account that the first laser plate-making systems had appeared in the very beginning of the 70-s (American Laserite and Lasergraph, Soviet LGA, later LogEscan et al).

This forecast however has not been realized because of a lot of reasons connected with laser beam controlling systems imperfection and the absence of plate materials possessing necessary printing properties in combination with a high laser radiation sensitivity.

The advantages of laser plate-making systems are doubtless because their application allows to reduce production output cycle, to exclude silver films and «wet» treatment and to have very high quality of printing production.

The economic efficiency of such systems depends on the laser type and a possibility of correlation of a couple (a laser and a plate coating) properties. For example, high energy lasers may be used in combination with conventional offset plate coating in order to compensate their insufficient sensitivity. But such a system would be unacceptable from an economic point of view.

On the other hand, the most of the known highly sensitive coatings do not possess necessary printing properties. That is why probably the development of laser plate-making methods is not so fast.

Anyhow in the last 5-7 years a lot of new laser systems appeared.

In the USSR and later in Russia the works connected with the laser plate-making systems application in the graphic arts industry have been carrying out for about 30 years. These works resulted in the creation of a lot of laser devices with different types of lasers and construction properties. Their main technical characteristics are shown in the table 1.

The choice of CO_2-laser for image recording in the first soviet plate-making systems (LGA, Copy-2, Romb) was due to its comparatavely high efficiency, a low cost and wide application for materials treatment.

Due to laser technique development it is possible now to solve the same problems more succesfully using IAG/Nd-laser. There are some reasons for it.

Table 1.

Model	LGA (1973)	Copy-2 (1980)	Romb (1988)	Laser-Graver (1990)	Granat (1991)
Laser wavelength /power, W	CO_2 10.6/25.0	CO_2 10.6/25.0	CO_2 10.6/35.0	LAG/Nd 1.06/16.0	LAG/nd 1.06/8.0
Resolution, dpi	762	762/1524	2000	2540	2032
Screen ruling, lpi	91	106	106	180	180
Recording productivity, cm^2/min	111	120	140	150	140
Printing plate size, sqmm	530×650	530×650	530×650	1010×820	530×650

On the one hand radiation of 1.06 μm can propagate nearly loseless through thin and flexible glass fibres allowing the design of rather simple and cheap beam guiding installations and devices.

The other important reason is the lower beam disturbancy by IAG/Nd-laser induced plasma. IAG/Nd wavelength which is lower than CO_2-laser's one allows to rise the resolution of the recording.

The last significant reason is the higher absorptivity of many materials of interest, especially metals, at the wavelength 1.06 μm as compared to 10.6 μm yielding a gain in process efficiency which is illustrated by the table 2 data.

Table 2

Laser λ_{max}, μm	Reflectance			
	Cu	Al	Cr	Ni
IAG, 1.06	0.901	0.733	0.570	0.741
CO_2, 10.6	0.985	0..970	0.930	0.941

All these considerations confirm the correctness of the choice of IAG/Nd-laser as a recording tool in the new plate-making systems namely Laser Graver and Granat.

It is quite evident now that graphic arts industry needs specially working out printing plate materials for laser recording.

The Russian Research Institute for Graphic Arts had begun these investigations simultaneously with the creation of the first laser devices. Now the Moscow Institute is the absolute monopolist in this field in Russia.

In order to be suitable for laser recording the offset plate coatings must satisfy the following demands:

— high sensitivity to the laser radiation of the choosen wavelength;
— a simple plate-making process following by very simple treatment or better the absence of it;
— long run life;
— resolution capacity (its necessary level depends on the type of production).

The offset plate coatings sensitive to the 10.6 μm radiation (CO_2-laser) were the first to be worked out for conventional and waterless offset printing plate-making. Their properties are shown in the table 3.

Table 3

No	Printing process (offset)	Support	Underlayer	Coating	Run length (thous.)	Energetic sensitivity J/cm^2
1	waterless	Al	special varnish	syloxane	10.0	8.2
2	waterless	Al	nitrocellulose	syloxane	10..0	7.5
3	waterless	Al grained anodized	no	syloxane	25.0	4.0
4	conven-tional	Al grained anodized	no	nitrocellulose +dye	50.0	2.0

Note: Run length for the plates 370×450×0,15 mm

The image formation on the plates 1-4 is the result of the ablation of a thin polymeric layer from an aluminium support in the process of 10.6 μm -laser recording.

As a result of CO_2-laser effect the polymeric coating is destroyed in the exposed areas thus forming printing elements on the metallic support for plates 1-3 and non-printing elements for plates 4. The remaining portions of the coating are ink-repelling in the first case and ink-receptive in the second case.

Industrial using practice showed that both types of plates (3 — for printing boards in electronics; 4 — for graphic arts productions) satisfy all the necessary demands.

Results and Discussion

It has been established in the process of the plate coatings 1-4 development that the CO_2-laser thermal effect realized in the interaction of 10.6 μm radiation with plate coatings thus resulting in polymers thermal destruction on the exposed areas and formation of simple gaseous compounds.

The IAG/Nd-laser radiation may also have a thermal effect on the substance and taking into account its shorter wavelength and consequently the smaller size of its «spot» on the surface of interaction it is possible to expect the higher energy density in comparison with CO_2-laser under condition of equal power of laser. If it is correct it would be possible to apply the plates 1-4 succesfully in the systems equipped with IAG/Nd-laser the more so that the absorptivity of metals is higher when the radiation wavelength is shorter [note table 2]. As it turned out however these plates have no sensivity to 1.06 μm radiation and only the partial destruction of polymeric layer was observed under the rising of the laser power

The possible explanation is the insufficient sensitivity of these plates. In this case the time of the radiation and a plate coating interaction is much less in comparison with CO_2-laser under condition of equal power and laser recording speed.

That is why the new plates have been worked out. Their properties are represented in the table 4

Table 4

No	Support	Thermo-sensitive coating	Radiation absorbent	Energetic sensitivity, J/cm^2	Treatment after laser recording	Run length (thous.)
5	Al	Nitro-cellulose-contained	Organic Dye (λ_{max} 1.05μm)	2,0	Development or UV-irradiation	50,0
6	Al	Nitro-cellulose-contained	Carbon Black	1,1	–	100,0

As a result of IAG/Nd-laser effect the polymeric layer on the exposed areas of the plates 5 is destroyed but not completely ablated so its remaining portions are ink-receptive.

There was made an attempt to rise the absorptivity of these plates by Al-support pretreatment like for the plates 3, 4 but it had no result because, probably, aluminium oxide has no absorbance in 1.06 μm part of spectra.

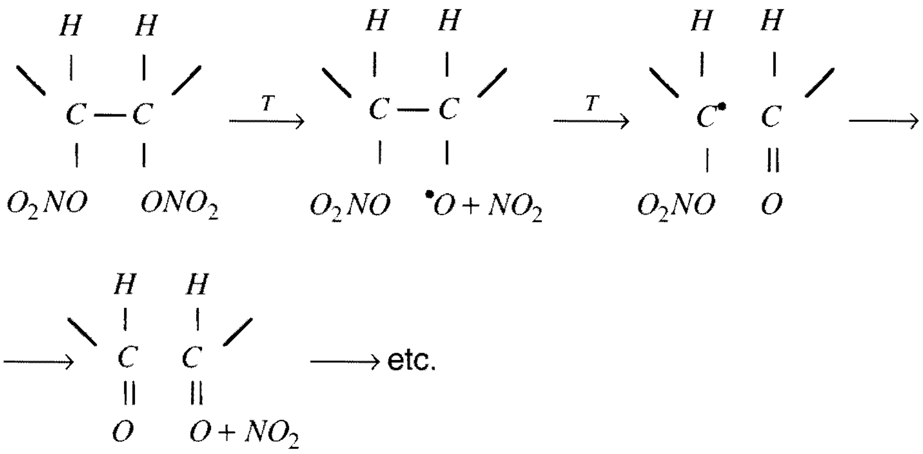
The non-printing areas of the plates 5 may be cleaned by special developer or by UV-irradiation, which apparently decomposes the C-C and C-O bonds of remaining cellulouse macromolecules. This additional treatment complicates the technological process.

By introducing the carbon black into the polymeric coating of plates 6 it is possible to rise its absorptivity.

As a result of IAG/Nd-laser effect the polymeric layer on the exposed areas of the plates 6 is completely destroyed thus forming non-printing elements without additional treatment.

The probable explanation of the difference between plates 5 and 6 is that thermal destruction mechanisms are different as a result of an unequal heating up under the 1.06 μm -laser effect.

In the case of the plates 5 nitrocellulose decomposition probably follows the low temperature mechanism with consequent splitting out of the nitrogroup in the 2-d, 3-d and 5-th carbon atoms of the nitrocellulose fragment according to the scheme:



Thus forming dialdehydes then react with the formation of a solid residue having a high thermal stability. That is why the non-printing areas of plates 5 are ink-receptive. Presumably the organic dye ablation occures before the polymer destruction or dye's concentration in the polymer composition is insufficient for its volume-heating-up.

Carbon black particles in the plates 6 polymeric coating as an efficient laser radiation absorbent promote its fast volume-heating-up and the nitrocellulose decomposes according to the high temperature mechanism with formation of gaseous compounds, i.e. the exposed areas are clean and ink-repelling.
In order to ensure the different directions of the IAG/Nd-laser activated thermal destruction of the CN-contained coatings an IR spectroscopic study was performed of both initial samples of the coating and of the samples exposed by the IAG/Nd-laser at different interaction times. The results are summed up in the table 5.

Table 5

Group	Band, cm^{-1}	Reference	Absorption, %			
			Initial coating	Interaction time, sec		
				$1,5\times10^{-5}$	5×10^{-6}	$2,5\times10^{-6}$
OH	2950	ν OH	60	27	36	46
O-NO_2	1650	ν_{as} NO_2	85	15	32	42
C-O esters	1290	ν_s CO	82	23	34	53
O-N	845	ν_s O-N	86	21	30	42
NO_2	745	δ NO_2	68	6	20	36
C-O-C bridges	1160-1000	ν_{as} C-O-C	84	54	67	72

Note: Plates 5 samples were investigated; when the plates 6 samples were exposed to IAG/Nd-laser the coating is completely removed at all values of interaction time.

The table shows that with an increase in the interaction time the absorption band intensity of NO_2, CO, and NO groups sharply decreases. At the same time the band absorption intensity of O-H and C-O-C bonds decreases gradually. Even when the interaction time is the longest there is some unremoved coating in the non-printing elements.

Thus, spectroscopic investigations confirm the low-temperature mechanism of the coating destruction on the plates 5.

When the plates 6 samples were exposed to IAG/Nd-laser radiation the polymeric coating is completely removed at all values of interaction time, i.e. it is obviously that the high-temperature mechanism of the nitrocellulose coating destruction takes place.

So the spectroscopic researches confirm the proposals about the thermal mechanism IAG/Nd-laser induced coating destruction. Consequently the composition of laser destruction compounds is quite analogous to thermal destruction ones.

Conclusions and Recommendations

The performed researches results are correlated well with the earlier investigations of the CO_2-laser and printing plate coating interaction and illustrate the thermal effect of IR-lasers. In the case of CO_2-laser however it is possible to use for laser recording such a plate material which consists of a transparent (of half-transparent) polymeric coating applied to an absorptive support

The IAG/Nd-laser sensitivity is supported by the high absorptivity of the coating independently of the background.

As follows from the table 4 data the plates 6 answer all the technological demands and they applied now for the laser plate-making in the systems Laser Graver and Granat. The 15-years industrial using of laser plate-making method in Russian printshops allows for making some conclusions.

This process may be employed succesfully in local newspaper, job and commercial printing and some other types of black-and-white production.

At the same time some new technological solutions and plate materials are necessary for the full-scale employment of laser technology in graphic arts industry.

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