

PENETRANTS WITH CASCADE LUMINESCENCE IN LUMINESCENT TESTING METHOD

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Paper is devoted to creation of high-sensitive luminescent penetrants, used in liquid penetrant inspection. Colored and luminescent penetrants in combination with respective cleaning agents and developers are applied in aviation, machine-building, nuclear power and other branches of industry. These materials are intended for detection of defects in surface during testing of parts and end products. They are designed for revealing discontinuities open to surface in metal or non-metal parts: cracks, laps, cold shuts, porosity, grinding checks, hot tears and other defects. Using these materials one display presence, location, nature and magnitude of the revealing discontinuities.

One of the main properties of penetrants consists in their ability to ensure high sensitivity during testing, i.e. ability to detect, where possible, defects of minimal size. These penetrants are designed to meet the most critical inspection applications. The problem of penetrants creating with high sensitivity for capillary defectoscopy is an important practice task and that's why it is an urgent problem.

Fundamental requirements to penetrants are present as following :

- certain physico-chemical properties, determining capacity to spread over surface and penetrate in defects (viscosity, surface tension)
- compatibility with construction materials
- relatively slight toxicity and low fire hazard
- ability to provide high sensitivity.

Therefore indication penetrants must comprise organic solvents with specific physico-chemical properties (viscosity, tension), organic luminophores and surface-active substances for enhancing wetting and penetrating in defects.

In particular, requirement of high sensitivity is met for the account of selection of efficient luminophores. Moreover, such luminophores must possess sufficient light intensity in certain region of spectrum and high quantum yield of luminescence in solutions and on absorbents, used in developers .

In order to increase sensitivity of luminescent penetrants, i.e. to increase light intensity in defects, it is possible to use mechanism acting in so-called “multi-fluorophores” systems. In this case, penetrant contains, in particular, two luminophores operating on the principle of “cascade luminescence” for the account of intermolecular transfer of electronic excitation energy [1,2]. Herewith, luminophore-donor absorbs light in the radiation domain of UV-lamp used for inspection of parts during testing ($\lambda_{\max} = 366 \text{ nm}$). Luminophore-acceptor, in addition to absorption of the UV-lamp radiation, absorbs also radiation of luminophore-donor and radiates in the domain being the most sensitive for human eye (yellow-green region of spectrum), thus increasing the method sensitivity.

Luminophore-donor	$\lambda_{\max.}^{\text{abs.}} = 360\text{-}375 \text{ nm}$ $\lambda_{\max.}^{\text{fluor.}} = 440\text{-}460 \text{ nm}$
Luminophore-acceptor	$\lambda_{\max.}^{\text{abs.}} = 440\text{-}460 \text{ nm}$ $\lambda_{\max.}^{\text{fluor.}} = 500\text{-}520 \text{ nm}$
Luminor №2	$\lambda_{\max.}^{\text{abs.}} = 390 \text{ nm}$ $\lambda_{\max.}^{\text{fluor.}} = 480 - 490 \text{ nm}$

When the only one luminophore is used [3], on the one part, a lot of light is lost in order to achieve the required fluorescence area and intensity; it is due to the incomplete overlapping of radiation spectra of lamp and absorption spectrum of luminophore; on the other part, radiation region that optimal for human eye is not achieved, because Stokes-shift of luminophores does not exceed, as a rule, 100 nm.

The indicated data are illustrated in fig.1, 2.

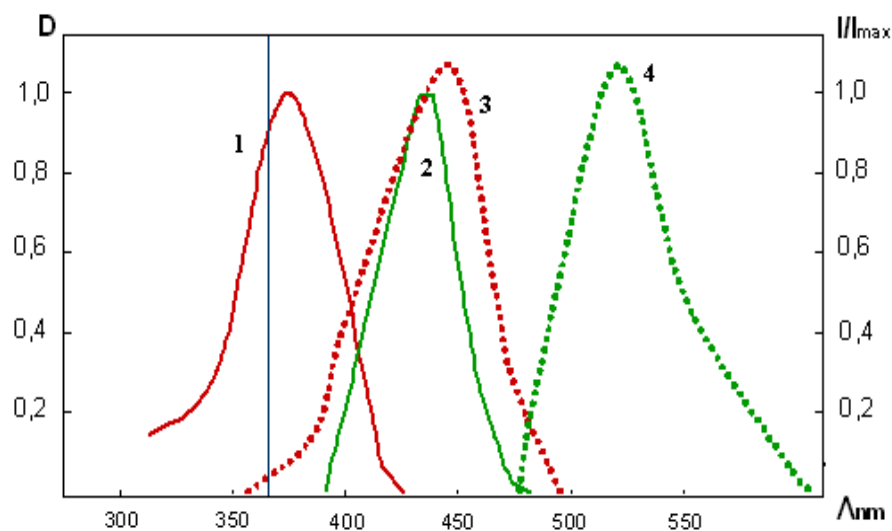


Fig. 1 Absorption (1,2) (—) and fluorescence spectra (3,4) (---) of coumarin-donor (1,3) and coumarin-acceptor (2,4).

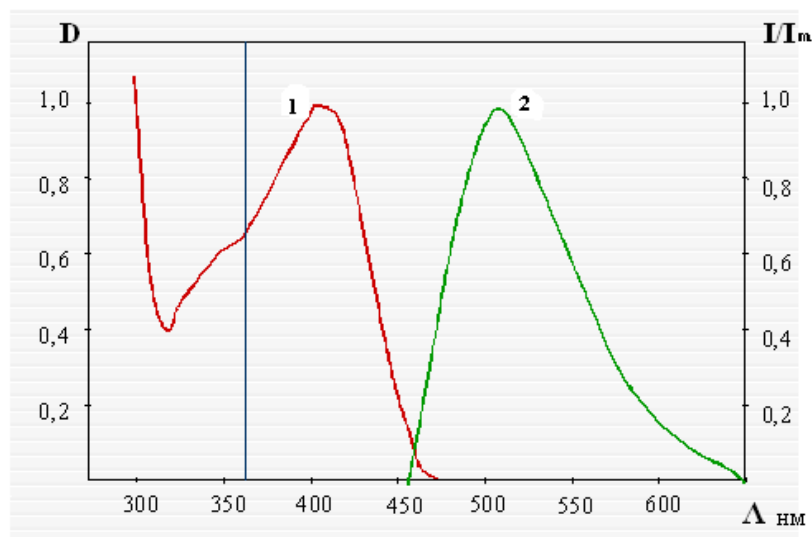


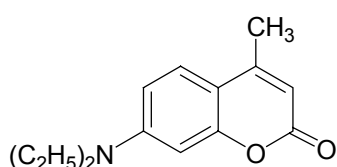
Fig. 2 Absorption spectra (1) (—) and fluorescence spectra (2) (—) of *Luminor 2*

Furthermore, for higher reliability of defects detection, it is necessary, as far as possible, for both luminophores in the penetrant composition to have equal chromatographic mobility and solubility in solvents used in a penetrant and developer (values R_f for both luminophores measured by thin-layer chromatography method must be close to each other).

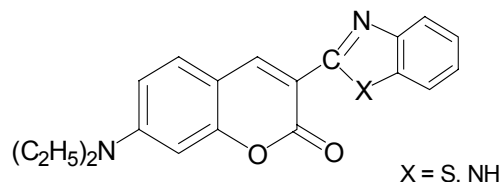
Under development of high sensitive penetrants, we have used dyes with absorption maximum at 375 nm and luminescence maximum in the range of 440-450 nm as a luminophore-donor. Luminophore-acceptor, in its turn, has absorption maximum at 440-450 nm and luminescence maximum within the range of 520-530 nm (region being most sensitive for human eye).

There are known penetrants, comprised luminescence dye (luminophore) and visible dye (absorbing in visible spectral region) [4]. In this case, depending on radiating light we can reveal defects of different sizes : under irradiation by visible light we can reveal defects, for example, with size of 2-3 microns; on radiation by UV-light we can reveal defects, for example, with size of 1 – 2 microns. But these compositions do not find practice application.

Using above disclosed approaches domestic penetrants with extra high sensitivity are developed [5]. Developed penetrant compositions include coumarin with blue-violet fluorescence (for example substance I and its analogs) as a luminophore-donor, and one or several coumarins with yellow-green fluorescence (for example substances II) as a luminophore-acceptor.



I



X = S, NH

II

Moreover, propylenecarbonate and dibutylphthalate were used as organic solvents with high boiling point. Therefore penetrants have low volatility. As result these penetrants possess reduced toxicity and low fire hazard. They comply with the requirements of GOST 18442 concerning I class of sensitivity and with the requirements of DIN EN ISO 3452-3 concerning III class of sensitivity, respectively. Developed penetrants are able to reveal defects 0,0005 mm (and more) in width and 0,01 mm (and more) in depth (and more).

Литература

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