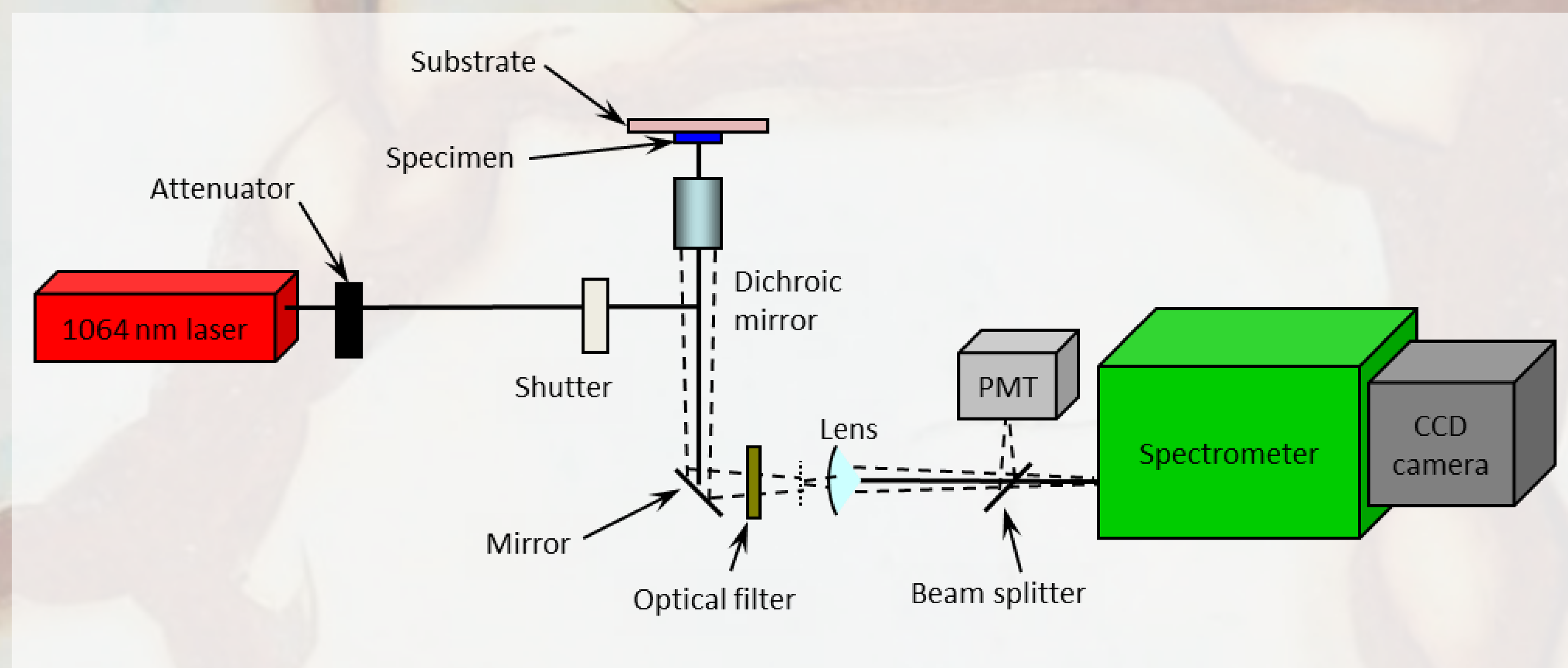
Gubkin University

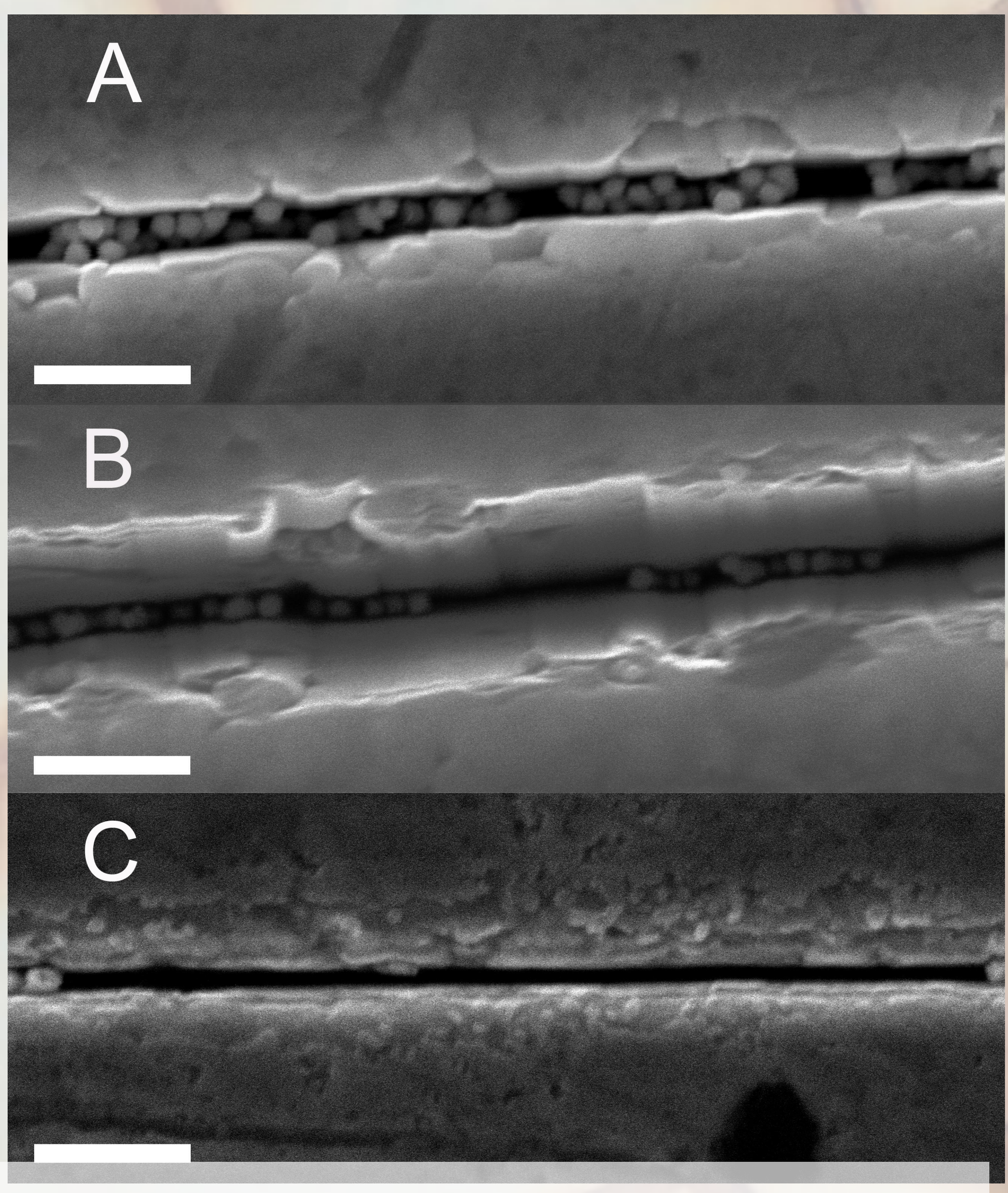
Detection of surface defects contrasted by photoluminescent nanoparticles

M.V. Gorbachevskiy, D.S. Kopitsyn, I.A. Tiunov, M.S. Kotelev, A.A. Novikov

Pipeline corrosion can be prevented if the cracks are detected early by non-destructive testing (NDT) methods. There are a lot of NDT methods available for corrosion monitoring, but they suffer from numerous drawbacks. For example, they are not applicable for rough surfaces, their contrast ability is low and a size-selective contrasting of nano-sized corrosion defects is unavailable. We have developed a modified penetrant method in which gold nanoparticles are used to selectively contrast the corrosion-induced cracks. Visual inspection is replaced by mapping of nanocracks contrasted by the penetrant—photoluminescent metal nanoparticles. Nanoparticles fill cracks that are wider than the nanoparticles diameter. After that the nanoparticles can be detected by femtosecond laser-induced photoluminescence and second harmonic generation (see picture 1) , thus enabling size-selective contrasting of surface defects. In our work we investigated width-selective [1] and depth-selective contrasting of cracks on metal surface.

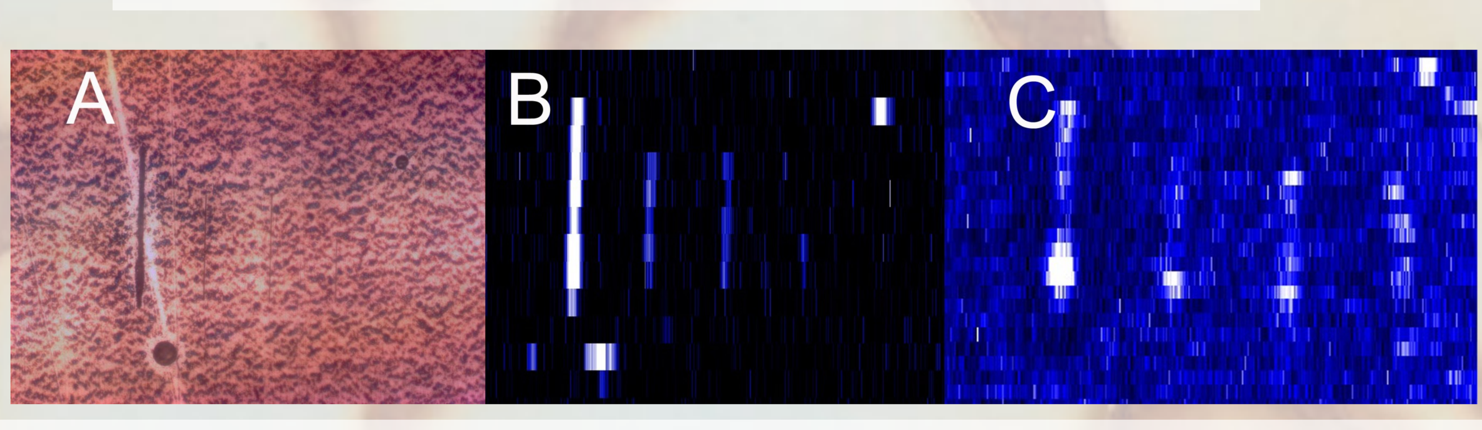


Picture 1 – Optical scheme of the femtosecond-laser scanning microscope for photoluminescence detection

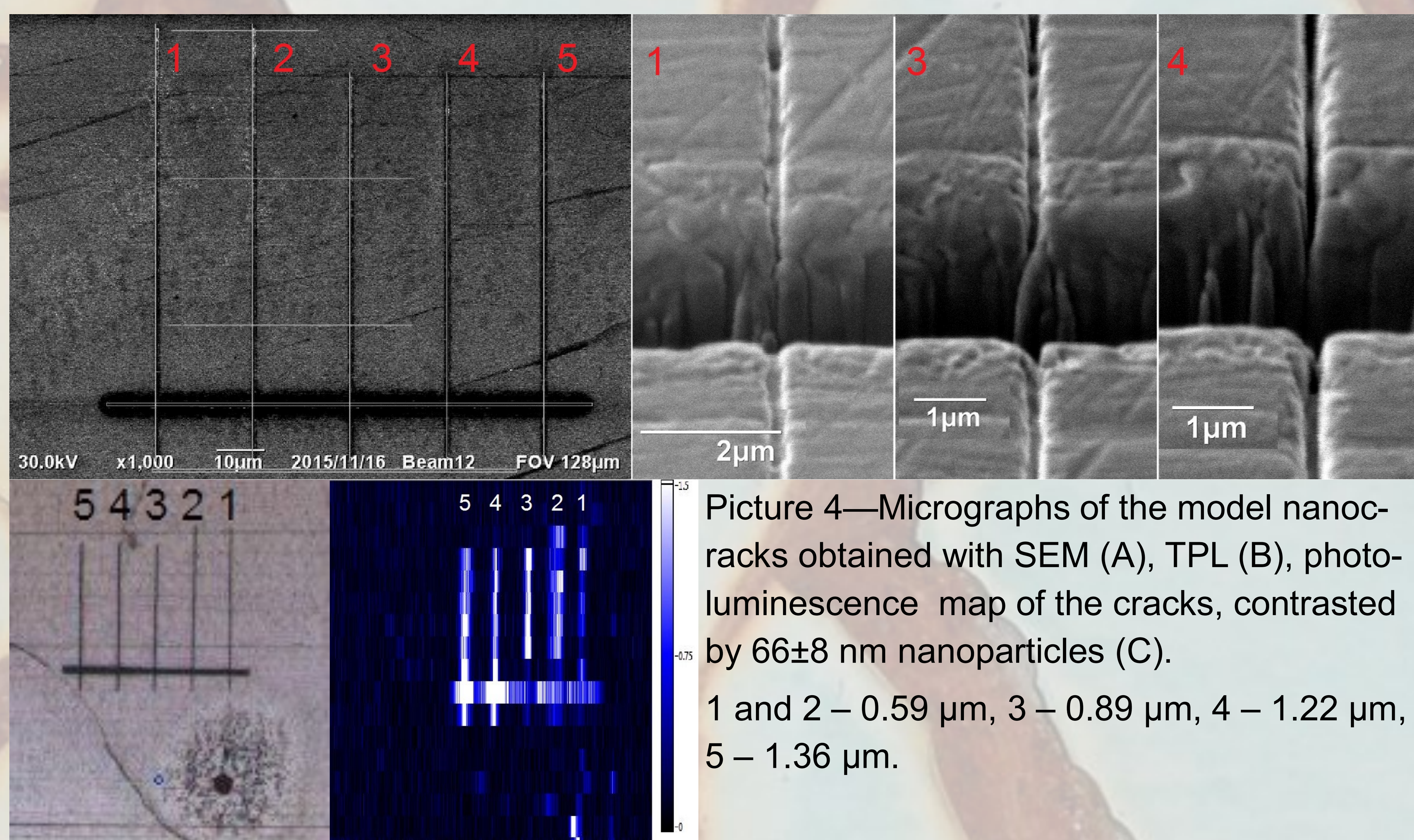


Picture 2—SEM micrographs of the model nanocracks of 400 (A), 200 (B) and 100(C) nm wide, contrasted with 252±45 нм gold nanoparticles. Bar 1 μm

In first experiment the method was tested on model nanocracks with different width: 2500, 400, 200 and 100 nm (using nanoparticles with two sizes: 252±45 and 66±8 nm). The model nanocracks were contrasted at first with the 252±45 nm nanoparticles, imaged, and then contrasted with the 66±8 nm gold nanoparticles and imaged again. The gold nanoparticles with the larger diameter fill the nanocracks of 2000, 400 nm wide and the nanocracks of 200 nm wide but with lower loading, and don't fill 100 nm wide crack (see picture 2). In second experiment, the method was tested on model nanocracks with depths of 0.59, 0.89, 1.22, and 1.36 μm. The model nanocracks were contrasted with the 66±8 nm gold nanoparticles. The photoluminescence intensity varied with the nanocrack's depth. The highest intensity was observed on nanocracks 1.22 and 1.36 μm deep, and lesser intensity – on nanocracks 0.59 and 0.89 μm deep. Thus, the nanocracks of different depth can be contrasted and differentiated at the metal surface.



Picture 3—Micrographs of the model nanocracks obtained with optical microscope (A), photoluminescence map of the cracks, contrasted by 252±45 nm nanoparticles (B), photoluminescence map of the cracks, contrasted by 66±8 nm nanoparticles (C)



Picture 4—Micrographs of the model nanocracks obtained with SEM (A), TPL (B), photoluminescence map of the cracks, contrasted by 66±8 nm nanoparticles (C).

1 and 2 – 0.59 μm, 3 – 0.89 μm, 4 – 1.22 μm, 5 – 1.36 μm.

CONCLUSIONS

The developed method can be used for size-selective contrasting of surface defects of construction materials, in particular, for detection of dangerous nanosized cracks on pipeline steel. Furthermore, it is possible to distinguish deep cracks from shallow surface defects.

References

1. Kotelev, M. S., Kopitsyn, D. S., Tiunov, I. A., Vinokurov, V. A., & Novikov, A. A. (2015). Size-selective contrasting of cracks on a metal surface by gold nanoparticles. *Mendeleev Communications*, *25*(5), 356-357.

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