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PROPERTIES OF THERMAL-CONDUCTIVE CERAMIC-BASED COATINGS DEPOSITED USING FORE-VACUUM PLASMA-CATHODE ELECTRON SOURCE

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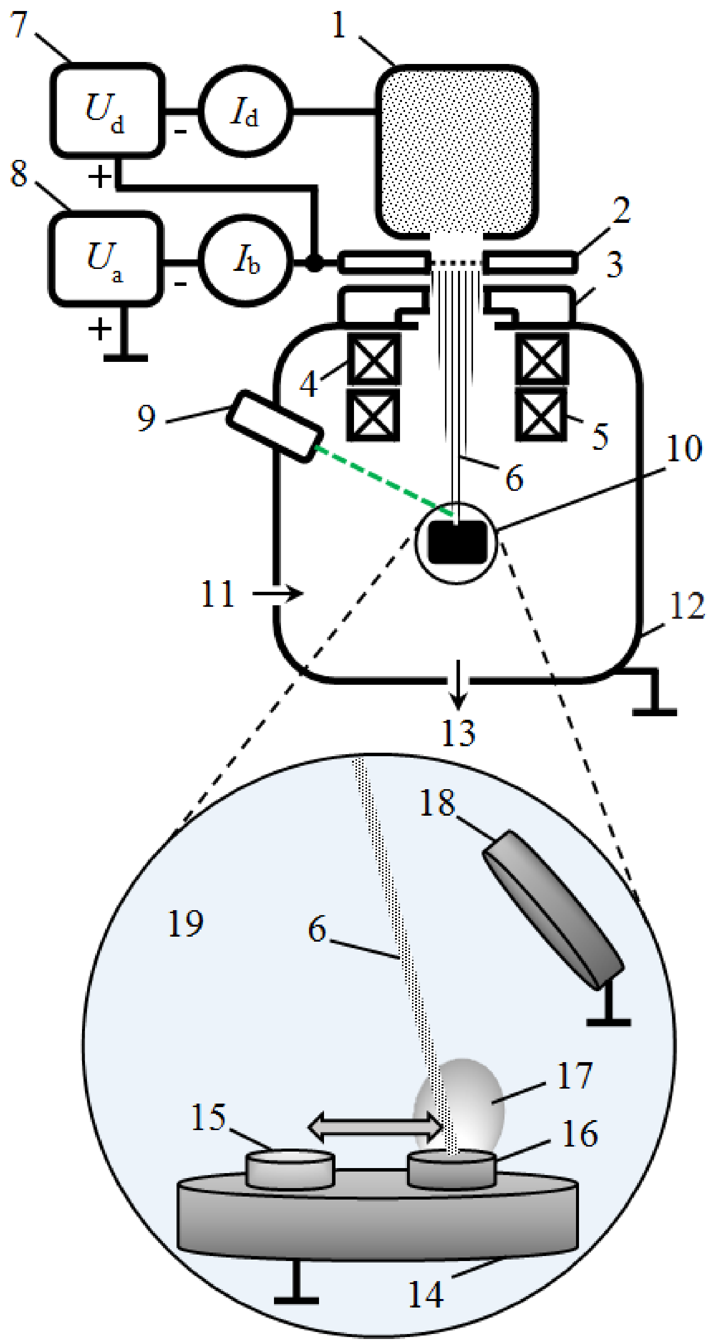
Relevance & Outline

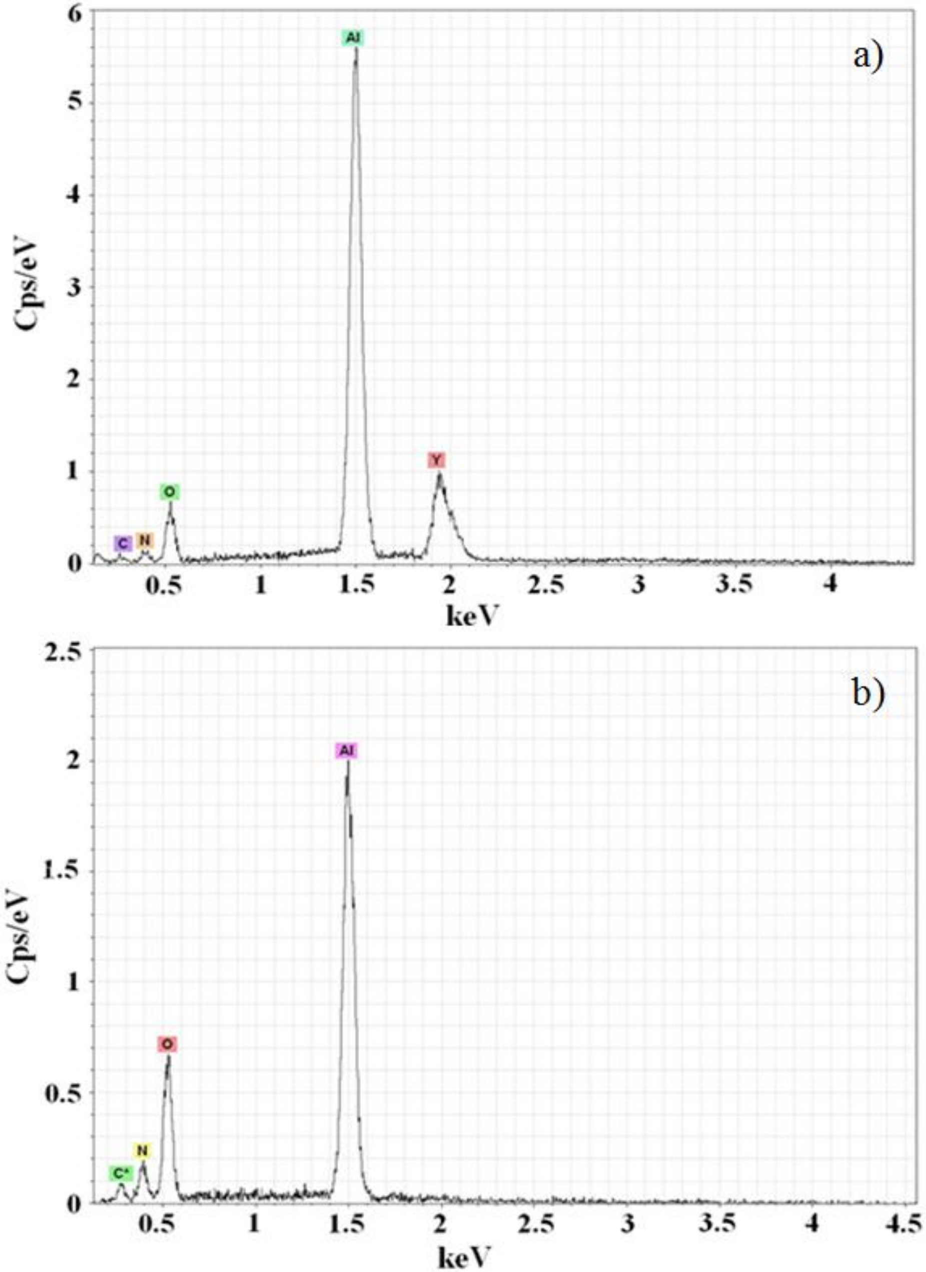
- Polymers are usually used as protective, sealing and functional coatings in microelectronic devices. Polymers properties can be enhanced by including the fibers of aluminum nitride into their structure. Such inclusions lead to a thermal conductivity increase of up to 1 W/m·K. Our analysis allowed us to conclude that the optimal combination of dielectric and heat-conducting properties can be achieved with aluminum nitride or aluminum oxynitride-coatings.
- Another important issue is the choice of method for the deposition of coatings. We propose to apply a fore-vacuum plasma electron source that have been developed in our lab. This device allows forming electron beams in the previously inaccessible (so-called fore-vacuum) pressure range of 1-100 Pa. Under such a high pressure, the beam-produced plasma neutralizes the charge of the electron beam accumulated on the dielectric target, and also provides active neutral and ionized nitrogen species, which, in turn, bind free atoms of aluminum.
- Therefore, the goal of this work is to create the scientific basis of electron-beam and plasma method for deposition of heat-conducting ceramic coatings for various purposes in microelectronics.
- Here, we present our experimental results on the deposition of heat-conducting ceramic-based coatings on various substrates. The composition of the obtained coatings and their thermo-physical properties has been studied.

Experimental setup



1 – hollow cathode;
2 – anode;
3 – extractor;
4 – focusing coil;
5 – deflecting coil;
6 – electron beam;
7 – discharge power supply;
8 – accelerating voltage power supply;
9 – infrared pyrometer;
10 – irradiated object;
11 – gas inlet;
12 – vacuum chamber;
13 – pumping system;
14 – collector;
15 – alumina ceramics;
16 – aluminium nitride ceramics;
17 – vapors of the evaporated material;
18 – substrate;
19 – beam plasma.

Experimental Results and Discussion: target and coating elemental compositions



The analysis has revealed that the coatings based on aluminium nitride ceramics, deposited by evaporation of a solid-state sample in nitrogen atmosphere, contain mostly aluminium and oxygen.

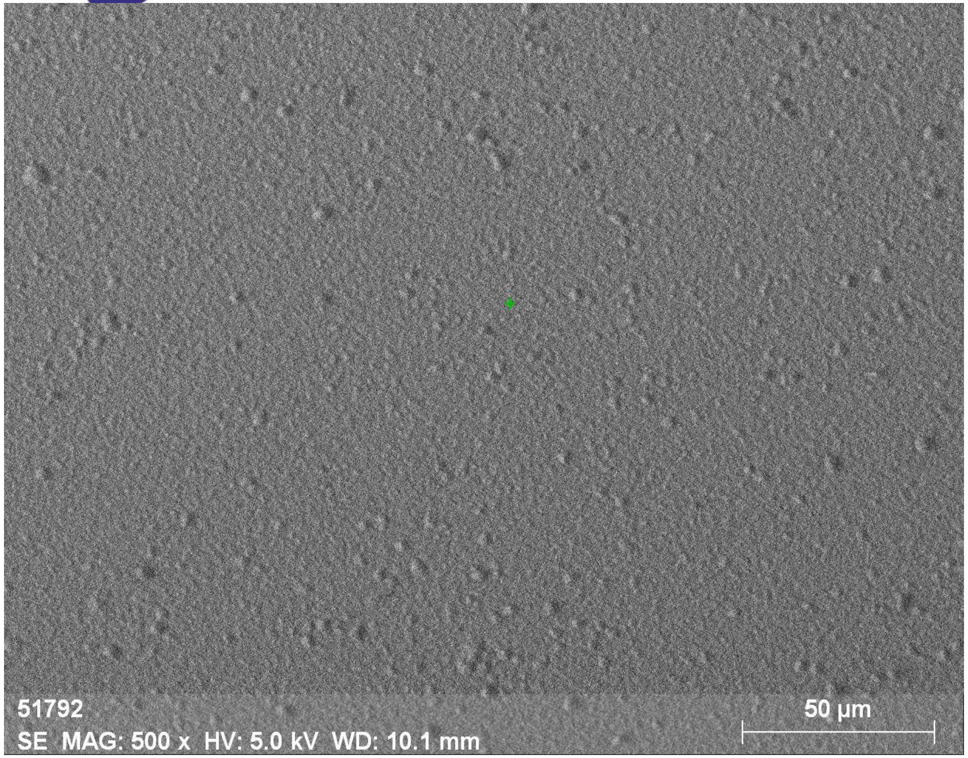
As seen (a), the original material of the target contains yttrium which is not present in the deposited coating (b). This fact may be connected with a higher boiling temperature of yttrium (3611 K) than that of aluminium (2790 K).

The small peak of nitrogen seems to be related with a strong nitrogen absorption in the bulk of deposited coating; as a result, the spectrum readings show the nitration lines emitted mostly from the coating subsurface.

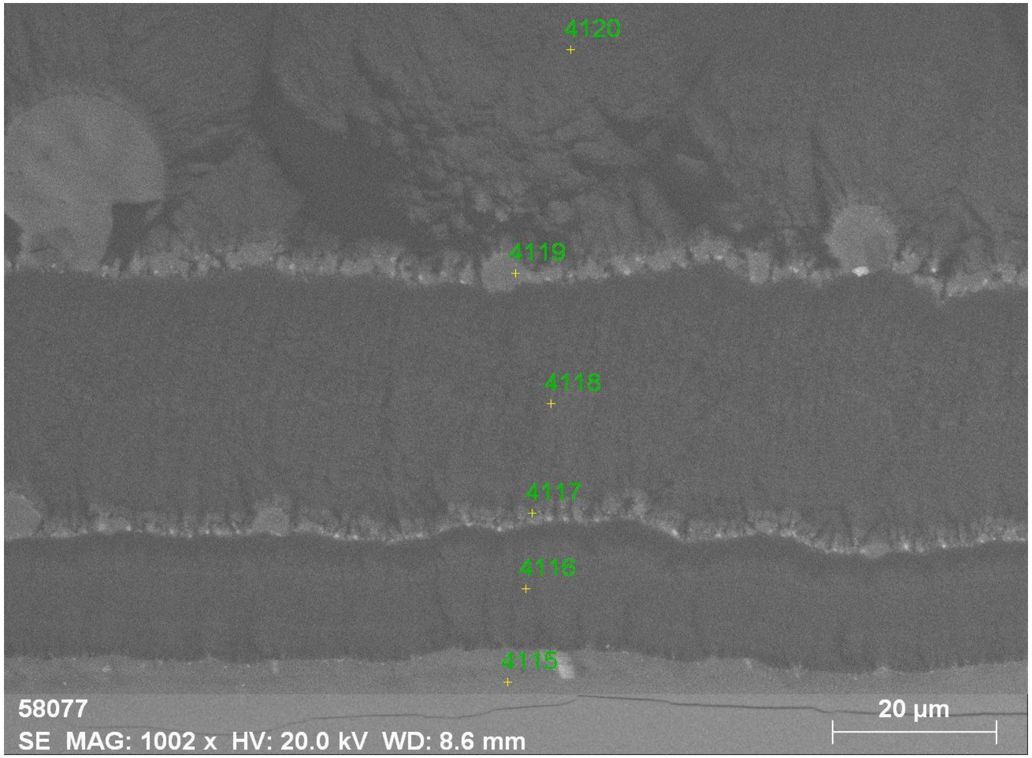
Note that the deposited coating does not contain any “extraneous” admixtures despite carrying out the process at elevated (fore-vacuum) pressure set by using exclusively a mechanical pump.

There is no difference between the elemental composition of the original aluminium oxide ceramics and that of the coating.

Experimental Results and Discussion: multi-layer coating analysis



Microphotograph of the coating deposited during evaporation of aluminium nitride ceramics.



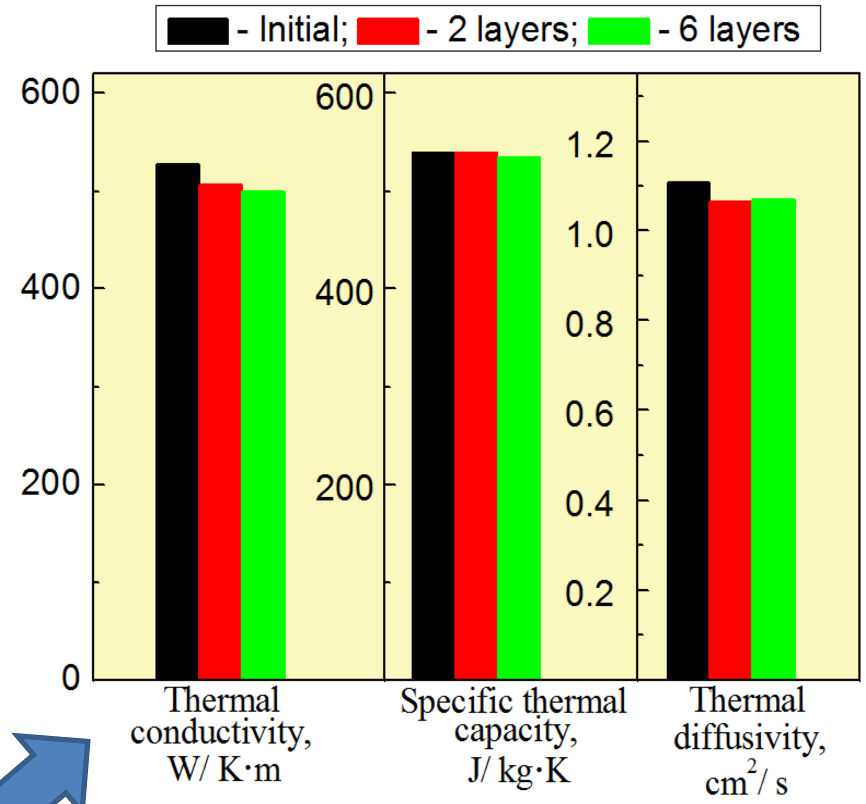
Microphotograph of a multi-layer coating chip.

As seen from the photograph, the thickness of alumina ceramic layers is about 2 µm and that of aluminium nitride ceramics ranges from 10 to 30 µm. Such difference arises from the purpose of the coating deposition process: enhancement of electrical insulating properties or the heat distribution over the surface by depositing thicker layers of aluminium nitride ceramics.

Experimental Results and Discussion

TABLE I. ELEMENTAL COMPOSITION OF COATINGS LAYERS

Spectrum	Elements			
	N	*O*	*Al*	*Si*
4115	0.71	4.90	18.80	75.59
4116	5.74	36.67	44.34	13.25
4117	0.56	33.09	49.32	17.03
4118	7.84	25.92	46.35	19.89
4119	0.89	10.52	66.65	21.93
4120	6.23	32.09	45.43	16.25



The coefficients of thermal conductivity and diffusivity decrease with increasing number of coating layers, which testifies to an improved efficiency of heat dissipation by alternating layers with different thermal conductivity.
Note that, despite a reasonably thin coating, its thickness is sufficient to provide an efficient heat conductivity of dielectric coatings. It makes the proposed method promising for depositing multi-layered thermally conductive coatings.

Thermal conductive properties of fabricated samples.

Conclusion

Using a fore-vacuum source of continuous, powerful and focused electron beam in the presence of beam plasma, we have carried out the deposition of electrically insulating multi-layered coatings with alternating thermally insulating and thermally-conductive properties.

It has been found that the thermal conductivity of multi-layered coating diminishes as the number of layers increases, which speaks for a more efficient heat distribution.

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Thank you for attention!