Diamond-Carbide Silicon Composites Ceramics "IKRAM"

Structure, Properties, Prospects of Application

RUSSIAN COMPOSITE TECHNOLOGIES

Vostok Composite LLC, Russia, 2025

About IKRAM

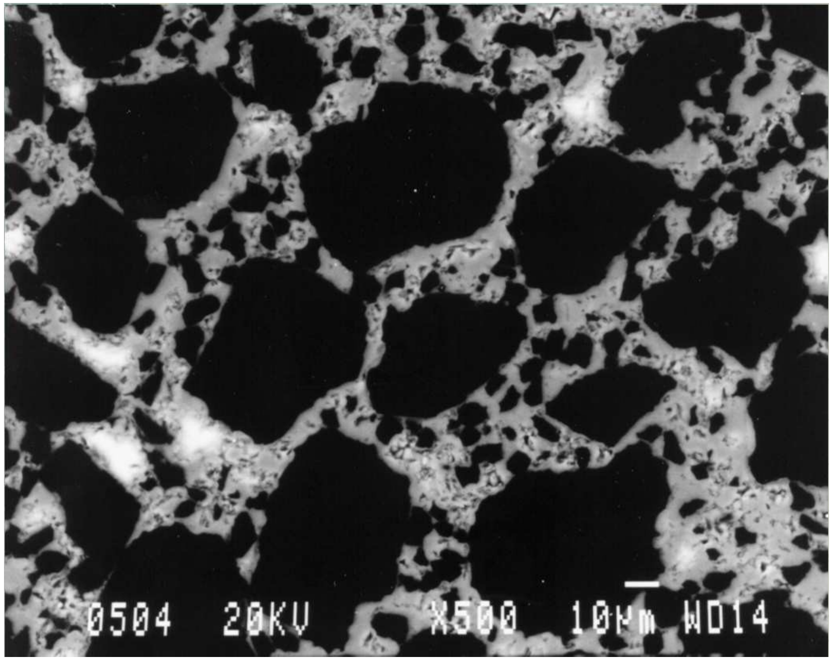
1. IKRAM is a group of super-hard ceramic composites, from which it is possible to obtain products of very complex shapes and large sizes, implementing the "non-shrinkage" technology.

2. IKRAM combines unique properties in terms of wear resistance, rigidity, thermal conductivity, and TKLR.

3. The possibility of controlled variation in the composition and properties of materials, obtaining gradient materials with an uneven distribution of diamond particles throughout the volume of the material allows them to be easily adapted to different applications.

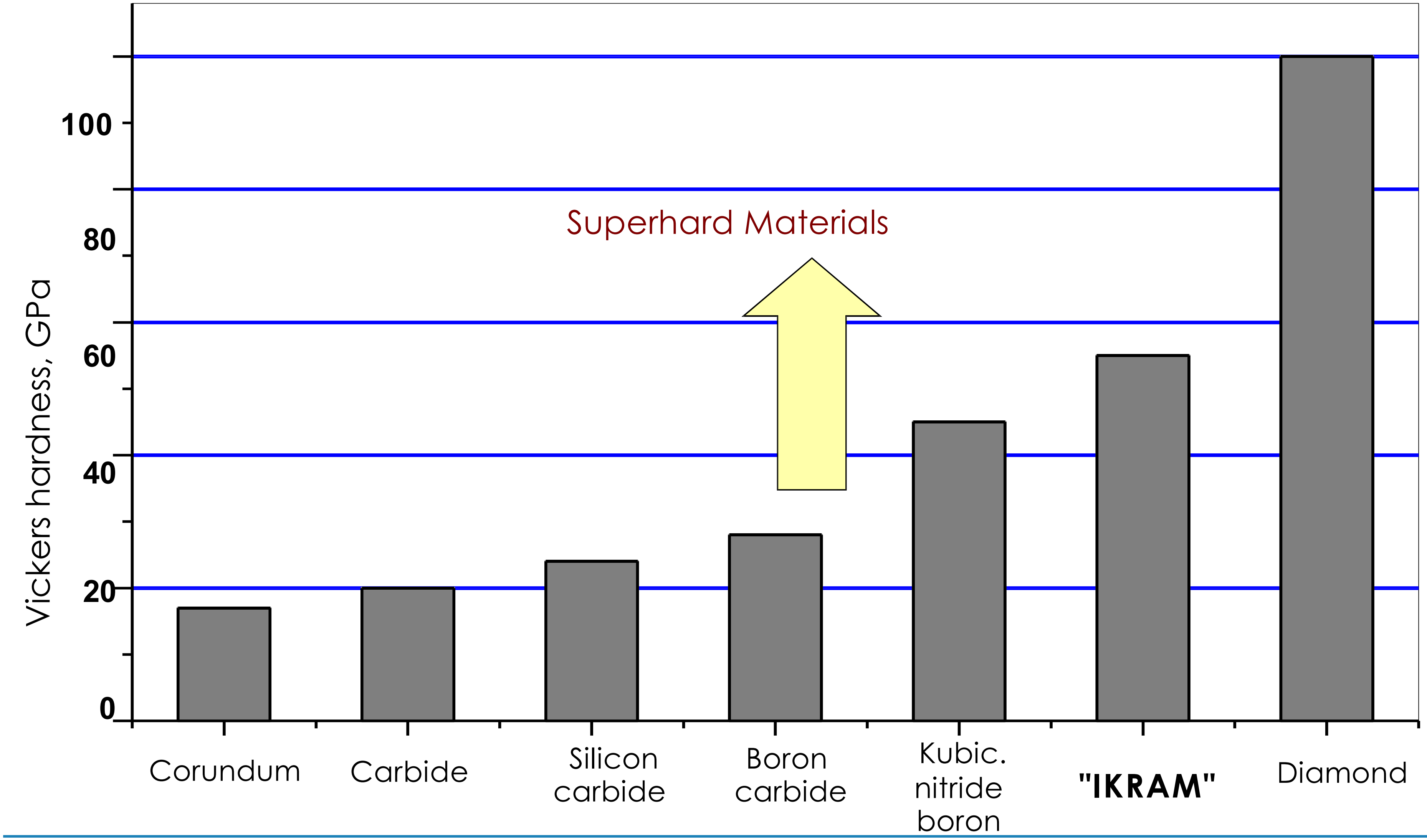
Composite diamond/SiC (IKRAM)

Diamond-Silicon Carbide Composites "IKRAM" are the group of materials, the structure of which includes diamond particles bound into a single composite by a silicon carbide matrix.
Variable component content allows for a wide range of material properties to be changed.



- Microstructure of the surface of IKRAM containing diamond particles of two sizes: 10-14 µm and 63-50 µm.
- The photo shows the relationship of phases:
- diamond (black),
- silicon carbide (gray),
- silicon (white)

Hardness of "IKRAM"



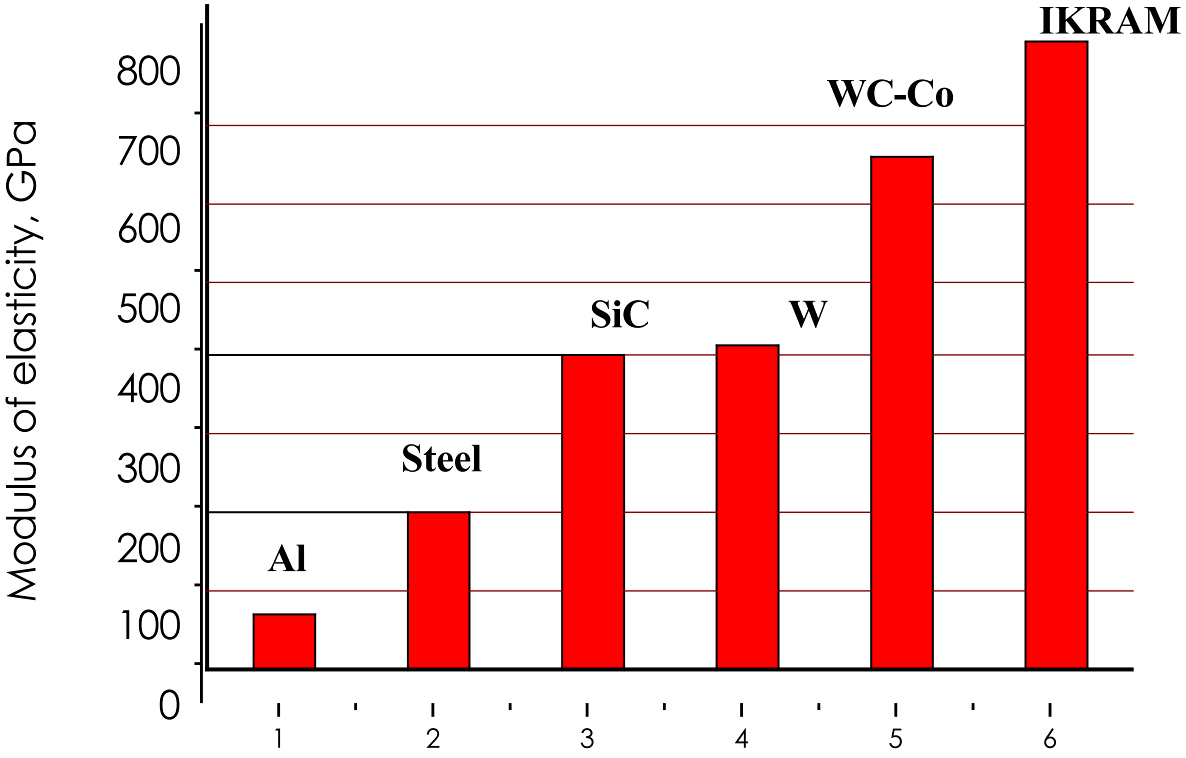
Parts of complex shapes made of "IKRAM"

Technological features of obtaining "IKRAM" make it possible to manufacture parts of complex shapes from it without further machining, which is extremely difficult due to the extremely high hardness of the material.

The change in linear dimensions after converting a workpiece into a composite does not exceed 0.2%. This makes it possible to produce parts with complex shapes

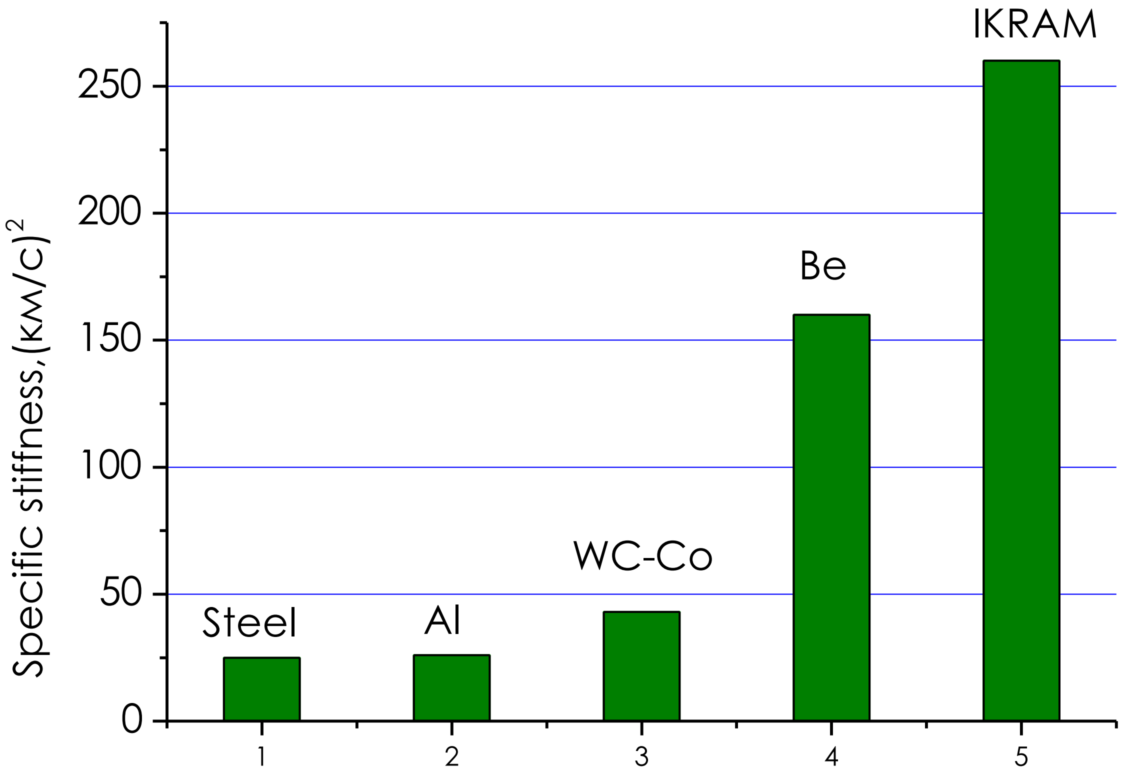
Application of technology for the manufacture of nozzles and tools for drilling

Modulus of elasticity of "IKRAM"



- IKRAM has a very high rigidity.
- Its modulus of elasticity is 500-830 GPa.
- This is the highest result for structural isotropic materials.

Specific stiffness of "IKRAM"



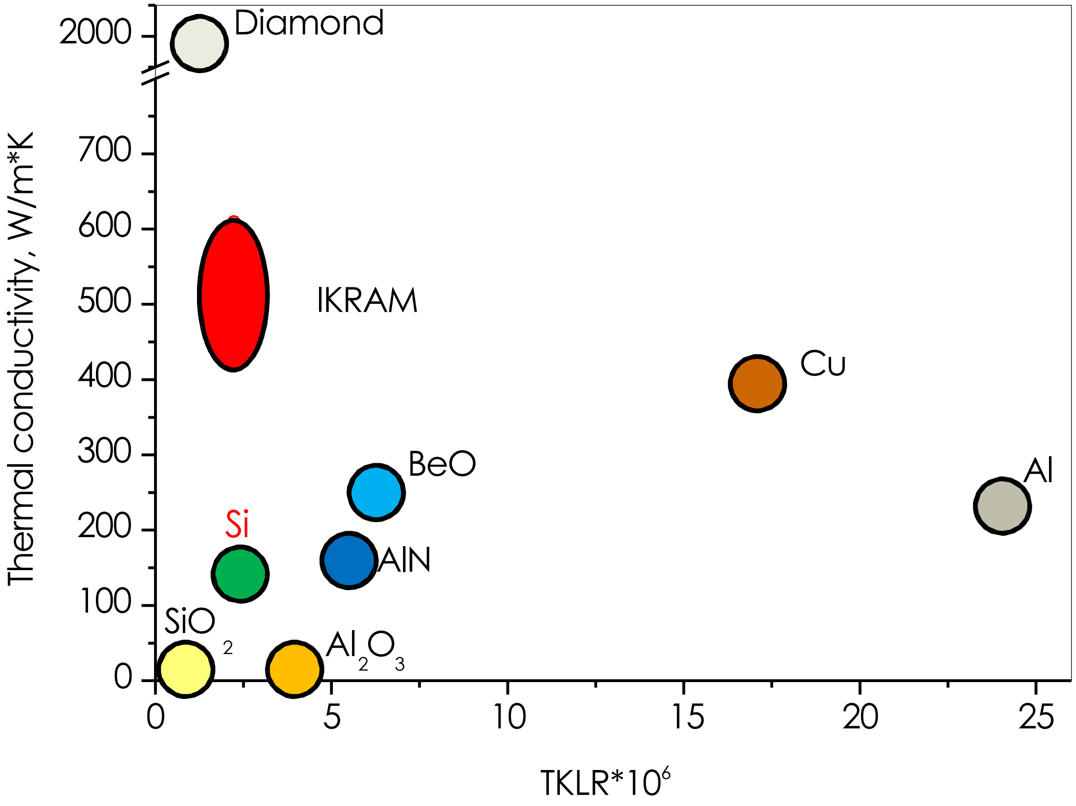
IKRAM is significantly higher than other structural materials in terms of specific stiffness (module relation elasticity to density)and the speed of sound in it.

Thermal stability of "IKRAM"

Change in Modulus of Elasticity of Material after Heat Treatment at High Temperatures in Vacuum for 45 Minutes at Each Temperature

t, °C	20	1200	1400	1500	1600	1800
E, GPa	718	718	713	709	709	destruction
$(1-E_T/E_{20})\cdot 100\%$	0	0	1	1	1	----

Thermophysical properties of "IKRAM"

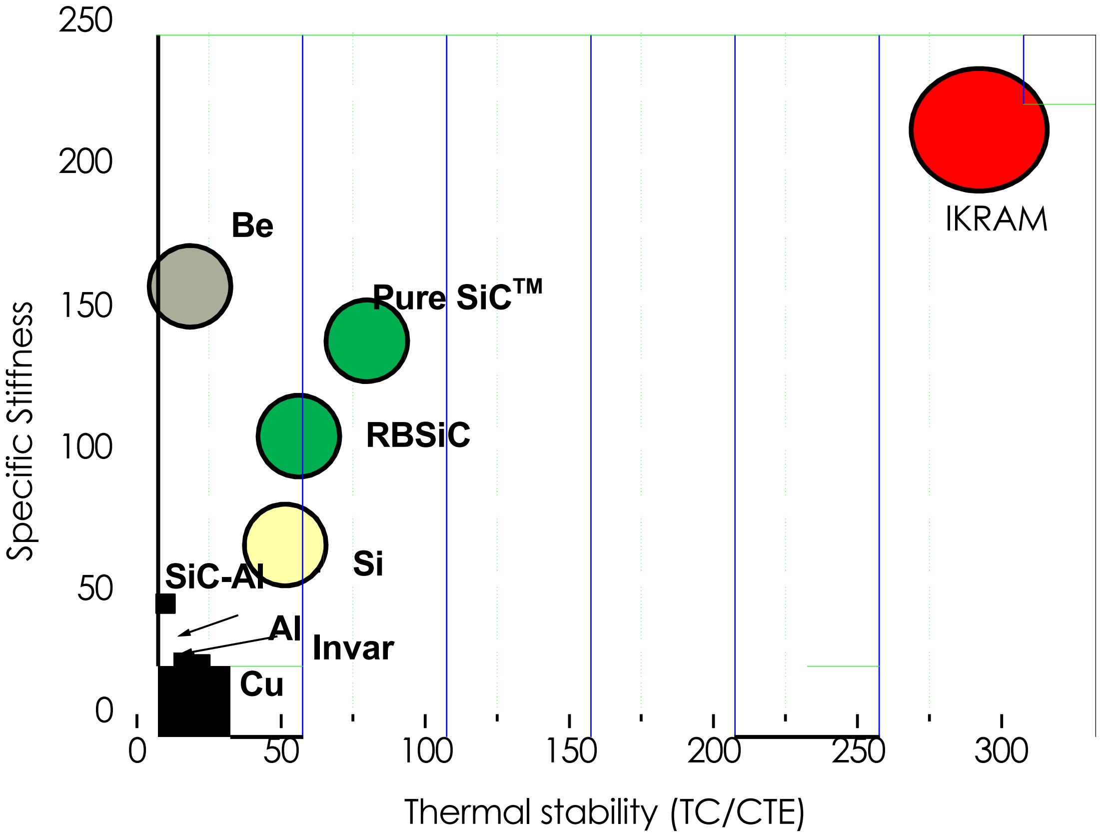


IKRAM has high thermal conductivity, low temperature coefficient of expansion, which coincides with the TCLR of silicon.

"IKRAM"

for optical elements

Modern Mirror Materials made of "IKRAM"



Specific stiffness – E/p [(km/s)2], TC/CTE is the ratio of thermal conductivity to thermal expansion [106 W/m]

Models of mirrors from "IKRAM"

120 mm mirror

60 mm spherical mirrors

Lightweight mirror 160 mm

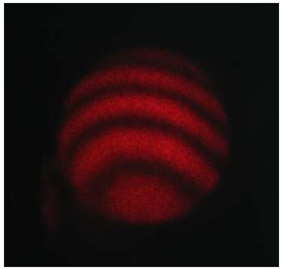
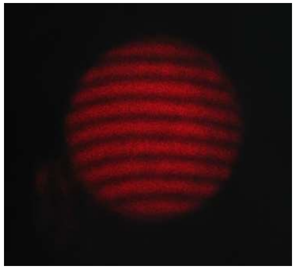
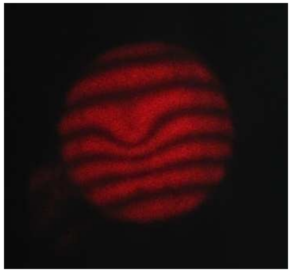
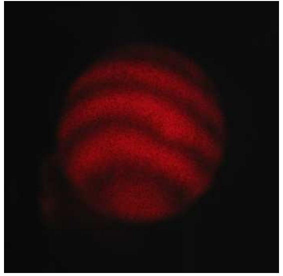
Main characteristics of experimental samples of mirrors made of "IKRAM"

Mirror	Structural coating	Surface Finish Class	RMS_{WFE} (λ=633нм)	Rq, нм
120x85x7 mm "Ellipse"	Si	IV	0.14λ	2.5
120x85x7 mm "Ellipse"	Si/SiC	V	0.12λ	4.0
160x85x15 mm "Ellipse"	Si	IV	0.09λ	2
Diameter 60 mm "Sphere"	Si/SiC	IV	0.05λ	2.3
Diameter 60 mm "Plane"	Si	III-IV	0.065λ	2.7

Values of thermal deformation coefficients for mirrors made of different materials

Mirror Material	Copper	Silicon	**IKRAM/Si**
Uncooled mirrors, (k, 10^{-9} м/Вт)	6.7	2.5	**0.5**
Cooled mirrors (k,10^{-12} м^3/Вт*с)	5	1,5	**0,3**

Thermal deformation of mirrors

Mirror Material	**SteelX18H10T**	**Copper M1**	**"IKRAM"**
Initial interferogram			
Under load			

Laser radiation with an intensity of 4 kW/cm2 was focused on the surface of the mirrors into a round spot with a diameter of 2 mm.

Mirror substrate 300 x 200 mm

"IKRAM" for heat sinks of electronic devices

IKRAM, Russia, 2025

Experimental Results of Determining the Thermal Conductivity of "IKRAM"

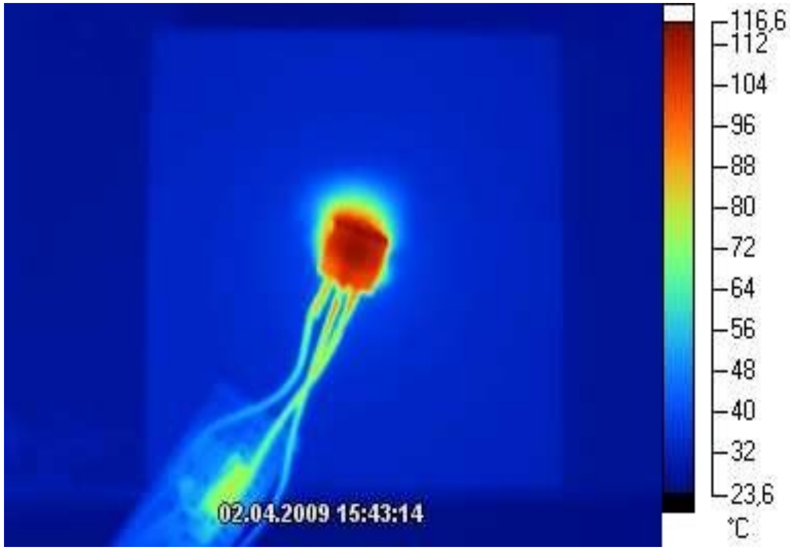
The thermal conductivity of IKRAM depends on the composition of the material, mainly on the diamond content. Thermal conductivity coincides well with the design values according to the developed model.

Material composition, % vol.			**Thermal conductivity, W/m K**	
Diamond	**SiC**	**Si**	**experiment**	**calculation**
43	46	11	280	264
52	37	11	370	365
58	30	12	490	480
59	30	11	510	480
68	25	7	610	580
70	23	7	600	605

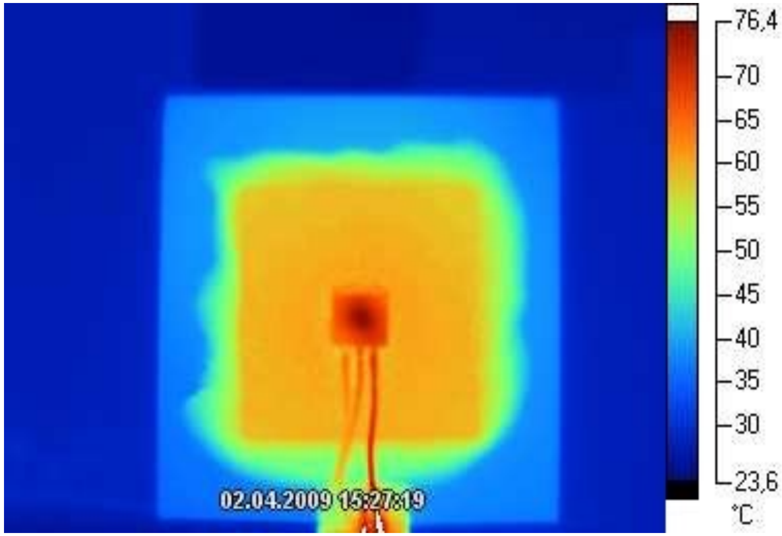
Change in the thermal field when using IKRAM materials

The use of heat sinks from IKRAM for cooling electronic components and assemblies from electronic components is based on the effective "smearing" of the heat flux from local separation on transistors by plates and further heat transfer to the heatsink.

The above example shows the possibility of reducing the transistor temperature by 40°C when using a heat sink plate made of IKRAM with minimal temperature gradients along the surface.

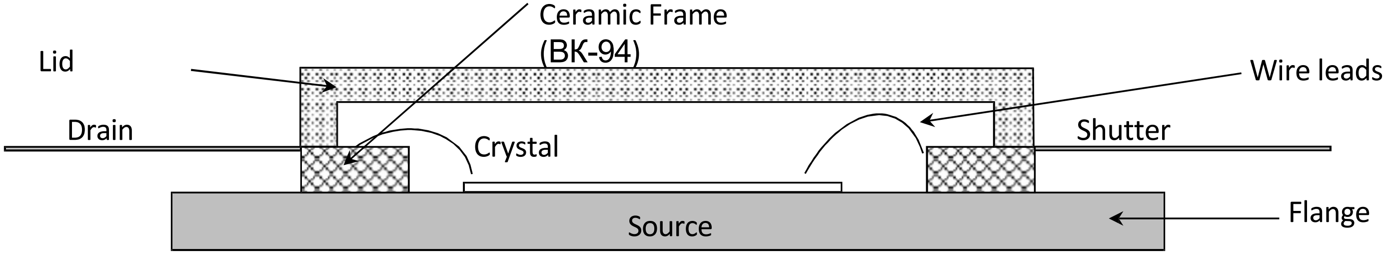


Aluminum plate (85x85 mm) + fuel element (transistor)

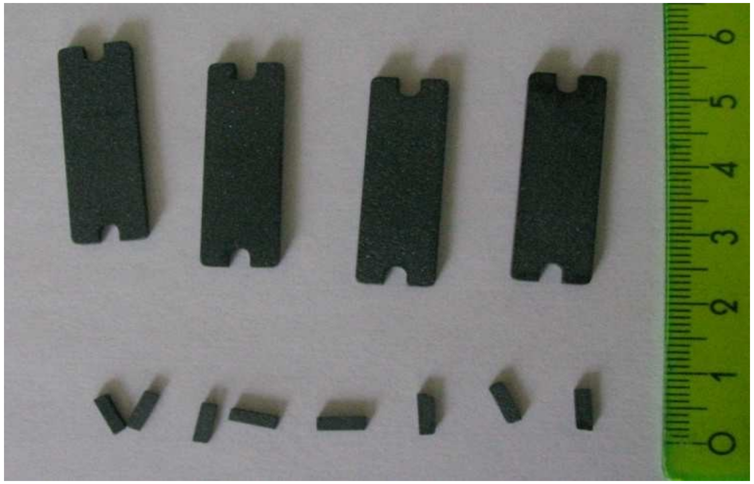


Aluminum plate (85x85 mm) + AKK plate (44x44x3 mm) + fuel element (transistor)

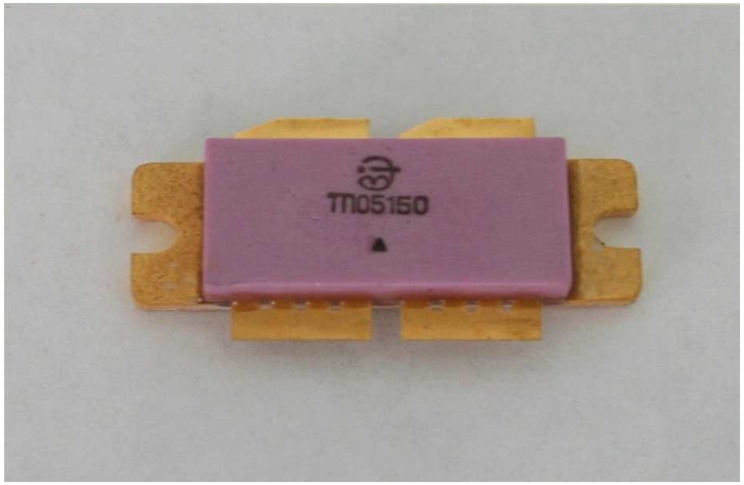
Application of IKRAM Automatic Compressor Complex in Microwave Transistors



Design of a high-power LDMOS microwave transistor with a high specific dissipation power based on a flange made of IKRAM



Heat sinks-flanges made of IKRAM for series of microwave LDMOS transistors with output power of 6, 35, 150 and 250 W

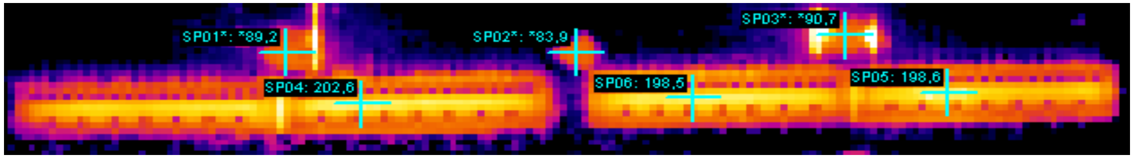
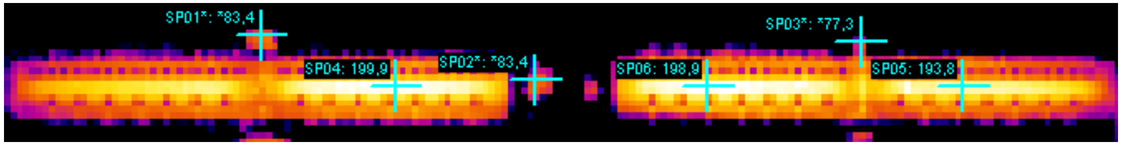


LDMOS transistor type TP 05150-28L based on ICRAM AKK flange»

The weight of the transistor is 3.5 g, which is two times less than a similar transistor with a metal flange made of MD-40 alloy

Comparative Study of Rt Transistors

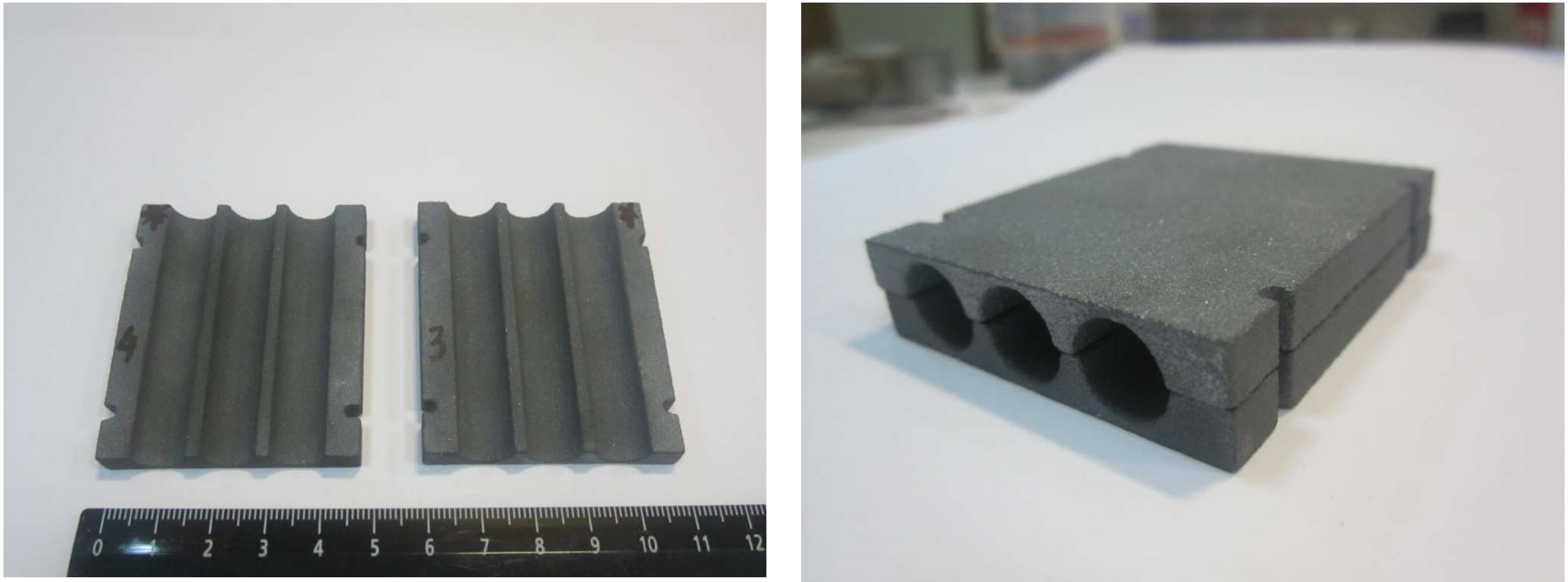
(Pout=150Вт, К=15dB, η=50%, f=500 MHz)

Thermal field The tests were carried out in a quasi-dynamic mode of f=1 MHz, at a maximum permissible crystal temperature of 200 °C	Thermal Resistance °C/W
with flanges made of "IKRAM"  	0,55
with MD-40 flanges  	0,73

Reducing the value of thermal resistance allows you to increase the maximum power dissipation, expand the range of applications and increase the reliability of microwave transistors.

Effect - 30%

Heat Sinks from "IKRAM" for Thermal Stabilization Systems



Heat pipes are installed in the holes

Heat sinks made of IKRAM material

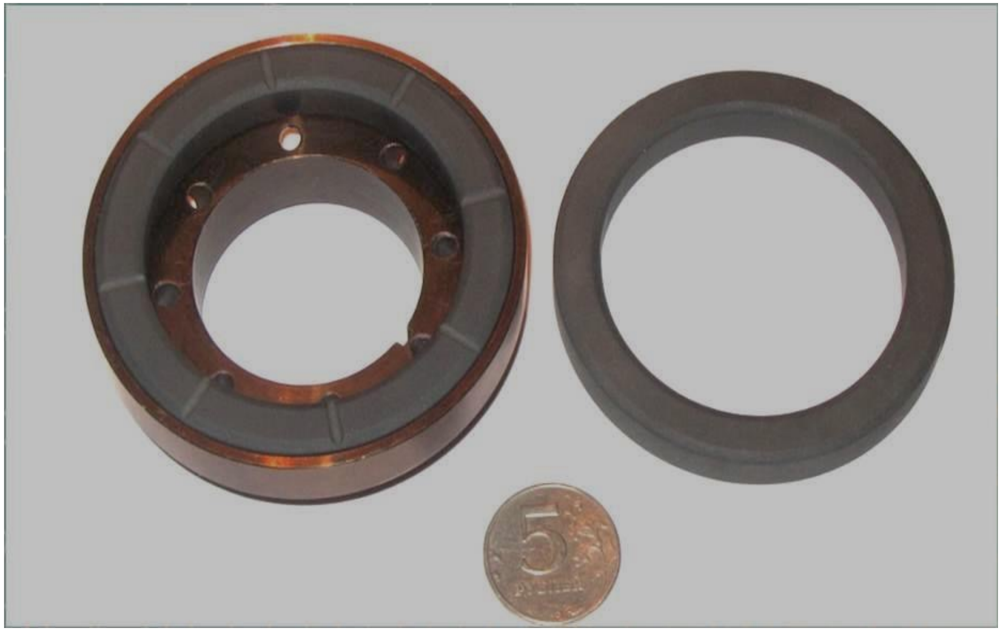
- Advantages Thermal conductivity is 2-4 times higher than that of AlN and BeO
- Dimensional and shape stability (TCRR = 2*10-6 K-1)
- TCRR "ACC" = TCRR Si
- High strength

Photo of heat spreading plates made of IKRAM material

Electrical resistance in the Z direction - 200 Ohm

"IKRAM" for friction units

Thrust bearings



Movable (in the housing) and fixed rings of the thrust bearing with a diameter of 75 mm made of "IKRAM".

Bench tests have shown that the friction coefficient of ACC/ACC is (load - 85 kgf/cm2, rotation speed - 2900 rpm) in water - 0.052, in oil - 0.013, which is not worse than that of carbide ceramics and hard alloys. A decrease in the roughness of rubbing surfaces was noted (from Ra=0.25 µm to Ra=0.1 µm).

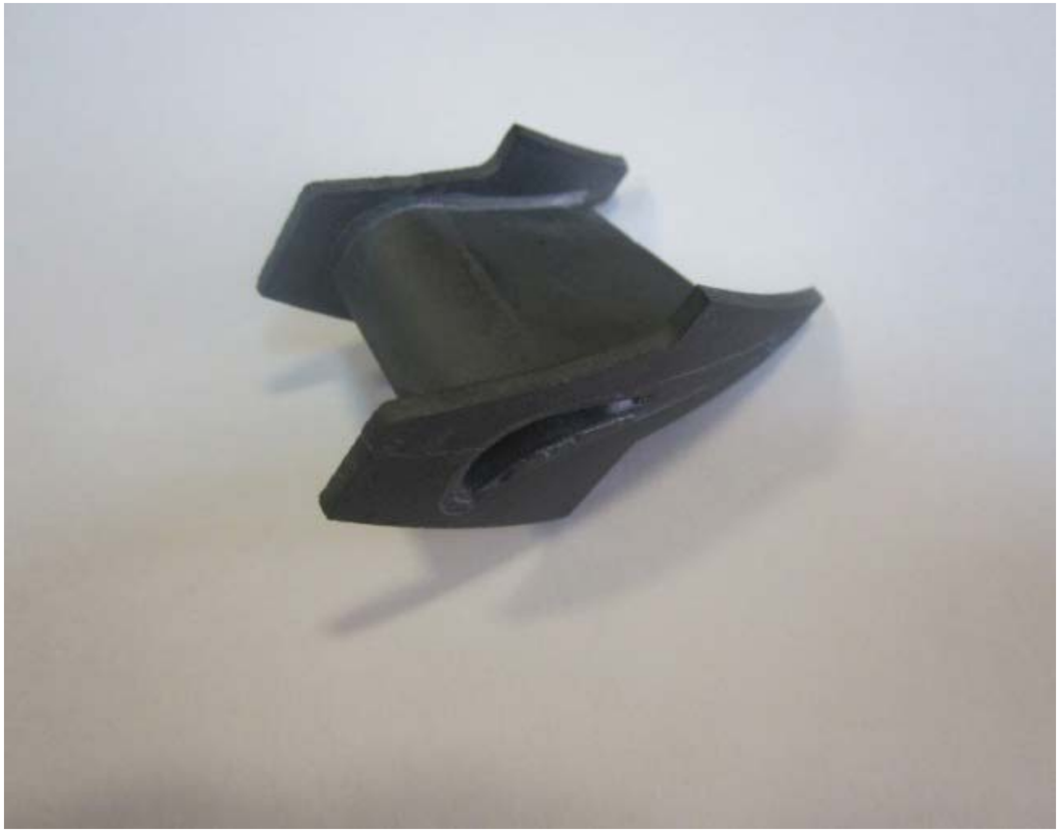
Balloons from AKK "IKRAM"

Results of comparative tests of balls from "IKRAM" with balls made in Germany

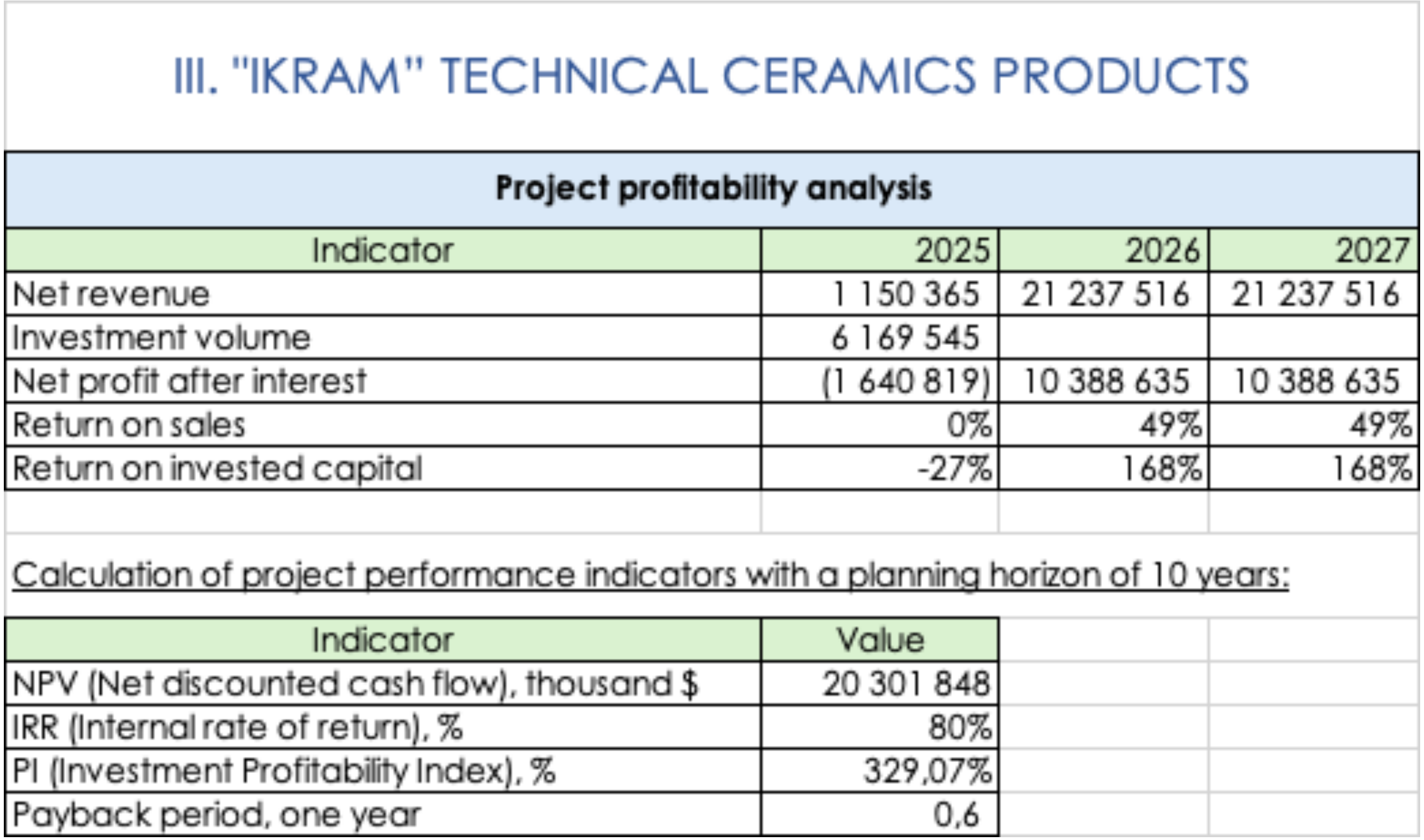
№ Ball	Breaking load on the ball, P, kgf		Footprint diameter, mm	Notes
	The beginning of the destruction	Complete destruction		
Balls with a diameter of = 10.23 mm, made of IKRAM				
3	7080	9860	3.76	The circumference of the print is broken by fragments of the ball
11	6950	9720	3.73	-------------------
Balls with a diameter of □ = 10.23 mm made of Si3N4 made in Germany				
1	6250	6250	3.1	Instant Destruction
2	8940	8940	3.8	Instant Destruction

Rolling bearing cage made of "IKRAM"

Parts of complex shapes made of "IKRAM"



FINANCIAL INDICATORS OF THE PROJECT



III. "IKRAM" TECHNICAL CERAMICS PRODUCTS

Project profitability analysis

Indicator	2025	2026	2027
Net revenue	1 150 365	21 237 516	21 237 516
Investment volume	6 169 545		
Net profit after interest	(1 640 819)	10 388 635	10 388 635
Return on sales	0%	49%	49%
Return on invested capital	-27%	168%	168%

Calculation of project performance indicators with a planning horizon of 10 years:

Indicator	Value
NPV (Net discounted cash flow), thousand $	20 301 848
IRR (Internal rate of return), %	80%
PI (Investment Profitability Index), %	329,07%
Payback period, one year	0,6