

FINE GRINDING OF HARD CERAMIC WASTES IN ROTARY-VIBRATION MILL

Sidor Jan^a, Wójcik A. Mariusz^b and Kordek Jacek^c

Academy of Mining and Metallurgy - Technical University,
Av. Mickiewicza 30, A-3, 30-059 Cracow, Poland

^aFaculty of Mechanical Engineering and Robotics, Department of Technological Equipment and Environment Protection,

^bFaculty of Materials Science and Ceramics, Department of Building Materials,

^cFaculty of Mining, Department of Mineral Processing, Environmental Protection and Utilization of Wastes,

ABSTRACT

Some results of grinding of two high purity and hard ceramic wastes as corundum insulator of sparking plugs (*CSP*), filaments of sodium lamp tubes (*CLT*) and semiconductive silicon (*Si*) were presented in this paper. Experiments consists of preliminary crushing and grinding in vibratory crushing (*VC*) and final very fine grinding in rotary vibration mill (*RVM*). Results revealed that ground material characterize with a high purity and a very fine particle size distribution below $5+10\mu\text{m}$. Ground wasted corundum powder can be again used in ceramic technological processes or can be used as abrasive material while silicon powder can be used in the production of high purity silicon carbide.

1. INTRODUCTION

Technological ceramic wastes of high purity and hardness are generated in any of special ceramic technologies. High purity means that ceramic wastes does not contain more than 0.1% of total harmful impurities while hardness is close to 6+10 in Mohse's hardness scale. Ceramic wastes are usually created in such unit operations as: forming, sintering, mechanical treatment and assembling of ready goods and increase the production costs when they are in many tons. Ceramic wastes created in forming operation does not make problems because they can be again used in technological processes but the ones such as: defective by-products, cut technological surplus or defective final products created in the remaining ones are inconvenient. This troublesome are made by necessity of grinding of such hard materials to particle size distribution close to raw materials, i.e. below $5+10\mu\text{m}$ keeping high purity of powders during grinding.

The possibilities of utilization of ceramic wastes are conditioned by the following considerations:

- high purity and price appearing from high quality of raw materials,

- renewal application of ground ceramic waste in the same or other technological processes influences on lowering of production costs,
- protection of natural environment.

The original laboratory vibration machines as *VC* and *RVM* characterized with low activity on natural environment were used to provide the effectiveness of grinding processes and to high purity of corundum and silicon ceramic wastes. Choice of these machines were done on the basis of their high technical and technological advantages confirmed in previous preliminary grinding of hard ceramic materials and ceramic wastes. The very high degree of comminution and high purity of products were obtained in *VC* during crushing of the titanium silicon carbide⁽¹⁾, aluminium nitride, ferrosilicon^(2,3). Positive results were obtained in very fine grinding and colloidal grinding in *RVM*. The preliminary experiments of grinding of hard materials such as titanium silicon carbide, silicon carbide⁽⁴⁾, corundum wastes⁽⁵⁾, alumina^(6,7), fly ashes⁽⁸⁾, hydroxyapatite⁽⁹⁾ and other materials⁽¹⁰⁾ were carried out in *RVM*.

2. EXPERIMENTAL

2.1. Materials.

The following ceramic wastes were used in crushing and grinding experiments:

- corundum insulators of sparking plugs (*CSP*) of maximum dimensions $\phi 14/\phi 4 \times 65$ (tube),
- corundum filaments of sodium lamp tubes (*CLT*) of maximum dimensions $\phi 9.6/\phi 8 \times 90$ (tube),
- semiconductive silicon (*Si*) of $20 \times 25 \times 40$ (irregular grains).

2.2. Vibration crusher.

KW 40/1 *VC* (Fig.1) was used to preliminary crushing of *CSP*. Crusher's jaws set in swinging motion will always move in the opposite direction: either inward or outward. Crushing takes place when jaws move inward while during their outward movement the crushed material is poured down.

Basic parameters of KW 40/1 are as follows:

- inlet dimensions: 100×160 mm,
- maximal feed dimension: 40mm,
- slit adjustment range: 1-10mm,
- frequency of jaw vibrations: 8+25Hz,
- motor power: 2.2kW,
- output: 50+500kg/h,
- dimensions: $840 \times 420 \times 920$,
- mass: 145kg.

2.3. Rotary vibration mill.

LAMOW-C-5x2 *RVM* (Fig.2) was used to preliminary crushing of *CLT* and fine grinding of *CSP*, *CLT* and *Si*. Grinding is done by setting the mill chamber with the grinding media and ground material in the motion combine vibration motion with the vibration amplitude perpendicular to the axis of cylindrical chamber and the rotary motion.

Basic parametes of LAMOW-C-5x2 are as follows:

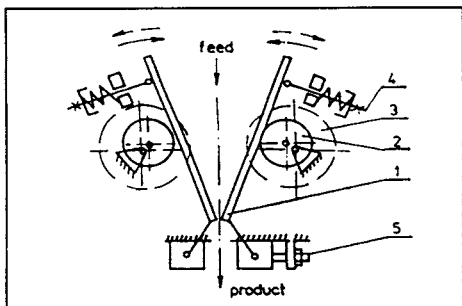


Figure 1 Scheme of KW 40/1 VC.
1-jaw, 2-kinematic vibrator, 3-vibrator drive, 4-elastic unit, 5-slit adjustment mechanism

- vibrations frequency: 14Hz,
- vibration amplitude: 2+8mm,
- capacity of the chamber: 5 and 10 liter,
- number of chamber: 2,
- motor power: 1.5kW,
- dimensions: 1270x800x960,
- mass: 240kg.

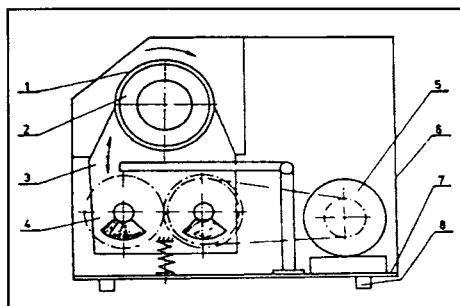


Figure 2 Scheme of LAMOW-C-5x2 RVM: 1-chamber unit, 2-chamber, 3-vibrator, 4-vibrating unit frame, 5-mill drive, 6-shield, 7-base plate, 8-vibro-insulator

2.4. Experimental procedure of preliminary crushing.

The main objective of preliminary crushing was to obtain disintegrated material of such particle size distribution that it could be introduced into the RVM. Ceramic wastes of CSP was feed into VC in natural shape while Si was first hand crushed till the dimensions were smaller than 40mm. The CTL was preliminary crushed in LAMOW-C-5x2 because of thin tube walls and avoidance of metallic pollution from jaws. Crushing was carried out on dry in chamber with polyamide lining using corundum grinding media.

In preliminary crushing the slit was 1mm and the vibration frequency was 18Hz.

2.5. Results of preliminary crushing.

The particle size distribution before and after crushing of CSP and Si were shown on Fig. 3 and 4. Corundum was polluted with metallic contaminations during crushing and was cleaned by the use of magnetic separator.

2.6. Experimental procedure of fine grinding.

The preliminary crushed fraction class of corundum CSP below -0.40mm was used in grinding while ceramic wastes of CTL was used on the whole. The particle size distribution of preliminary crushed ceramic wastes determined on wet Fritsch microsieves was shown in Table 1. Both corundum wastes CSP and CTL were ground on wet in distillate water in LAMOW-C-5x2 during 1, 2, 4 and 7h. The chamber has polyamide lining and its capacity was 5dm³. The feed consists of 800g of material, 6000g of corundum grinding

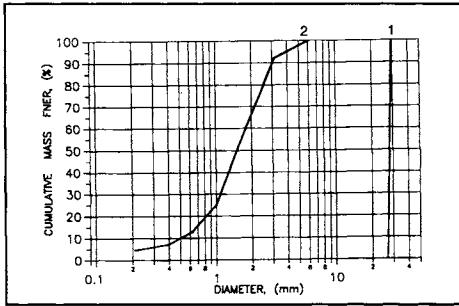


Figure 3 Particle size distribution of CSP before and after crushing: 1-feed, 2-product

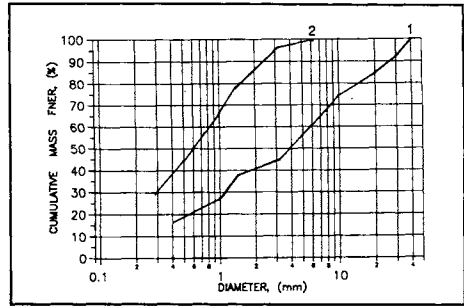


Figure 4 Particle size distribution of Si before and after crushing: 1-feed, 2-product

Table 1 Particle size distribution of CSP and CTL wastes.

Class, μm	+400	400-315	315-250	250-125	125-63	63-40	-40
CSP, %	4,3	22.8	18.4	24.7	14.6	2.4	12.8
CTL, %	-	-	-	18.2	17.3	10.3	53.2

media and 400cm³ of water.

Grinding of Si was carried out on dry in air in this same RVM during 2,4,6 and 10h. The chamber has also polyamide lining and its capacity was 5dc³. The feed consists of 1000g of material and 4000g of silicon grinding media.

Particles size distribution were determined using laser granulometer Fritsch Analyzette 22. Samples of all fine ground powders were also observed under scanning microscope JEOL 5400.

2.7. Results of fine grinding of CSP.

Results of fine grinding of CSP were shown in Table 2. SEM of ceramic wastes before and after grinding (sample CSP-4) were shown on Figure 5 and 6.

Table 2 Results from fine grinding of CSP.

Sample Grinding time, h	CSP-1 1	CSP-2 2	CSP-3 4	CSP-4 7
Particle size d_{50} , μm	5.2	4.5	3.3	2.6
Particle size d_{90} , μm	16.8	15.0	12.5	10.2
Fraction, $-10\mu\text{m}$	71.6	79.2	83.7	89.7
Fraction, $-4\mu\text{m}$	41.7	49.2	56.1	63.3



Figure 5 SEM of ceramic waste CSP before grinding, 50x. **Figure 6** SEM of ceramic waste CSP-4 after grinding, 2000x.

2.8. Results of fine grinding of CTL.

Results of fine grinding of CTL were shown in Table 3. SEM of ceramic wastes before and after grinding (sample CTL-4) were shown on Figure 7 and 8.

Table 3 Results from fine grinding of CTL.

Sample Grinding time, h	CTL-1 1	CTL-2 2	CTL-3 4	CTL-4 7
Particle size d_{50} , μm	5.2	4.5	3.3	2.6
Particle size d_{90} , μm	16.8	15.0	12.5	10.2
Fraction, $-10\mu\text{m}$	71.6	79.2	83.7	89.7
Fraction, $-4\mu\text{m}$	41.7	49.2	56.1	63.3

Also other 10h grinding of CTL with higher mass of feed (1250g) with another set of grinding media were done. Results shown that d_{50} was $1.5\mu\text{m}$ and d_{90} was $7.9\mu\text{m}$ while fraction $-10\mu\text{m}$ was 92.9% and $-4\mu\text{m}$ was 78.9%.

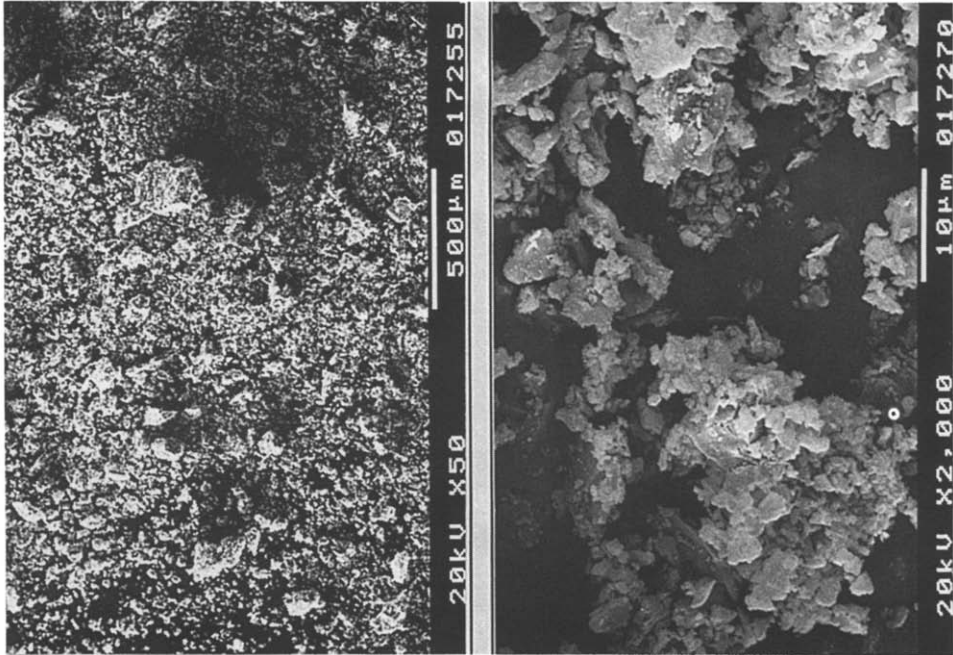


Figure 7 SEM of ceramic waste CTL before grinding, 50x.

Figure 8 SEM of ceramic waste CTL-4 after grinding, 2000x.

2.9. Results of fine grinding of Si.

Results of fine grinding of Si were shown in Table 4. SEM of waste stuffs before and after grinding (sample Si-4 were shown on Figure 9 and 10).

Table 4 Results from fine grinding of Si.

Sample Grinding time, h	Si-1 2	Si-2 4	Si-3 6	Si-4 10
Particle size d_{50} , μm	16.7	11.4	9.5	5.6
Particle size d_{90} , μm	53.6	41.8	39.0	21.0
Fraction, $-10\mu\text{m}$	55.2	66.2	70.8	85.3
Fraction, $-4\mu\text{m}$	31.9	41.1	45.8	59.4

Also other 4h grinding of Si with an addition of 0.2% of activator was carried out. Results shown that d_{50} was $7.9\mu\text{m}$ and d_{90} was $28.3\mu\text{m}$ while fraction $-20\mu\text{m}$ was 80.1% and $-8\mu\text{m}$ was 50.4%.

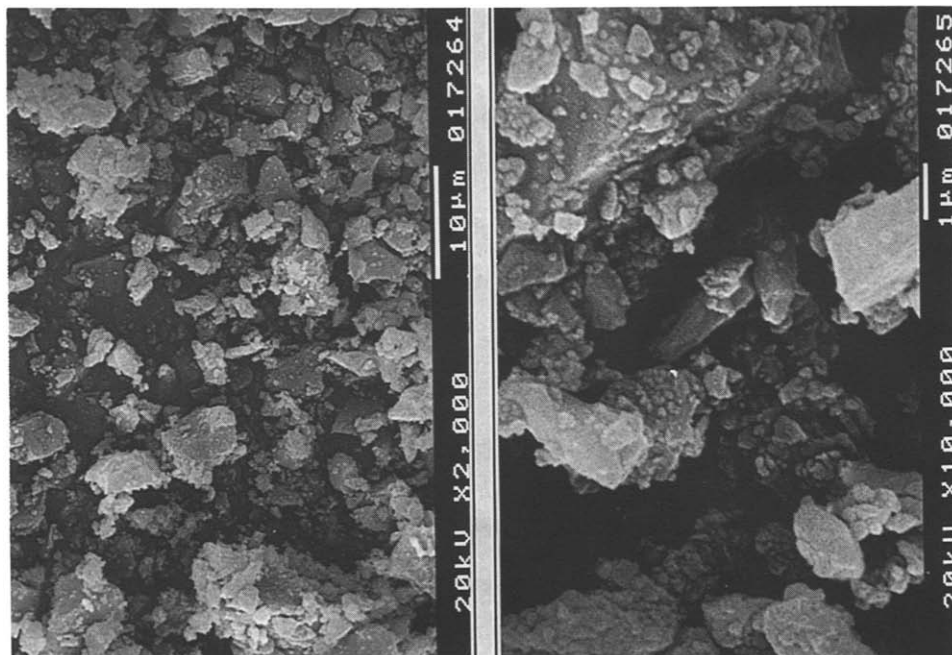


Figure 9 SEM of ceramic waste **Figure 10** SEM of ceramic waste
Si-4 after grinding, 2000x. *Si-4* after grinding, 10000x.

3. CONCLUSIONS

Results of presented experiments allows to draw the following conclusions:

- 1 Application of VC and RVM created the practical possibility of grinding processes - fine crushing i fine grinding of corundum and silicon wastes.
- 2 Preliminary grinding can be carried out in VC when grains are bigger than 3÷10mm or in RVM when grains are below 1÷3mm.
- 3 Application of chamber with polyamide abrasive resistance lining and grinding media made from the same material as ground ones make the autogenic grinding and provide high purity of ground materials.
- 4 Corundum wastes CSP despite of higher particle size distribution before grinding were ground faster in the first stage of process (1÷3h) than CTL and they were only slightly finer but close to CTL after next 4h of grinding.
- 5 The crushing process of ceramic wastes of Si runs more effectively in VC but grinding in RVM much slowly. Process was two times accelerated when grinding activator was used.
- 6 Applied in presented experiments relatively big laboratory devices make the possibility for their usage in the industry conditions for grinding of the high quality ceramic wastes with 9 Mohse's hardness.

The output of VC KW 40/1 amounts 40÷60 and 75÷85kg/h for crushing of corundum and silicon wastes respectively

while for LAMOW-C-5x2 is ranged from 0.5+2 and from 0.2+3kg/h for grinding of corundum and silicon wastes respectively depending on particle size distribution.

RVM MOW-G-50 and MOW-H-200 with 50dm³ and 200dm³ capacity of chamber can be used when the need of higher output will be required.

4. REFERENCES

1. Sidor J., "Fine grinding of Ti₃SiC₂ powders using rotary vibration mill", FOURTH EURO CERAMICS - Vol.1- pp. 121-128. Developments in processing of advanced ceramics - Part 1. Edited by C.Galassi, C.N.R. - IRTEC, Faenza Italy (1995).
2. Sidor J., "Some results of examination of superfine crushing in the vibratory crusher", VIII Conf. of Probl. in Constr. and Expl. of Met. and Cer. Machines, Zakopane 22-26 Jan.1996 Vol.III, Ed. by Polish Acad. of Sc., Warszawa
3. Sidor J., "Vibration machines in fine grinding processes", I Conference-Seminar "Kierunki Rozwoju Maszyn Budowlanych i PMB", Kielce 9-10 Oct. 1996, pp.15-18, Edited by Instytut Mechanizacji Budownictwa i GS, Warszawa (1996)
4. J.Sidor, E.Ermer-Kowalczewska, "Preliminary investigation of the colloidal grinding of SiC in the laboratory rotary-vibration mill", Material Science Bulletin, Nr4, (1989)
5. Sidor J., "Preliminary tests of grinding of high quality corundum scrape in rotary-vibration mill", III Inter. Symposium "Milling and Air Classif. in Industry", Rudy 13-15 Oct. 1993, Ed. by Inst. Chemii Nieorg., Gliwice
6. Sidor J., "Preliminary tests of a prototype of the industrial rotary-vibration mill for fine milling of aluminum oxide", Physicochemical Problems of Mineral Processing, 26, p.57-64, Wrocław (1992)
7. Wójcik M.A., Sidor J., Kabała J., Pałyż J., Purska E., "Effect of the morphology and grains size distribution of alumina ceramic mass on the green and fire density and shrinkage of moulders", LIGHT METALS 1996, AIME 1996
8. Sidor J., Wójcik M.A., "Disintegration of the ashes in the rotary-vibration mill", WASCON'94 Conference, Maastricht, Environmental Aspects of Construction with Waste Materials, Elsevier Science B.V., Amsterdam, Holland (1994)
9. Sidor J., "Some results of the investigation of superfine and colloidal grinding of hydroxyapatite in a rotary-vibration mill", CERAMICS 46, 1994, Polish Ceramic Bulletin 8, Polish Academy of Science, pp.117-126, (1994)
10. Sidor J., "Some results of investigation of superfine grinding of selected waste materials in a rotary-vibration mill", XXVI Cracow Conference "Eng. and Prod.Techn. in Benef. Raw and Waste Materials", Ustroń 7-8 Sept. 1994, Edited by AGH Kraków (1994)