

# RAKU - my never-ending passion

## Part 2: Transparent glaze, crackle and post-firing reduction

Georg Krüger gives a course on raku for our readers



Even the best glaze recipe is useless if post-firing reduction is not carried out with the necessary keen observation.

As soon as you begin to get involved with glazes, you encounter a large number of technical terms. I shall deal with this problem by printing all of them in the text in **bold italics**, which are explained in a glossary at the end of the article. Any unfamiliar expressions can be found here; if you know the term, just carry on reading.

This is the tried and tested recipe for the basic glaze from article no. 1, in case you do not happen to have the last issue of NC handy, to make 1 kg: 200 gr M 1233; 400 gr D 90157; 200 gr M 233864; 100 gr China clay; 50 gr quartz; 50 gr calcinated borax.

To explain the **reduction process**, this glaze is coloured with 4% copper carbonate, which produces a green-blue turquoise when it is not subjected to **reduction cooling**. A whole range of stains from ceramics suppliers can be used as colouring agents here too, but the sample in the shop will not always correspond 1:1 with your own glaze. Tests have to be made. Especially the heavily **alkaline** raku glazes change the colours of stains quite markedly, and even break up the chemical bonds, absorbing the stain in the atomic lattice of the glaze. This is why a blue or a yellow slip, for instance, may not change colour at all after the glaze firing, may change partly or totally. I do not agree with the makers' recommendations for quantities of colouring agents, because in my experience they are far too low for raku glazes to produce satisfactory results. Using **stains** makes sense particularly for colours that use dangerous basic ingredients like red, yellow, orange and a number of others. In a stain, these ingredients are well integrated – they are “coated”, with zirconium silicate for instance, which prevents the dangerous substances dissolving in water and also makes them much less harmful in the form of dust

rubbing off the pots.

**Crackle!** The development of crackle depends on a number of factors, which can all be controlled to a certain degree. Because this article is intended to be practically orientated, these are the most important factors (with some omitted in the interest of economy).

### 1. Advance considerations

- Clay body: not all raku bodies produce the same crackle effect, all other things being equal. It depends largely on the particle size of the grog, the iron content of the clay, the surface tension in the clay and a number of other factors. It is worthwhile getting to know one or two bodies and sticking to these. Various commercially available light-coloured or white tile-making bodies are suitable. For handbuilt ceramics, at least 40% grog is recommended with a particle size of 1.5 – 2mm. The particle size also affects the crackle. But the following factors are more important:

- Smoothing the clay surface is the raku potter's most important tool!

The smoother the surface, the larger the crackle, and the degree of influence increases. Ideally, the leatherhard pot should be covered with a fine slip or smoothed over with a series of spatulas until it is completely smooth.

- Form: the form is crucial for the kind of crackle pattern appearing after the firing because the development of cracks depends on the difference in tension between the cooling glaze and the surface of the body. A sphere, a bowl or a sharp-edged stele will all produce their own typical crackle pattern if all other factors are equal (cf. illustrations).

- Using slips has a very positive effect on colour and development of crackle if they are correctly composed. The use of colloidal slips (e.g. **terra sigillata**) or porcelain slip will be



The above-mentioned glaze on pots and in a bowl: the cooling and post-reduction have been watched carefully. The basis is the basic glaze and a perfectly smooth clay surface!  
Clay: Witgert 50/20; 1040°C

covered in one of the following articles.

- The glaze: this is the most important element in the development of crackle. The most important thing here is to ensure the following ingredients are added to the glaze (via *frits*): oxides of sodium, potassium and some others with a high surface tension. I would like to mention Wolf E. Matthes glaze book in this connection. He includes easy to understand tables and background knowledge. But it is possible to concentrate only on the ingredients of the frits: in the recipe quoted here, it is mainly the oxide of sodium that is used in the frits.

- The thickness of the glaze: the glaze should be adjusted with an *hydrometer* to achieve good consistent results. The glaze quoted has an ideal value of 46 – 48°Bé without colouring agents. This glaze can be applied by dipping, spraying or pouring. If you wish to brush it on, which does not produce good results, a medium will be required. Adding colouring agents alters the density of the glaze!

## 2. The firing

- The *firing curve*: completely underestimated in its importance for the development of crackle by many raku potters. In many of my raku workshops, the participants tell me how quickly their raku kilns heat up. But this is not the point. Between the glaze and the body, an *intermediate layer* develops, which firmly bonds the two. If the temperature rises too fast, this layer cannot develop fully. I am convinced that raku is not merely an artistically orientated branch of ceramics but should also aim at high quality. Only a good intermediate layer guarantees a physically and chemically sound ceramic product. This is why I take four hours to fire up to 1,000°C and a further half an hour to reach 1,040°C. This corresponds to a good maturing range. The glaze will reward us with a deeper crackle and in the end, improved *carbonisation*. These firing times are based on dry pots with a diameter of less than 50cm. I fire damp and very large pieces much slower to avoid explosions and cracking.

- Removing from the kiln: taking the pot out of the kiln when it is too cool has a distinct, usually negative effect on the crackle. For the sample glaze, the lowest suitable temperature is about 900°C! If you are removing several pieces from the kiln at once, the burners should be kept running during unloading, and as soon as temperatures drop below 900°C, heating can be resumed.

## 3. After the firing, the most important element

- The development of crackle is heavily dependent on the cooling process. The biggest problem for beginners is that crackle develops during a very brief phase. The duration of this phase is dependent on a number of factors: ambient air temperature, type of reduction material and its degree of moisture and the surroundings, i.e. is the pot to cool in a metal box or in a bed of sawdust? In this point, every raku potter must find their own preferences. But when these prerequisites have been established, there are countless ways to influence them:

- 1) The point *reduction* begins, i.e. when do I cover the glaze with reduction material? If the glaze does not yet have a surface skin of glass, the surface can become rough and grey. The earliest point for the sample glaze is at about 850°C. You cannot apply a thermostat to the glaze, so the pot can only be taken out at 950°C. The glaze skin has formed by the time it comes into contact with the sawdust. This is only partly true for coloured glazes.

- 2) With a partial or total covering of sawdust, which must not be renewed, it is possible to achieve a virtually crackle-free glaze. This may be important for areas of slip decoration or *monoprints* under the glaze, or where a crackle pattern would spoil the overall design. Or with a sphere or a stele, it is possible to accentuate a certain area. The development of these crackle-free areas is due to the fact that carbon volatilizes above 500°C. Underneath the sawdust, a small-scale crackle pattern develops, which is stained by the burning sawdust. Through the high temperature, a burned layer of sawdust develops that contains hardly any carbon. This deficit causes the carbon to migrate from the glaze, and we achieve a stable, crackle-free glaze.

- 3) If we want to achieve a large, deep crackle pattern, it is necessary to observe very closely and to be patient. With this glaze, the crackle develops at around 720-680°C. It develops on the one hand because of the difference in surface tension between the glaze and the clay surface and on the other, the difference between the temperature of the glaze and the core temperature of the body. This makes it clear that the thickness of the walls of the pot have a distinct influence on the development of the crackle. In my experience of this transparent glaze, it is necessary to use very little fine sawdust and to add more when the first layer has burned away. This guarantees that the crackle will be



*The crackle on this egg form has been controlled as described by partial covering at an early stage with a tightly packed layer of sawdust.*

*The transparent glaze on perfectly smooth, normal raku clay. The monoprint in the middle was cooled with sawdust scattered on very early (950-930°C) to produce fine, shallow crackle. The surrounding crackle is thus distinctly influenced. Only patient, focussed working procedures permit such effects.*





The transparent glaze with cobalt and an addition of 2% copper; cooled with the re-oxidising method, large area of raku black. D 55 cm

The same glaze as on bottle the opposite page, but coloured green by early reduction, caused by a different stage of oxidation in the copper oxide.



large and deep, and that the body will not be grey and smokey in appearance. The further cooling process only influences whether the pot itself will crack, but not the crackle pattern. I leave the pots in the bed of sawdust in a closed container until they have cooled to about 40-100°C.

The crackle is heavily influenced by the addition of colouring agents such as copper oxide. Only with "instant" stains can the crackle be produced as described above. I now want to move on to describe the coloring of this glaze and the carbonisation of the body. As examples, I will describe how to achieve the following colours:

1. **blue** with and without the possibility of post-firing reduction;
2. **blue-green** (the typical glaze colour in raku for experimenting with reduction);
3. **red** (as an example of the group of glaze stains. Yellow, orange, etc. can be achieved in a similar way).

**Blue:** can best be achieved with cobalt oxide or carbonate. The glaze reacts heavily to cobalt oxide. So to achieve a clear blue colour, 0.75% cobalt oxide are enough, i.e. to a kilo of dry glaze, only 7.5 gr cobalt oxide are required. The illustration shows an example with 1.25%. If **reduction effects** are desired with this glaze, 3% copper carbonate may be added. If the glaze contains copper carbonate, lustre effects are possible as it **re-oxidises** at around 700°C. If reoxidation occurs, the glaze remains blue. It can also show a broad palette of colours aside from a pure lustre (if reduction is early and heavy, without re-oxidation). A metal container that can be closed for a time is suitable for the reduction.

**Blue-green:** This colour can be achieved with copper oxide or carbonate. With copper oxide, 4-5% are enough. Larger additions can produce excessive lustre colours if post-firing reduction is heavy. If you are aiming to achieve this kind of effect, it is wise to raise the quantity of copper because the maximum colour development in this glaze is reached at 4%. Whether the colour tends to be more green or blue depends on the alkali content of the glaze. If it is very alkaline, it will tend more towards blue. The development of this blue depends on a relatively reduction-free cooling phase. Heavy reduction in the early stage of cooling leads to lustre or produces a green if there is sufficient re-oxidation. Any addition of copper reduces the crackle.

**Red:** It is best to aim for this colour with a stain. Many other colours can be achieved in this way. The above mentioned glaze requires

**Glossary**

**Borax** - a heavy flux, non-toxic, best used in calcinated form.

**Carbonates** - carbonates of almost all metals exist, e.g. copper carbonate. To produce the same colouring effect, a larger quantity of carbonate is required as the concentration of oxide is lower.

**Carbonisation** - refers here to the bonding of carbon to the glaze and/or body through heat and a distinct excess of carbon in the air.

**Dextrin** - organic adhesive which sticks the glaze firmly to the pot after drying and keeps glaze ingredients in suspension.

**Firing curve** - shows temperature rise in relation to time.

**Frit** - correspond largely to the function of stains, but in this case in relation to water-soluble glaze ingredients.

**Instant stains** - easy to mix and chemically very stable; practically non-toxic. Very expensive (from Euro 40 per kilo).

**Melting point** - this means the temperature at which the glaze spreads over the clay body like a film of honey and does not yet run off.

**Metal oxide** - the reactive part of the metal in a ceramic compound.

**Monoprint** - transfer of a ceramic print by a printing process using a stain.

**Quartz** - suitable for raising the maturing temperature in raku glazes without seriously affecting colour.

**Reduction** - in raku this means an increasing concentration of carbon and a low oxygen content in the air, especially with reference to glaze and body. With reducible metallic oxides, this produces a heavy change in colour; causes blackening of areas not covered by glaze.

**Reduction cooling** - the alternation of reduction and oxidation in the cooling process.

**Reduction effects** - caused by the application of sawdust (or other reduction material) to the glaze on a very hot pot. The sudden removal of oxygen from the glaze means oxygen is also removed from the oxide. In extreme cases, this produces a lustre of the element. These processes may be reversible in certain circumstances.

**Reduction process** - This means the interplay of reduction and re-oxidation of the glaze, which produces entirely different surface effects to simple single reduction.

**Re-oxidation** - when a glaze has been heavily reduced, it may re-oxidise in contact with the air again. This means the original glaze colour can be produced again if the glaze is still hot enough.

**Segger formula** - formula of the molecular composition of a glaze; it is not possible to see which substances are in the glaze, only the proportions of the elements introduced via various raw materials.

**Stain** - difficult or toxic stains are industrially bonded to ingredients which make both results and working with these pigments safer.



a 16-18% addition of stains to achieve a reliable colour. This makes the glazes relatively pricey, but they do have very vivid colour and are reliable. I like to use the following stains: red (279944), bright red (FK 6904), orange (D279942) and yellow (FK R 407).

These additives only have a slight effect on crackle and post-firing reduction can be carried out in the same way as with the transparent glaze. But remember that if you apply a double layer of glaze, it makes for a very dense glaze surface, which can make the glaze turn grey. The red and orange stains are very sensitive to this. Adjust the glazes to 43-44°Bé for dipping and pouring in this case.

*To be continued in the next issue.*

*left -*

*Thrown, beaten and cut, with 4% copper oxide; traces of reduction on the right caused by direct contact with the sawdust at 930°C, good crackle on the left, caused by a perfectly smoothed surface and sawdust only sprinkled on at 650°C.*

*below -*

*This brilliant red was achieved with stain FK 6904, a thin layer of glaze and late but heavy reduction.*

